Sponsored by: Councilmembers Jani Hitchen and Dave Morell
Requested by: County Executive/Planning and Public Works Department

ORDINANCE NO. 2023-41

An Ordinance of the Pierce County Council Adopting the "2023 Pierce County Comprehensive Flood Hazard Management Plan"; Amending Chapter 19D.60 of the Pierce County Code, "Pierce County Storm Drainage and Surface Water Management Plan," to Include the Pierce County 2023 Comprehensive Flood Hazard Management Plan as a Comprehensive Planning Document; and Commending the Members of the Flood Plan Advisory, Steering and Executive Committees for Their Dedication and Assistance in Development of the Flood Plan.

Whereas, the Pierce County Council adopted Ordinance No. 91-197 on January 28, 1992, which adopted the "Puyallup River Basin Comprehensive Flood Control Management Plan" (1991 Plan); and

Whereas, the 1991 Plan focused on flood hazard reduction for the unincorporated areas along the Puyallup, White, and Carbon Rivers, and recommended a set of capital improvement projects and actions, many of which have been implemented; and

Whereas, the 1991 Plan did not include the Nisqually River, Mashel River, Greenwater River, or South Prairie Creek; and

Whereas, since the 1991 Plan was adopted, the Pierce County Council adopted the Comprehensive Plan for Pierce County, Washington in November 1994 pursuant to the State Growth Management Act; and

Whereas, the 2013 Pierce County Rivers Flood Hazard Management Plan and 2018 Update were adopted as a comprehensive planning document in Chapter 19D.60 of the Pierce County Code (PCC); and

Whereas, the Growth Management Act requires consistency between the Comprehensive Plan for Pierce County, Washington and capital improvement plans for public facilities; and

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Tacoma, WA 98402

Whereas, the previous versions of the Flood Plan did not include other types of flood hazards beyond those associated with riverine systems; and

Whereas, the Pierce County Comprehensive Flood Hazard Management Plan is a long-term plan to address all types of flooding (riverine, urban, coastal and groundwater) and channel migration risks. The planning area for the Flood Plan includes unincorporated Pierce County, and also includes programmatic recommendations from incorporated cities within Pierce County; and

Whereas, as a part of the County's participation in the National Flood Insurance Programs Community Rating System Program, the County is required to update Pierce County's Flood Hazard Management Plan once every five years. This comprehensive update sets policy and direction for the next five-year period. The Pierce County Planning Commission conducted a public hearing on August 8, 2023, and recommended approval of the Flood Plan Update. The Pierce County Council has received the Staff Report and recommendation for approval of the Flood Plan from the Pierce County Planning Commission; and

Whereas, the Pierce County Council has determined that the proposed Flood Plan implements the Comprehensive Plan of Pierce County Washington; and

Whereas, adoption of the Flood Plan Update will continue to protect the public health, safety, and welfare and will benefit all the citizens of Pierce County by minimizing the loss of life, property, and economic activities due to flooding and channel migration; and

Whereas, Pierce County is currently a Class 2 community through the Community Rating System program which allows Pierce County residents to receive a 40 percent discount on their flood insurance **Now Therefore,**

BE IT ORDAINED by the Council of Pierce County:

Section 1. The Pierce County Council hereby adopts the "Pierce County 2023 Comprehensive Flood Hazard Management Plan," as shown in Exhibit A, which is attached hereto and incorporated herein by reference.

Section 2. Chapter 19D.60 of the Pierce County Code, "Pierce County Storm Drainage and Surface Water Management Plan," is hereby amended as shown in Exhibit B, which is attached hereto and incorporated herein by reference.

Pierce County Council
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Tacoma, WA 98402

Section 3. The Pierce County Council commends the members of the Flood Plan Advisory, Steering and Executive Committees for their dedication in assisting in the development of the Comprehensive Flood Hazard Management Plan.

PASSED this 17th day of October, 2023.

ATTEST:

Denise D. Johnson

Denise D. Johnson
Clerk of the Council

PIERCE COUNTY COUNCIL
Pierce County, Washington

Ryan N. Mello

Ryan N. Mello
Council Chair

Bruce F. Dammeier

Bruce F. Dammeier
Pierce County Executive
Approved X Vetoed ______, this 31st day of October, 2023.

Date of Publication of
Notice of Public Hearing: September 27, 2023

Effective Date of Ordinance: November 10, 2023

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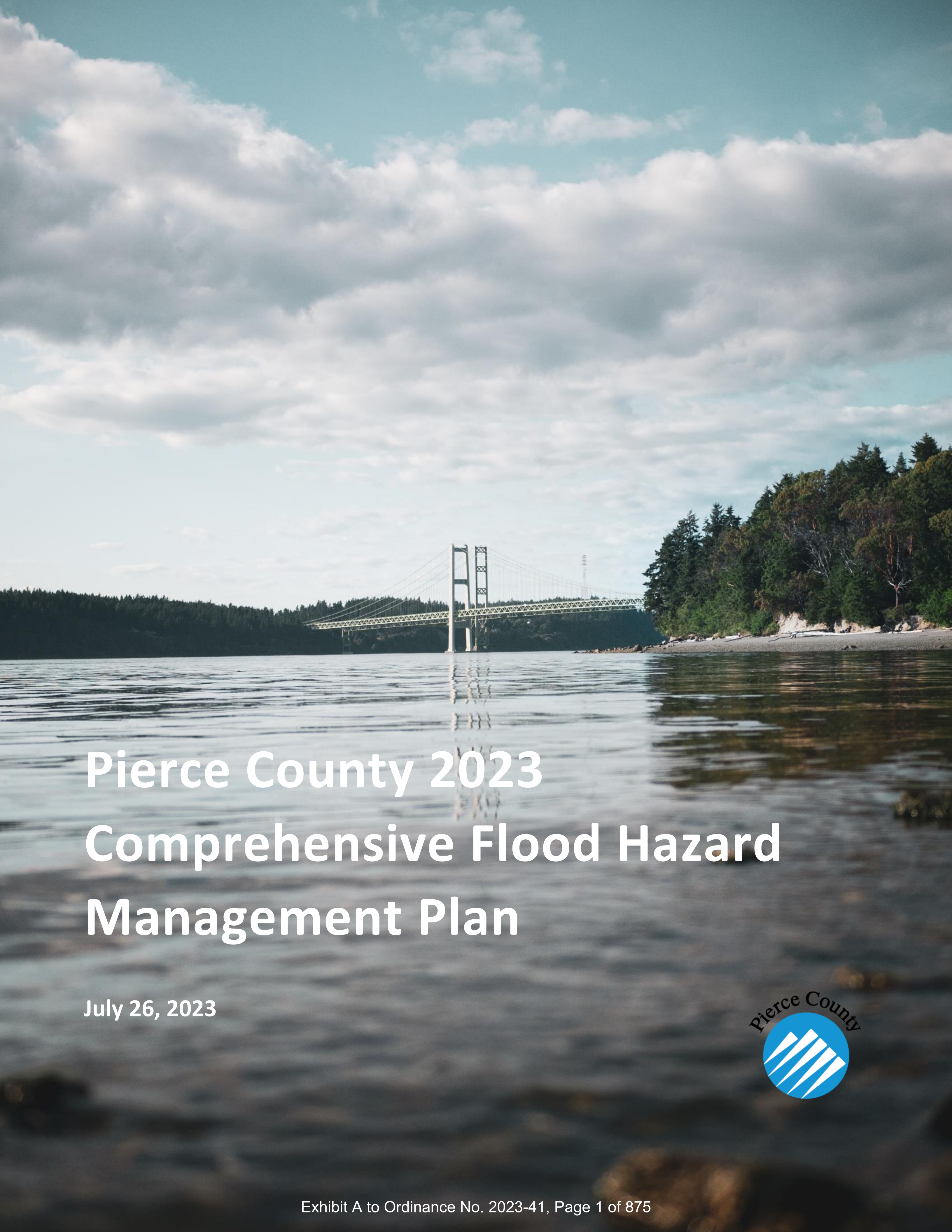


Pierce County 2023 Comprehensive Flood Hazard Management Plan

July 26, 2023

Pierce County

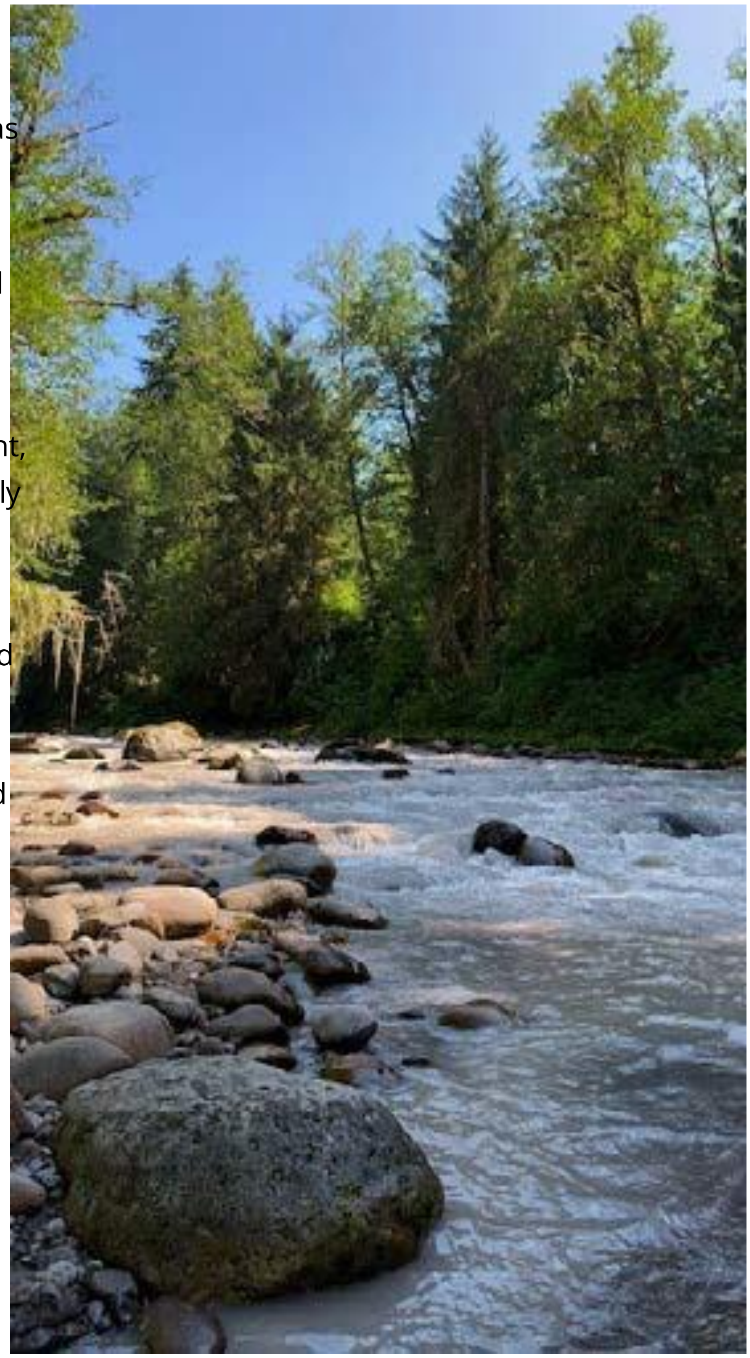
LAND ACKNOWLEDGMENT

The land now identified as Pierce County has for thousands of years been the traditional territory and home for the Puyallup, Nisqually, Squaxin Island, and Muckleshoot people.

We respectfully recognize the people of these four federally recognized tribes as past, present, and future guardians of this land both culturally and legally, as evidenced by their respective treaties.

We acknowledge these Tribal governments and their respective roles today in protecting and taking care of these lands and resources. We are grateful to have the opportunity to live and work here.

With this plan, we commit to working together in stewardship of their homeland where we mutually work, reside, and recreate.



2023 Comprehensive Flood Hazard Management Plan Contributors

The following tables below include the names of those committee members that were a part of the 2023 Comprehensive Flood Hazard Management plan. Without these key individuals, this plan update would not have been possible.

2023 Comprehensive Flood Hazard Management Plan Advisory Committee Members	
Name	Organization or Interest
Lisa Tobin	City of Auburn
Tim Carlaw	City of Auburn
Jason Sullivan	City of Bonney Lake
Royce Young	City of Dupont
Jeremy Metzler	City of Edgewood
Greg Vigoren	City of Fife
Chris Larson	City of Fife
Brian Avis	City of Fife
Tyler Bemis	City of Fircrest
Jeff Langhelm	City of Gig Harbor
Paul Bucich	City of Lakewood
Dustin Madden	City of Milton
Jose Magana-Bedolla	City of Milton
John Bielka	City of Orting
Scott Larson	City of Orting
Greg Reed	City of Orting
Jim Morgan	City of Pacific
Hans Hunger	City of Puyallup
Robert Wright	City of Sumner
Dana Deleon	City of Tacoma
Sue Coffman	City of Tacoma
Angela Gallardo	City of Tacoma
Jim Parvey	City of Tacoma
Shauna Hansen	City of Tacoma
David Swindale	City of University Place
Nuri Avcular	City of University Place

2023 Comprehensive Flood Hazard Management Plan Advisory Committee Members	
Name	Organization or Interest
Terri Berry	Town of South Prairie
Tony Caldwell	Town of South Prairie
Carolyn Norris	Town of South Prairie
Paul Loveless	Town of Steilacoom
Marie Wellock	Town of Wilkeson
Emily Terrell	Sound Municipal Consultants
Jessie Gamble	Master Builders of Pierce County
Patrick Reynolds	Muckleshoot Indian Tribe
Martin Fox	Muckleshoot Indian Tribe
Brent Bower	National Weather Service
Justin Hall	Nisqually River Foundation/Nisqually River Council
Isabel Ragland	Pierce Conservation District
Kjristine Lund	Pierce County Flood Control Zone District
Alisha Pena	Northwest Seaport Alliance
Char Naylor	Puyallup Tribe of Indians
Russ Ladley	Puyallup Tribe of Indians
George Walter	Nisqually Tribe
Matt Mega	Tahoma Audubon
Matt Gerlach	Washington State Department of Ecology
Darrin Masters	Washington State Department of Fish and Wildlife
Ben Welch	National Park Services
Duncan Foley	Local resident
Cathy Tarricone	Local resident
Jerome O'Leary	Local farmer/ Real Estate Agent
Kevin Freeman	Local resident

2023 Comprehensive Flood Hazard Management Plan Steering Committee Members	
Name	Organization or Interest
Angela Angove	Pierce County Surface Water Management
Al Amirzehni	Pierce County Surface Water Management
Angie Silva	Pierce County Planning and Public Works
Brian Johnston	Pierce County Office of the County Engineer
Chris Cooley	Pierce County Executive's Office
Debbie Bailey	Pierce County Department of Emergency Management
Helmut Schmidt	Pierce County Surface Water Management
Harold Smelt	Pierce County Surface Water Management
Jesse Hamashima	Pierce County Office of the County Engineer
Hugh Taylor	Pierce County Council Office
Mark Schumacher	Pierce County Maintenance & Operations
Todd Essman	Pierce County Surface Water Management
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Miranda Heimbuch	Pierce County Sewers
Anne-marie Marshall-Dody	Pierce County Surface Water Management
Melissa McFadden	Pierce County Office of the County Engineer
Tiffany O'Dell	Pierce County Parks
Harold Smelt	Pierce County Surface Water Management
Mitch Brells	Pierce County Planning and Public Works
Sarah Grice	Pierce County Office of the County Engineer
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Sean Gaffney	Pierce County Planning and Public Works
Tom Kantz	Pierce County Surface Water Management

2023 Comprehensive Flood Hazard Management Plan Executive Management Team	
Name	Organization or Interest
Jen Tetatzin	Director of Planning and Public Works
Bruce Wagner	Deputy Director of Planning and Public Works
Melanie Halsan	Assistant Director of Planning and Public Works
Kevin Dragon	Assistant County Engineer
Chris Cooley	Strategic Advisor
Catherine Rudolph	Strategic Advisor Community and Regional Affairs
Sarah Colleen Sotomish	Senior Counsel for Tribal Relations
Jody Ferguson	Director of Emergency Management

Consultant Team	
Consultant Name	
Environmental Science Associates	2021 Comprehensive Levee Setback Feasibility Study
Herrera Environmental Contractors	Flood Hazard Management Plan Technical Support
EcoNorthwest	Flood Risk Assessment and Economic Analysis
UW Climate Impacts Group	How will Climate Change Affect Flooding in Pierce County?
Herrera Environmental Contractors	Environmental Impact Statement

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Chapter 1

2023 Flood Plan	Pierce County Comprehensive Flood Hazard Management Plan
2013 Flood Plan	Pierce County Rivers Flood Hazard Management Plan
2018 Flood Plan Update	Pierce County Rivers Flood Hazard Management Plan
CMZ	Channel Migration Zone
CRS	Community Rating System
DFIRM	Digital Flood Insurance Rate Map
DTG	Disappearing Task Group
EIS	Environmental Impact Statement
ESA	Endangered Species Act
FEMA	Federal Emergency Management Agency
FPW	Flood Plan Wide
GIS	Geographic Information Systems
GMA	Growth Management Act
LiDAR	Light Detection and Ranging
Muckleshoot Tribe	Muckleshoot Indian Tribe
PCC	Pierce County Code
PL	Public Law
Puyallup Tribe	Puyallup Tribe of Indians
RCW	Revised Code of Washington
RV	Recreational Vehicle
SEPA	State Environmental Policy Act
SWIF	System Wide Improvement Framework
SWM	Surface Water Management
USACE/Corps	United States Army Corps of Engineers
WAC	Washington Administrative Code

Chapter 2

CFS	Cubic Feet Per Second
RM	River Mile
SR	State Route
USC	United States Code

USGS	United States Geological Survey

Chapter 3

BIBI	Biotic Index of Biological Integrity
°C	Degrees Celsius
CFR	Code of Federal Regulations
CWA	Clean Water Act
DFF	Deep and Fast Flowing Water
EA	Environmental Assessment
Ecology	Washington State Department of Ecology
EPA	Environmental Protection Agency
ESU	Evolutionary Significant Unit
°F	Degrees Fahrenheit
HCP	Habitat Conservation Plan
ICRI	Inter-County River Improvement Agreement
ITP	Incidental Take Permit
LIO	Local Integrating Organization
NEPA	National Environmental Policy Act
NEP	National Estuary Program
NFIP	National Flood Insurance Program
NMFS	National Marine Fisheries Service
NPDES	National Pollutant Discharge Elimination System
NTA	Near Term Action
PSP	Puget Sound Partnership
RCW	Revised Code of Washington
TMDL	Total Maximum Daily Load
USFWS	United States Fish and Wildlife Service

Chapter 4

CMIP	Coupled Model Intercomparison Project
GCMs	general circulation model
IPCC	Intergovernmental Panel on Climate Change
JBLM	Joint Base Lewis McChord
WDFW	Washington Department of Fish and Wildlife

Abbreviations

Chapter 5

ARL	Agricultural Resource Lands
BFE	Base Flood Elevation
CBA	Cost Benefit Analysis
FIRM	Flood Insurance Rate Map
FFP	Farming in the Floodplain Project
FFTF	Floodplains for the Future
FT	gauge height (in feet)/stage
HIRA	Hazard Identification and Risk Assessment
ICC	Increased Cost of Compliance
KGI	Key Peninsula-Gig Harbor-Islands Watershed
LAMP	Levee Analysis and Mapping Approach
LWM	Large Woody Material
NAVD	North American Vertical Datum
NWS	National Weather Service
PC	Pierce County
PCC	Pierce County Code
PCWARN	Pierce County Warning, Alert and Response Network
RAMP	Rivers Asset Management Program
UGA	Urban Growth Area
WebEOC	Internet-based emergency information management
WRIA	Water Resource Inventory Area

Chapter 6

BMP	Best Management Practices
CR	Carbon River
D.S.	Downstream
IRRMS	Interim Risk Reduction Measures
LF	Lineal Feet
MOA	Memorandum of Agreement
OHWM	Ordinary High Water Mark
PCRI	Pierce County River Improvement
PR	Puyallup River
SEPA	State Environmental Policy Act
SFHA	Special Flood Hazard Area

STARR II	Strategic Alliance for Risk Reduction
U.S.	Upstream
WSDOT	Washington State Department of Transportation

Chapter 7

ESA	Endangered Species Act
ILA	Interlocal Agreement
REET	Real Estate Excise Tax
WDNR	Washington Department of Natural Resources

Appendix

CIP	Capital Improvement Program
HDPE	High Density Polyethylene
PSE	Puget Sound Energy
WQ	Water Quality

1 Introduction

Since 1994, Pierce County has experienced an estimated 30 major flooding events that were either classified as riverine flooding, urban flooding, coastal flooding, or groundwater flooding. Flooding impacts our community in many ways and affects our agriculture, residential, commercial, and industrial lands. Pierce County continues to expand our knowledge and understanding of the various flood hazards that impact our community and will continue to provide flood services throughout the county while working together with our local jurisdictions.

This 2023 Pierce County Comprehensive Flood Hazard Management Plan (2023 Flood Plan) outlines how Pierce County will address and manage flooding and channel migration hazards throughout the county over the next 10 years. This plan will also identify a level of service that the county will provide as new projects are constructed.

The Flood Plan replaces the 2013 Rivers Flood Hazard Management Plan and its 2018 Flood Plan update and expands its scope to include urban flooding, groundwater flooding, and coastal flooding. Like its predecessor, this 2023 Flood Plan was developed to meet the requirements of Washington Administrative Code (WAC 173-145) related to Comprehensive Flood Control Management Plans, Chapter 86-12 RCW (flood control by counties), and the Federal Emergency Management Agency's (FEMA) Community Rating System guidance for floodplain management planning under the National Flood Insurance Program.

1.1 Purpose of the Plan

The purpose of this plan is to identify, policies, programs, and projects that will:

- Reduce the impacts to the community from major flooding events.
- Reduce damage to critical infrastructure and private improvements.
- Reduce ongoing maintenance costs.
- Improve habitat conditions while protecting and maintaining the regional economy.

This 2023 Flood Plan addresses the range of resource and policy issues facing local governments, resource managers, Tribes, property owners, and businesses and recommends specific actions that Pierce County and its partners can take to address all types of flooding (riverine, urban, coastal, and groundwater) and channel migration risks.

This 2023 Flood Plan was developed using the best available technical information, an inclusive stakeholder and public-involvement process, and a multi-disciplinary team of Pierce County staff and supporting consultants. See Section 1.6, Planning Process, and Figure 1.2 in that section, for more detailed description of the process and those involved. This plan considers complex economic, social, and cultural conditions in county watersheds; federal, state, and local regulations; and existing legal agreements (e.g., Tribal, U.S. Army Corps of Engineers [USACE]). The recommendations found within this plan have the support of Pierce County staff and the Flood Hazard Management Plan Advisory Committee (Advisory Committee).

1.2 Geographic Scope

The geographic scope of this 2023 Flood Plan includes Pierce County's nine watersheds, all cities and towns, the two major river systems in the county (Puyallup and Nisqually) and their major tributaries, streams, and the Puget Sound shoreline. Table 1.1 shows the planning area covered by this plan.

Table 1.1. Watersheds in Pierce County

Watersheds	Total Acres
Chambers Bay/ Clover Creek	106,798
Clear/Clarks Creek	21,044
Gig Harbor/Key Peninsula	79,292
Hylebos-Browns Point-Dash Point	15,959
Middle Puyallup	33,357
Muck Creek	56,467
Nisqually	232,170
Upper Puyallup	253,310
White River	241,706
Watershed Total	**1,040,113**

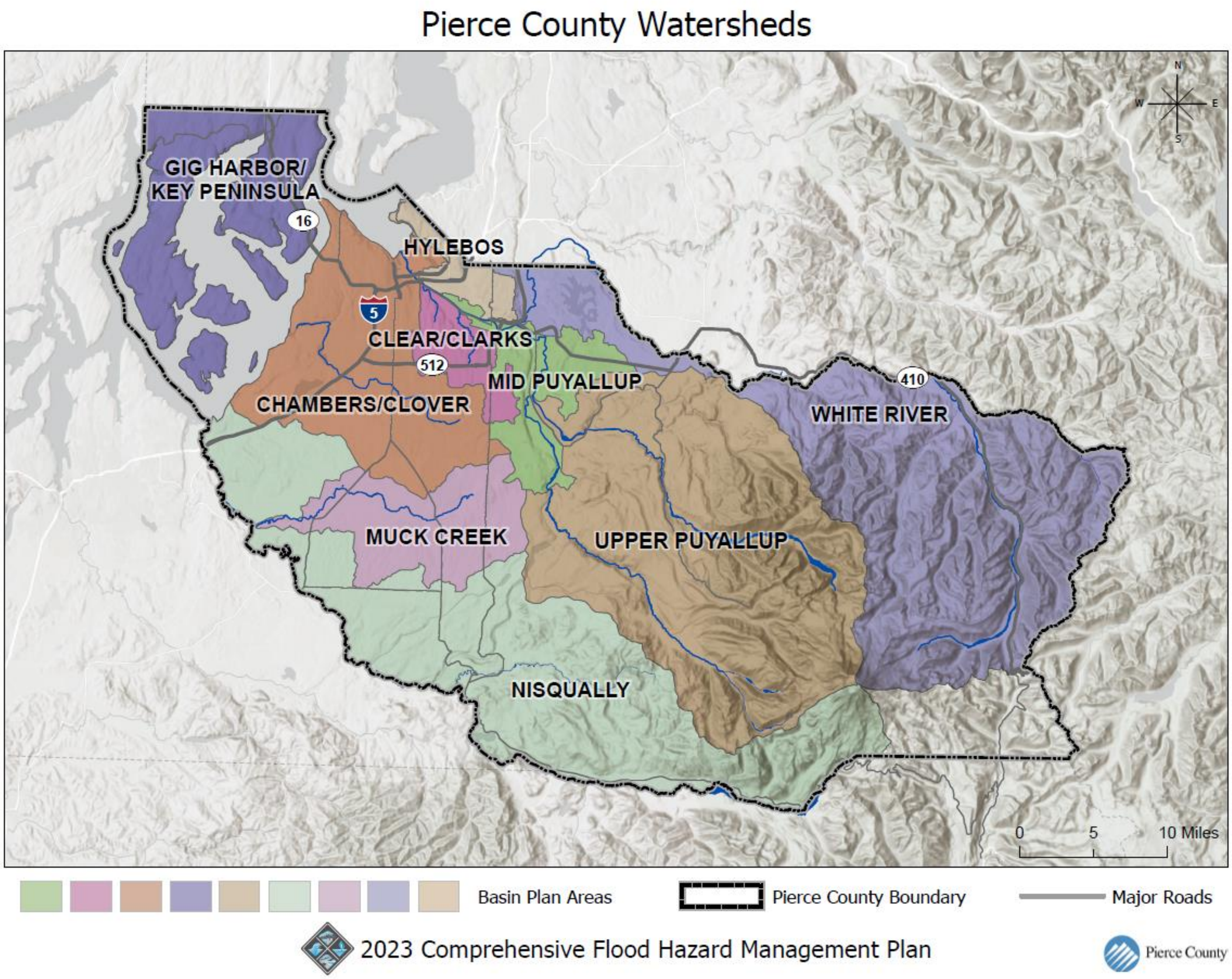
Note:

Source: EcoNorthwest Flood Risk Assessment and Economic Analysis April 2022

Pierce County's nine watersheds (see Figure 1.1) include forests, national parks, and wilderness areas in the upper watersheds; rural and agricultural uses in the mid to lower watershed areas; and urban areas dispersed throughout the Chambers Bay/Clover Creek watersheds.

This 2023 Flood Plan also captures the planning areas that include the urban, coastal, and groundwater flooding areas of Pierce County.

Figure 1.1. Watersheds in Pierce County



1.3 Goals

Goals describe broad outcomes that this 2023 Flood Plan should achieve, as agreed upon by the Comprehensive Flood Hazard Management Plan Advisory Committee and Steering Committee. These goals, which are listed below, provide direction and focus on the end results.

- Support resilient communities, compatible economic activities, and improve habitat conditions in areas prone to flooding/channel migration.
- Identify and implement flood hazard management activities in a balanced, cost-effective, and environmentally conscious manner.
- Reduce risks to life and property from river/channel migration and coastal, groundwater, and urban flooding.

- Address all flooding types in this plan in a cost-effective and financially achievable manner over a 10-year period.
- Support municipalities in their efforts in floodplain management practices.

1.4 Objectives

The 2023 Flood Plan objectives listed below are more specific statements of action that the two committees involved in the planning process (see Figure 1.2 in Section 1.6, Planning Process, below) agreed would move the plan toward attainment of its goals.

- Evaluate the risks to public safety and existing development from all flood hazards (e.g., critical facilities, infrastructure, and structures).
- Examine and prioritize opportunities to reduce risk to life and property, while reducing economic and environmental impacts of flood hazards.
- Regulate development in flood-prone and channel migration hazard areas to minimize risks to life, property, and habitat.
- Manage riverine flood risk reduction facilities in a cost-effective manner that makes the facilities less susceptible to future damage, reduces impacts on habitat, and ensures consistency with public law (PL) 84-99, and similar federal, Tribal, and state laws and programs.
- Identify and pursue projects with multiple benefits (e.g., salmon recovery, aquatic and riparian habitat, water quality, open space, public access, and agricultural resources).
- Prioritize projects and programs based on the level of risk, benefit, cost effectiveness and effects on habitat over the life of the plan or facility.
- Coordinate among Pierce County departments, local governments, and other agencies and Tribes to seek consistency in flood hazard management, development regulations, and flood disaster response and recovery.
- Implement an adaptable county-wide public education and outreach program to improve flood awareness that includes actions people and communities can take to reduce their risks (e.g., flood insurance, flood-proofing).
- Where feasible, remove or modify existing flood risk reduction facilities to protect, restore, or enhance critical riparian or in-stream habitat that benefits threatened or endangered species; protect and enhance natural systems that reduce flood risk.
- Increase our understanding and incorporate best available science regarding climate change into flood hazard management decision-making.

- Review current and establish future design and management strategies for existing and new flood risk reduction facilities.
- Identify repetitive-loss properties and properties needed for future flood risk reduction facilities.
- Provide for the participation of stakeholders in the assessment of acceptable risks, evaluation, and ranking alternatives; natural resources management issues; and development of plan recommendations.
- Identify supplemental funding sources for implementing recommended flood hazard management activities.
- Monitor the effectiveness of projects and repairs to learn from successes, develop long-term cost-effective approaches, and reduce the need for costly solutions.
- Maintain a network of accurate stream flow weather gauges and water quality stations to inform management decisions.

1.5 Guiding Principles

Guiding principles are the facts, scientific foundation, and broad philosophy agreed upon by the two committees involved in this flood plan development (see Section 1.6). The guiding principles listed below guided the development of this 2023 Flood Plan recommendations and projects. These principles serve as a frame of reference for evaluating flood risks, identifying the range of management alternatives, and developing recommendations.

- River flooding and channel migration are natural processes that continually form and alter river valleys and the floodplain landscape. Rivers transport water, sediment, and woody material that may threaten public safety and infrastructure in flood-prone areas. Biological productivity and diversity are sustained by natural riverine processes, such as flooding, that create and alter aquatic habitats that sustain fish and wildlife species.
- Activities in the watersheds impact flooding, channel migration, habitat, shorelines, groundwater, and water quality.
- Flood damage creates costs for both public and private entities. Effective flood hazard management can reduce long-term damage costs. Public infrastructure and private improvements located in areas potentially affected by flooding are vulnerable to flood damage. Funding for structural flood risk reduction projects is limited.
- Development in flood-prone areas should be minimized and designed to reduce risks to life and property. Adverse impacts of development can be minimized by practices that preserve and enhance environmental functions.

- Flooding is a natural process that will continue to occur in many forms throughout Pierce County. The county will continue to find ways to avoid, minimize, and mitigate the impacts of flooding to the community and strive to build a more resilient community.
- Development of an effective flood hazard management plan requires communication and involvement of diverse groups of residents, stakeholders, and landowners.
- Promote community stewardship and a risk-informed approach to personal safety. Outreach should include information on programs at the state, federal, and local level for public agencies and individuals.
- Use an adaptive management approach when implementing the flood hazard management plan, while recognizing our levels of understanding of natural processes, climate change, and our use of the built environment will change over time.
- Leadership and cooperation among affected governments and public agencies is essential for the success of long-term flood hazard management.
- Beneficial functions of floodplains and rivers can be achieved by restoring, preserving, and enhancing natural processes.
- Adequate and stable funding is necessary for ongoing flood risk reduction activities and maintenance of existing facilities.
- A river and its valley floor, including adjacent floodplains, floodways, and potential channel migration areas, contribute a corridor through which floodwaters flow and within which opportunities exist for agriculture.

1.6 Planning Process

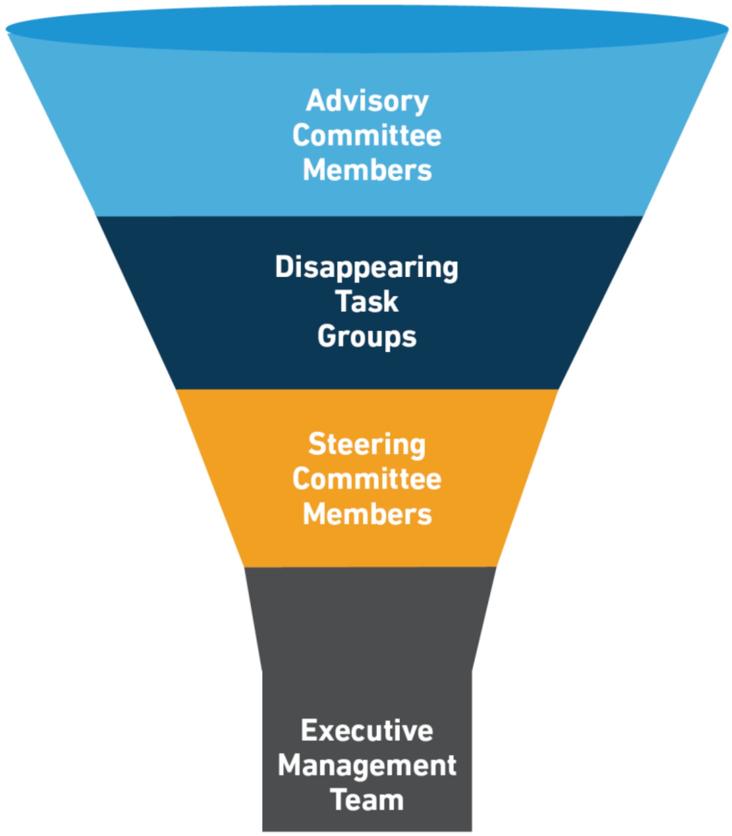
Development of this 2023 Flood Plan was led by the Pierce County Planning and Public Works, Surface Water Management (SWM) Division. Many Pierce County departments guided the development of this plan:

- Pierce County Emergency Management
- Pierce County Maintenance & Operations Department
- Pierce County Transportation
- Pierce County Government Relations
- Pierce County Parks and Recreation
- Pierce County Planning and Public Works
  - Pierce County Human Services
  - Pierce County Airports and Ferries
  - Pierce County Sewers
  - Pierce County Planning Department

- Office of the County Engineer
- Resource Management
- Economic Development
- Development Engineering

Figure 1.2 outlines the various planning teams that assisted with developing this flood plan.

Figure 1.2. 2023 Flood Plan Planning Teams



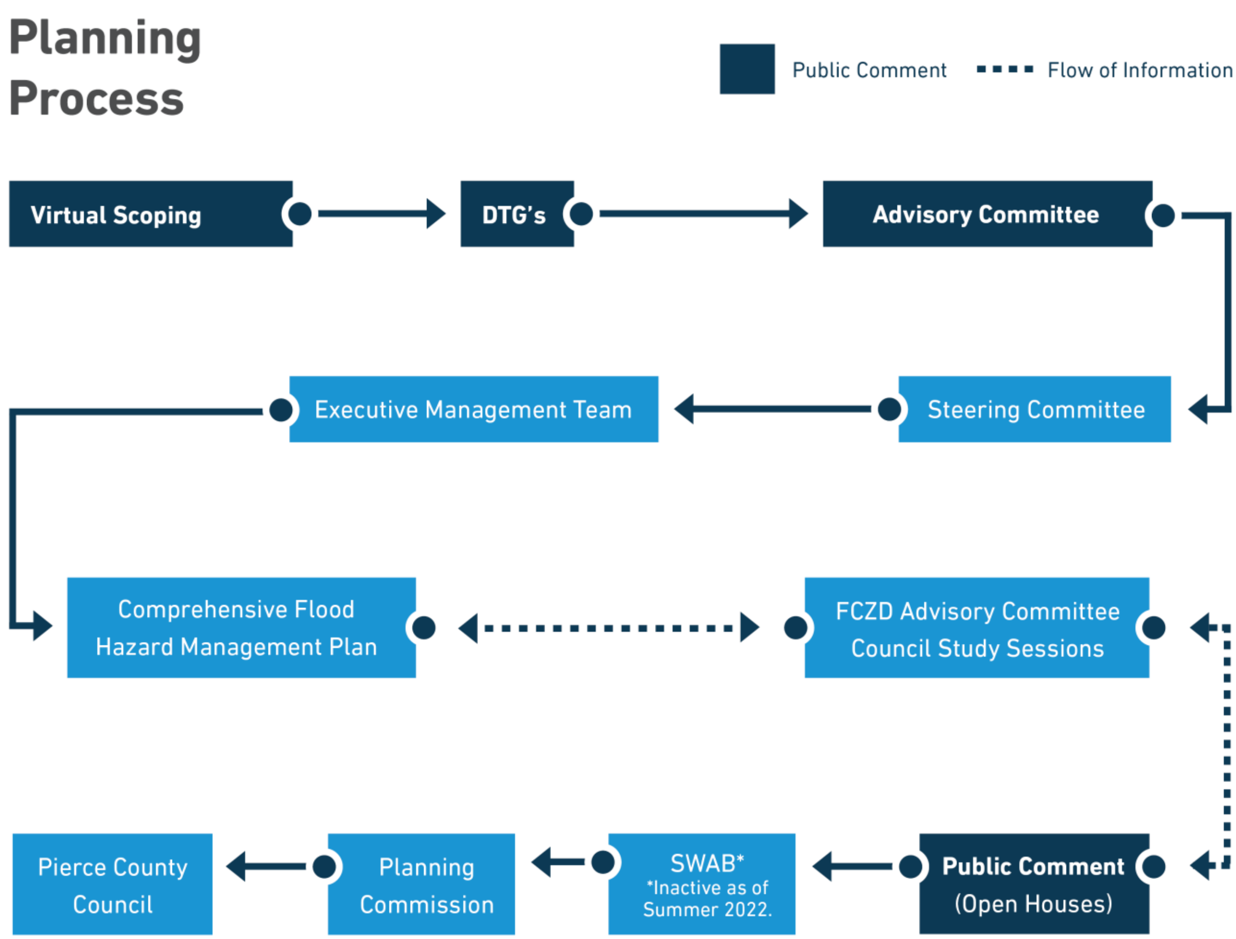
A Steering Committee (composed of the SWM management team) reviewed all elements of this flood plan prior to broader external review.

On April 8, 2021, the Advisory Committee was convened (virtually) to advise Pierce County on development of the 2023 Flood Plan and provide technical and other input on many of the plan's elements, including goals, objectives, and guiding principles. This committee also provided additional information on riverine, coastal, urban, and groundwater flooding and provided input on Pierce County capital projects. The Advisory Committee consisted of 30 members, of which over 50 percent live or work in the flood hazard areas covered by this plan. The Advisory Committee met 11 times between April 2021 through February 2023.

Throughout the planning process (see Figure 1.3), virtual Disappearing Task Group (DTG) meetings were held to discuss and provide input on various topics in this plan. A DTG is made up of individuals with expertise pertinent to a specific goal or goals; this ensures that the needed expertise is involved in discussions without partners/stakeholders needing to commit to yet another long-lasting committee. During the planning process, DTG group members met on the following topics:

- Problem/project ranking criteria
- Coastal flooding
- Urban flooding
- Groundwater flooding
- Cities' programmatic recommendations

Figure 1.3. Planning Process for 2023 Flood Plan Development



Information gathered during the DTG meetings is seen throughout this plan. Because of these DTGs, SWM was able to gather additional details on specific flooding locations needed for coastal, urban, and groundwater flooding across the entire county.

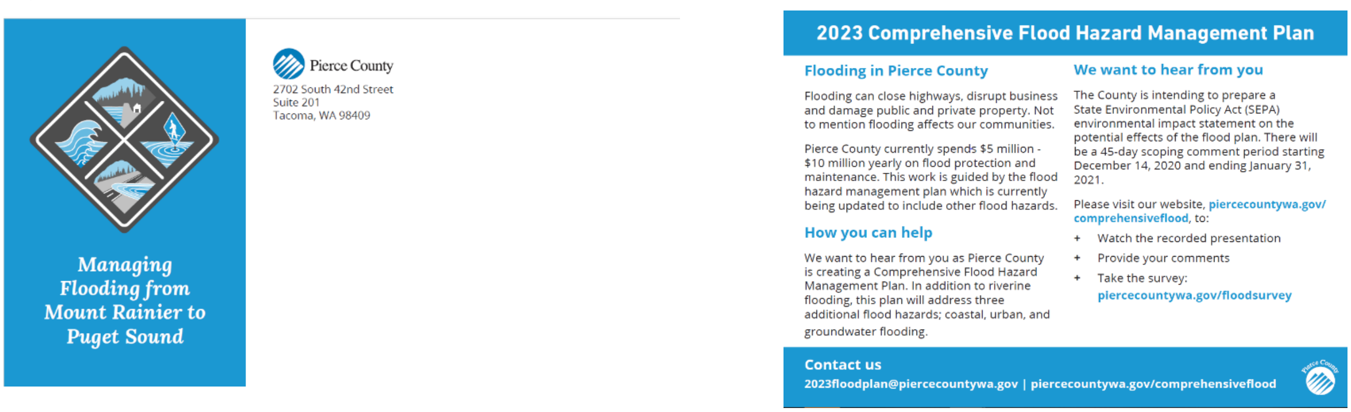
Additionally, 2023 Flood Plan elements that were created by the Advisory Committee and/or the DTGs were also reviewed by the Steering Committee (which was composed of Pierce County staff from various departments) and by the Executive Management team (which was composed of members from the Executives office and directors from Pierce County departments).

1.6.1 Outreach

In 2019, prior to drafting the 2023 Flood Plan outline, Pierce County SWM met with the Puyallup Tribe and the Muckleshoot Tribe to discuss the 2013 Flood Plan as well as supporting studies and methodologies that have been used since the development of the 2013 Flood Plan. Staff gathered input from both Tribes on what topics they would like to see in this 2023 Flood Plan, along with potential programmatic recommendations and actions.

In December 2020, the notification shown in Figure 1.4 was sent to all postal customers in Pierce County (including residential and business addresses) informing them about the flood planning process and inviting their input through a flood survey (http://piercecountywa.gov/floodsurvey). A total of 241 individuals responded to the survey, which allowed us to have a better understanding of how our community defines flooding and how flooding has impacted the the public within Pierce County.

Figure 1.4. Flood Plan Notification Post Card

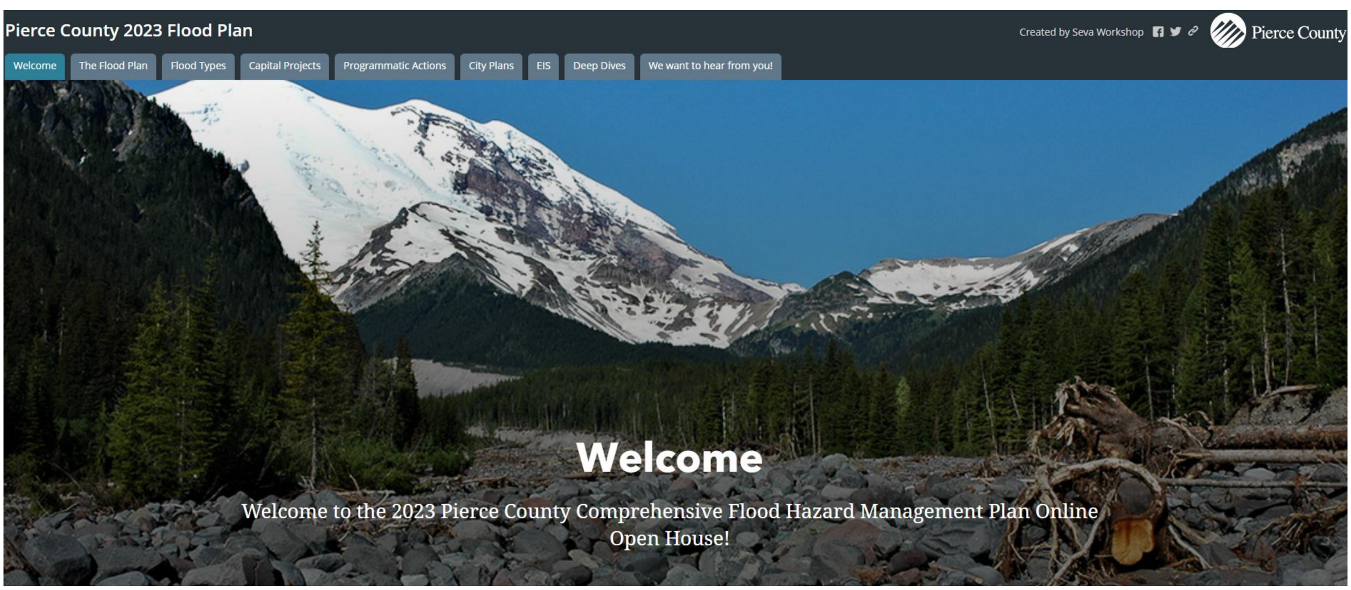


A combined flood plan and EIS scoping period was conducted from December 14, 2020, to January 29, 2021, during which the county invited community residents to share and provide feedback on the outline and scope for the 2023 Flood Plan. SWM received 14 responses or comment letters.

Open Houses

A series of in-person public open houses were held at four locations in Pierce County during the public comment period that started on March 21, 2023 and ended on May 3, 2023. During these open houses, the County sought: (1) input on issues, concerns, and problem identification, (2) perspectives on management strategies, plan alternatives, and options, and (3) comments on draft plan recommendations. The image shown below is of the postcard that was sent in March 2023 to residents that live in unincorporated Pierce County to notify them up the upcoming public comment. Media kits which contained postcards, a copy of the flood plan press release, a fact sheet, and social media content was sent out to each city in Pierce County to distribute in their communities.

If residents were not able to attend the in person open houses, a virtual open house was made available for individuals to provide comments on the draft flood plan. This online open house gave an opportunity to provide feedback on the draft plan before it went through various committees for approval and later adoption. Below is an image of the online open house that was used during the public comment period.



Twenty public comments were received during the open comment period. This included one letter from the Muckleshoot Indian Tribe, one letter stating there are no comments from the Puyallup

Tribe of Indians, three agency letters (received from Port of Tacoma, Department of Ecology and Department of Fish and Wildlife), 14 comment forms from the open houses, and one public comment letter. Comments have been evaluated and are addressed in this plan where appropriate.

1.7 2013 Flood Plan/2018 Flood Plan Update Accomplishments

The 2013 Flood Plan and the 2018 Flood Plan Update, while focused on Pierce County rivers, had a similar purpose as this plan: to recommend regional policies, programs, and projects that reduce the risks to public safety; reduce property damage; reduce maintenance costs; and improve conditions while protecting and maintaining the regional economy. Since the adoption of the 2013 Flood Plan and its 2018 update, SWM has continued to implement flood risk reduction actions in the community by the following:

- Completing nine flood risk reduction projects
- Removing 118 structures in the floodplain
- Increasing the number of flood insurance policies in the county due to an extensive public outreach program
- Improving partnerships with regulatory agencies and tribes; and
- Continuing as a Class 2 ranked community according to the Community Rating System program (for additional information see Chapter 5.6.1 in Chapter 5, Programmatic Recommendations)

Table 1.2 identifies the programmatic recommendations from the 2013 Flood Plan and its 2018 update and how Pierce County addressed these recommendations.

Table 1.2. Summary of 2013 Flood Plan/2018 Flood Plan Update Programmatic Recommendations

Summary of 2013/2018 Programmatic Recommendation		Accomplishment
Flood Plan-Wide (FPW) #1 Floodplain Mapping	These recommendations address the adoption and use of preliminary FEMA flood maps (DFIRMs) and other flood studies; subsequent periodic update of such studies; related communication with agencies and the public; and other issues related to flood hazard mapping.	Pierce County adopted DFIRMS in February 2017, which led to county code updates and improved standards for flood safety.
FPW #2 Channel Migration Zone Mapping Regulations (1)	These recommendations address adopting the channel migration zone (CMZ) studies and maps for South Prairie Creek (2005) and upper Nisqually River (2007) areas.	Pierce County's CMZ mapping project (1) adopted CMZ studies for upper Nisqually and South Prairie Creek and (2) completed studies for Greenwater and upper White Rivers.

Summary of 2013/2018 Programmatic Recommendation		Accomplishment
FPW #2 Channel Migration Zone Mapping Regulations (2)	These recommendations address mapping the CMZ hazards on the Greenwater, upper White, middle Nisqually, and Mashel rivers. Upon completion, these CMZ maps should be adopted.	Pierce County completed and adopted the upper Nisqually River channel migration zone study in 2017. Studies have also been completed for the Greenwater River in 2017 and the upper White River in 2020. Both of these latter studies have not been adopted at this time this flood plan was prepared.
FPW #3 Technical Assistance on Floodplain Information	These recommendations address internal Pierce County training for staff to remain subject matter experts and a regional resource for local communities in flooding and channel migration issues.	Pierce County conducted flood response training with Operations/SWM staff.
FPW #4 Flood Insurance and the Community Rating System	These recommendations address participation in the National Flood Insurance Program and the Community Rating System (CRS), to encourage communities to achieve a CRS rating of Class 5 or better.	Pierce County maintained a Class 2 rating in the CRS program while promoting and supporting other communities to join. By continued participation in the CRS program, the public in unincorporated Pierce County are allowed to buy flood insurance in their community.
FPW #8 Floodplain Acquisition and Home Buyouts	These recommendations address identification and evaluation of floodplain properties for home buyouts or property acquisition.	SWM successfully litigated flood regulations that led to the removal of illicit private levee, and now 32 mobile homes are no longer in the floodway. The existing RVs allow the business to continue at a much lower risk.
FPW #9 Home/Structure Elevation and Floodproofing	These recommendations address technical assistance provided to floodplain property owners.	Beginning in 2017, SWM re-vamped their annual outreach program to target specific floodplain areas to increase awareness of the type of flooding they may experience. SWM has also updated the website to provide more technical information and resources for homeowners.

Summary of 2013/2018 Programmatic Recommendation		Accomplishment
FPW #10 **River Channel Monitoring**	These recommendations address monitoring of river channel conditions, including river stage and flow, cross-sections, conveyance capacity, sedimentation trends, topography, light detection and ranging (LiDAR).	SWM monitors river channel conditions every fall prior to flood season to identify active hot spots. In 2020, the entire river system was flown with high quality LiDAR during winter low flow conditions in order to track channel migration and aggregation. Future LiDAR flights are planned every three years to continue tracking the fluvial geomorphology.
FPW #12 **Facility Repair & Maintenance – PL84-99 Program**	These recommendations address Pierce County's participation in: • U.S. Army Corps of Engineers' (USACE) PL84-99 program for emergency response activities and rehabilitation of flood risk reduction facilities • Engaging in review of levee maintenance standards • Maintaining program eligibility while pursuing bio-engineering designs • Notifying and coordinating with and seeking input from resource agencies and tribes in implementation	SWM developed a System-wide Improvement Plan that was completed and accepted by USACE in January 2017 that maintains eligibility in the PL84-99 program.
FPW #14 **Flood Education and Outreach Program**	These recommendations address consistency of education and outreach activities with the CRS program; outreach to floodplain property owners through an annual mailing; promotion of all aspects of the county's flood hazard management program; promotion of flood preparedness and purchase of flood insurance; and internal and external coordination and collaboration	SWM mailed notifications to more than 15,000 property owners regarding riverine, coastal, urban, and groundwater flooding.
	Pierce County should increase promotion of the purchase and maintenance of flood insurance through the National Flood Insurance Program (NFIP). Education and outreach efforts should focus primarily on river floodplain property owners, real estate agents, and insurance companies.	SWM responded to an average of over 600 assistance calls per year.

Summary of 2013/2018 Programmatic Recommendation		Accomplishment
	Pierce County should collaborate with cities, towns and other agencies and organizations on flood education and outreach.	Two SWM staff participate on national committees. Additional staff actively lead regional technical associations. Pierce County is a model community for good National Flood Insurance Program practices.
FPW #16 Emergency Response and Flood Fighting	These recommendations address regional coordination of response and recovery services during and after flood events through the Emergency Operations Center; coordination with cities, towns, tribes, state and federal agencies; documenting all costs associated with response activities; sand bagging support; flood emergency exercises; and periodic updating of guidance and protocols.	SWM worked with Pierce County's Emergency Management and Maintenance & Operations departments to support flood drills and flood activations. Each fall, SWM participates in the Pre-Winter Weather Seminar hosted by Emergency Management. During the winter, SWM also works with Maintenance & Operations to host a flood response training that covers topics such as Rapid Damage Assessment, flood preparedness and safety, and activation procedures.
FPW #17 Incidental Take Authorization	These recommendations address SWM seeking incidental take authorization for its activities that affect species listed as threatened or endangered under the federal Endangered Species Act (ESA).	SWM developed the Habitat Conservation Plan which is expected to be completed in 2023. The resulting incidental take permit is expected to be issued subsequently after.
FPW #18 Adaptive Management	Based on these recommendations, Pierce County should use the principles of adaptive management to assess problems, define strategies and actions, identify objectives, implement actions, and monitor to determine if actions are meeting objectives, evaluate and compare actual outcomes, and adjust future actions to reflect new understanding over time. Projects and programs should be monitored to assess their effectiveness and the degree to which they function relative to their stated purpose, goals, and objectives.	Pierce County completed the Clear Creek Strategy Plan in 2020. This plan identified several adaptation pathways towards addressing several issues in the Clear Creek community, including flooding and drainage, agriculture and land use, social challenges, and fish habitat ecosystem functions.

Summary of 2013/2018 Programmatic Recommendation		Accomplishment
FPW #19 **Climate Change**	These recommendations address development of an approach to incorporate information about climate change, including predicted changes in precipitation patterns, future peak flows, and sediment transport into future project designs and program implementation, and working with regional experts.	Pierce County published the Climate Change Resilience Plan.
FPW #23 **Coordination with Other Jurisdictions, Tribes, and Agencies**	These recommendations address coordinating with other jurisdictions in flood plan implementation, including cities/towns, counties, Tribes, state, and federal agencies, and coordinating with local governments adjacent to and across the river from proposed capital projects.	SWM established and is an active participant in the Floodplains for the Future group (see Section 4.4.1 for additional information in Chapter 4). SWM is also an active member in the White River Dialog group and also was a participant in the Countyline Setback project.
FPW #25 **Levee and Revetment Setback Program**	These recommendations address updating the levee and revetment inventory map; updating the Setback Levee Feasibility Study; performing a comprehensive hydraulic study to determine cumulative benefits of flood protection of setback build-out scenario; pursuing funding for design and construction of setback projects; and evaluating additional sites for possible levee/revetment setbacks as new needs are identified.	SWM completed an updated Levee Setback Feasibility Study was done in support of this 2023 Flood Plan. See Section 1.10.1 in this chapter for additional information. SWM completed feasibility studies for Carbon River Bridge Street project and 128th Street Comprehensive Levee Setback Feasibility Study.
PR #1/WR #1/CR #1 **Sediment Management and Gravel Removal**	These recommendations address the approach for sediment management and gravel removal, including use of technical data and studies; pursing levee setback projects as the preferred means to manage downstream sediment transport; conditions under which gravel removal may occur; evaluating alternative approaches to gravel removal; monitoring locations of gravel removal; and convening a sediment management work group to develop a plan to guide sediment management and gravel removal.	In 2019, for the Habitat and Flood Capacity Creation Project (formally called the Sediment Management as a Risk Reduction Tool pilot project), a final report that summarized the previous 10-year project history and lessons learned was completed.

1.8 Relationship to Other Pierce County Plans

Numerous Pierce County plans, polices, and agreements informed the development of this 2023 Flood Plan. A brief overview of some of these plans, policies, and agreements is provided in the following sub-sections.

1.8.1 Pierce County Comprehensive Plan, Community Plans, and Environmental Regulations

The Comprehensive Plan was first developed and adopted in November 1994 in response to the requirements of the Growth Management Act (GMA) and is codified in Title 19A of the PCC. It was developed to address growth in the county over a 20-year period. Since then, the county has created a new Comprehensive Plan adopted June 30, 2015, and effective June 30, 2016. This updated plan addresses 14 goals that have been outlined by the Growth Management Act (RCW 36.70A). These goals are not listed in any particular order:

- Urban growth
- Reduce sprawl
- Transportation
- Housing
- Economic development
- Property rights
- Permits
- Natural resources industries
- Open space and recreation
- Environment
- Citizen participation and coordination
- Public facilities and services
- Historic preservation
- Shorelines

The Comprehensive Plan can be accessed at ADOPTED-Comprehensive-Plan-with-Community-Plans-Effective-12-31-2020 (piercecountywa.gov).

Eleven unincorporated communities of Pierce County adopted individual community plans that are a part of Pierce County's Comprehensive Plan. These community plans are intended to supplement and refine policies laid out in the Comprehensive Plan as well as provide additional information on the unique characteristics of each community. Below are the communities in Pierce County that have an adopted community plan:

- Alderton-McMillin
- Anderson - Ketron Islands
- Browns Point – Dash Pont
- Frederickson
- Gig Harbor Peninsula
- Graham
- Key Peninsula
- Mid-County
- Parkland-Spanaway-Midland
- South Hill
- Upper Nisqually Valley

Pierce County recently updated community plans for the Frederickson, Mid-County, Parkland-Spanaway-Midland, and South Hill communities. Each update included a review of individual community issues and identified issues that are common to all four areas. These plans were updated simultaneously because they make up the majority of the county's central urban growth area. The major roads through these areas are connected, as are many of the issues facing these communities, such as rapid growth, traffic, jobs, and housing.

Consistency with the Pierce County Community Plans (Title 19B), Critical Areas (Title 18E), and the Shoreline Master Program (Title 20) is required for projects contained within the Flood Plan. The 2023 Flood Plan projects may be subject to special requirements (e.g., setbacks or buffers), design standards, and mitigation measures contained within the Comprehensive Plan, depending upon their location within the county and shoreline environment.

1.8.2 Surface Water Management Basin Plans

Within unincorporated Pierce County, SWM is guided by a series of nine basin-specific plans developed in the 1990s that address flooding of the regulated floodplain within the watershed for tributaries and other water bodies, identify existing conditions that affect storm drainage and surface water, forecast future drainage conditions, and identify potential solutions for the streams and tributaries not included within this 2023 Flood Plan. These basin-specific plans are used to develop capital improvement projects, maintenance and repair projects, property acquisition, and program schedules and budgets. During the development of this flood plan, the flood problems that were identified in the nine basin plans are mentioned in Appendix A, which provides additional information on the flood type, location, and the status of each problem.

There are basin-specific plans for the following:

- Clear / Clarks Creek Basin
- Clover Creek Basin
- Gig Harbor Basin
- Hylebos Browns-Dash Point Basin
- Key Peninsula – Islands Basin
- Mid-Puyallup Basin
- Muck Creek Basin
- Nisqually Basin
- White River Basin

1.8.3 Pierce County Natural Hazard Mitigation Plan

In 2000, Congress passed the Disaster Mitigation Act of 2000 that requires local governments to have federally approved natural hazard mitigation plans in order to be eligible for future pre-and post-disaster mitigation funds. The overriding goal of this Act is to reduce risk and ultimately reduce the cost of disaster recovery.

The Unincorporated Pierce County All Hazard Mitigation Plan identifies each department or division's role in providing services and its capabilities to protect and preserve Pierce County. The plan identifies Pierce County's "critical infrastructure," their locations, and the mitigation strategies necessary to protect these assets and services. The overall goals of the plan are listed below:

- Protect life and property
- Ensure continuity of operations
- Establish and strengthen partnerships for implementation
- Protect the environment
- Increase public preparedness for disasters
- Promote a sustainable economy

The Pierce County Department of Emergency Management is responsible for coordinating the development of the Pierce County All Hazard Mitigation Plan, which includes the divisions and agencies of Pierce County government. The Unincorporated Pierce County All Hazard Mitigation Plan is part of the larger Region 5 All Hazard Mitigation Plan that includes the mitigation planning of all other governments and local jurisdictions within Pierce County. As part of the adoption process, the 2013 Flood Plan/2018 Flood Plan Update was incorporated by reference into the Unincorporated Pierce County All Hazard Mitigation Plan. More information about the Pierce County All Hazard Mitigation Plan can be found online at Hazard Mitigation Plan | Pierce County Intranet, WA - Official Website.

1.8.4 System Wide Improvement Framework (SWIF)

The SWIF levee vegetation management strategy represents a local preferred approach to levee vegetation management in that it balances the needs of flood risk reduction with the habitat needs of salmonids and other aquatic species found within the Pierce County river systems. Currently, three of these species are listed as threatened under the ESA. The strategy acknowledges the agreement established by federal decree (United States District Court, Western District of Washington at Tacoma, Case No. C79-269T) between Pierce County and the Puyallup Tribe of Indians relating to vegetation management along the Puyallup River system. The strategy works within the constraints of that Court-ordered agreement and the USACE SWIF interim guidance policy (USACE 2014b).

The strategy provides basic guidelines to help establish an appropriate balance between maintenance of flood risk reduction structures and habitat considerations. The vegetation management strategy is implemented annually and monitored for effectiveness and potential impacts to fish and wildlife. The vegetation management program will be adaptively managed to make adjustments as identified through routine annual monitoring.

The SWIF vegetation management strategy will be performance-driven, centered by three main performance considerations:

- **Risk:** Flood risk reduction
- **Habitat:** Retention of functional habitat
- **Maintenance:** Maintenance efficiency

1.8.5 Clear Creek Strategy Plan

The Clear Creek Strategy Plan is a long-range vision and framework to improve conditions related to flooding and drainage, agriculture and land use, social challenges, and fish habitat ecosystem functions. The strategy plan, which was developed in partnership with the community and stakeholders, created solutions to achieve results desired by the people who live and work in the Clear Creek/Riverside community. The strategy plan is a flexible, comprehensive document intended to set the broader framework for projects and studies. It defines a pathway built on past successes to develop community-generated projects, studies, and processes. The plan, which was completed in 2020, guides decision-making, is a tool for education and communication, and provides a long-range perspective for the Clear Creek/Riverside area.

The strategy plan is updated annually and will reflect any changes, recommendations, and updates from this 2023 Flood Plan as they pertain to the Clear Creek/Riverside area.

1.8.6 Sustainability 2030: Greenhouse Gas Reduction Plan for Pierce County

The Sustainability 2030, Pierce County's Greenhouse Gas Reduction Plan (Sustainability 2030 plan) outlines a 10-year goal and actions to take to reduce greenhouse gas emissions across Pierce County government operations and the larger community. This plan was developed with numerous community Sustainability experts and Pierce County stakeholders. The Sustainability 2030 plan calls for Pierce County to reduce government operational and community-wide greenhouse gas emissions 45 percent by 2030.

The Sustainability 2030 plan acknowledges and promotes four main co-benefits of reducing greenhouse gas emissions: enhancing public health, improving water quality, promoting equity, and strengthening the economy. The plan does this across five areas of focus: energy and the built environment, transportation, consumption and waste reduction, carbon sequestration, and education and outreach. Some relevant proposed actions include incentivizing green infrastructure and removing impervious surfaces, creating a county conservation plan, partnering with Tribes and others to identify ways to sequester carbon in estuaries and the nearshore environment, and expanding programs to provide trees to county residents. These actions and the plan's larger greenhouse gas reduction goals support the 2023 Flood Plan's overall purpose to create a resilient community in part by improving habitat conditions and reducing risks to public health.

1.8.7 Climate Change Resilience Plan

When Pierce County Council passed legislation endorsing the Sustainability 2020 Plan in 2016, a portion of the plan called for "a completed Climate Change Resilience Strategy for Pierce County." This plan developed recommendations with priority action steps. The Climate Change Resilience plan formally starts the process of preparing for the impacts of climate change in a manner that should reduce risks to people and minimize financial losses to the County.

Just as this 2023 Flood Plan aims to create a community resilient to flooding, the Climate Change Resilience plan addresses preparing for the impacts of climate change to reduce risks to people and to minimize financial losses to the County. The Climate Change Resilience plan calls for updating flood mapping, reviewing floodplain building standards, incorporating climate change considerations into long-range planning efforts, and continuing to construct setback levees, among additional actions.

1.9 Major Studies Supporting Plan Development

Five studies were undertaken as part of this planning effort to inform development and implementation of the work outlined in this flood plan.

- Pierce County Comprehensive Levee Setback Feasibility Study Update (Environmental Science Associates 2021)
- Flood Risk Assessment and Economic Analysis (ECONorthwest 2022)
- Flood Inundation Study (ECONorthwest 2022)
- State Environmental Policy Act (SEPA) EIS (Herrera 2023)

1.9.1 Pierce County Comprehensive Levee Setback Feasibility Study Update

The Puyallup, Carbon, and White rivers within Pierce County have been continuously leveed since 1965. The placement of the levees not only straightened the channels, but also substantially altered the form and function of the river channels. Beginning in the early 1900s, the previously meandering rivers were disconnected from their respective floodplains to control flooding. Over the past several decades, the floodplains have been used for agriculture and, more recently, for urban development, which has significantly increased the risk of flooding and subsequent flood damages. Detachment of the floodplains has created conditions that are detrimental to both natural and developed environments—specifically, the loss of channel complexity and aquatic habitat, normal floodplain functions such as flood and sediment storage, and off-channel aquatic and riparian habitat.

The 2021 Comprehensive Levee Setback Feasibility Study Update (2021 study update) represents a continuation of prior efforts completed by Pierce County over the last two decades to identify, design, and implement projects to remove or modify levee structures that have been linked to flood and habitat impacts, to the benefit of both human and aquatic communities. To date, six levee setback projects have been completed in the Puyallup, Carbon, and White river watersheds.

Two previous studies have evaluated and prioritized levee setback project sites within the Puyallup, Carbon, and White river watersheds with the objective of identifying opportunities to set back existing levees and reconnect the river channel with its floodplain to recover lost flood storage and aquatic habitat. The 2008 Levee Setback Feasibility Analysis (GeoEngineers 2008) developed a strategy for prioritizing 32 sites in the greater Puyallup River watershed. In 2014, Pierce County completed a Floodplain Reconnection Feasibility Study (Natural Systems Design 2014) as a follow-up to the original site evaluations. The 2008 study evaluated the feasibility and benefits of levee setbacks primarily as a flood hazard mitigation strategy, while the 2014 update incorporated criteria related to fish habitat and to value the benefit of "clustered" projects. The 2014 study modified the site rankings based on the updated criteria and recommended future updates to the site boundaries and the identification of new setback sites with the intent of creating a more continuous river corridor to the maximum extent possible.

Environmental Science Associates prepared the 2021 study update to support the development of this 2023 Flood Plan and associated Capital Improvement Plan efforts by providing a complete catalog of prospective levee setback sites. The study update provides an updated assessment of a larger suite of project locations, both inclusive and in addition to the 32 project locations evaluated in the 2008 and 2014 studies. Since 2014, 27 new sites have been added to the catalog of levee setback locations. These additional sites span a wide range of locations within the watershed. Also, of the original 32 sites, three are not considered in this study given that they have since been completed. As such, the total number of sites evaluated in the 2021 study is 56.

Of the sites identified by Pierce County and stakeholders for evaluation, 18 are already undergoing separate, site-specific assessments by the County, City of Sumner, USACE, or others. For each of these 18 sites, a site characterization was completed to provide site information consistent with the remaining locations. However, concept designs and probable costs were not developed for these sites. Site characterizations were completed for two additional sites that are not currently under development, but due to the limited feasibility of a setback project at the site, conceptual designs and costs were not prepared.

1.9.2 Flood Risk Assessment and Economic Analysis

The Flood Risk Assessment and Economic Analysis focused on the 100-year floodplains of the Puyallup and Nisqually river systems, their tributaries, and large streams as well as flood impacts from future sea level rise. The report examined economic resources in the floodplain, economic impacts of flooding, distributional effects of flooding, flood impacts to properties, transportation impacts, sea level rise transportation impacts, flood impacts to the recreation sector, and flood impacts to wastewater treatment plants and overflows. A total of $2.8 billion assessed value of properties are within the 100-year floodplain extent (ECONorthwest 2022), with 76,046 acres of land within the 100-year floodplain in Pierce County (ECONorthwest 2022). There are approximately 1,958 business establishments and 15,416 employees in the 100-year floodplain (ECONorthwest 2022).

The analysis summarizes a range of estimates of economic impacts that were quantified as follows:

- Property damage is estimated to be $947.3 million based on estimates of building within the floodplain.
- A total of $4.3 million in labor income and $13.4 in output could be lost if all businesses and employees are disrupted for a 1-day period due to flooding.
- In a large flood event, road closures could cause up to $3.0 million in costs due to transportation disruptions. If a catastrophic levee breech occurs, the costs from transportation delays alone would be $59.3 million.
- Approximately $49,232 in daily farmland gross revenue is generated within the 100-year floodplain.
- Without future adaptation measures, sea level rise could inundate large portions of the Port of Tacoma by the end of the century, which is a source of 42,100 jobs and almost $3 billion in economic activity.
- Flooding disproportionally affects people living in manufactured homes and mobile homes, which are often located in the floodplain.
- Infrastructure (such as roads, bridges, tunnels, telecommunication cable, electrical infrastructure, and culverts) could be damaged from a 100-year flood event totaling an estimated $838.9 million for roads and bridges alone.

- Lost revenue during peak season for a 1-week closure at Mount Rainier National Park would result in a loss of $1.6 million in visitor spending.

1.9.3 Flood Inundation Study

In December 2022, Pierce County SWM completed a project to create a comprehensive set of static flood inundation maps for selected reaches of Pierce County's river systems. These maps are non-regulatory, and were created to supplement, but not replace, FEMA's Flood Insurance Rate Maps. The new maps will serve as a helpful planning and communication tool to estimate impacts along our rivers for a variety of river flows. The mapping for each reach listed below presents three key pieces of data: surface water elevations, water depth, and water velocity. The rivers and general reaches that were modeled and mapped include the following:

- Puyallup River:
  - Lower Puyallup – Commencement Bay to Puyallup
  - Middle Puyallup –Puyallup to McMillan
  - Upper Puyallup – McMillan to Electron
- Carbon River
  - Below South Prairie Creek
  - Above South Prairie Creek along 177th Street East
  - Upper Carbon River – downstream of Mount Rainier National Park
- South Prairie Creek
- White River
  - Lower –Sumner to Pacific
  - Upper –Greenwater to Crystal Village
- Nisqually River
  - Middle Nisqually River McKenna to Wilcox Farms
  - Upper Nisqually River – Elbe to Mount Rainier National Park

Along with creation of additional inundation mapping, this project also created 11 different flood warning matrices, which will be used as an interpretive guidance tool along with the geographic information system (GIS) river flood inundation mapping layers.

These matrices attempt to provide insight into anticipated impacts along mapped river segments using three anticipated impact categories: channel characteristics, potential water over roadways, and community notifications. To see these flow warning matrices, please refer to Chapter 6, Management Strategies and Recommended Capital Projects for Flood Hazards in Pierce County, in this flood plan.

1.10 State Environmental Policy Act

1.10.1 SEPA Process

In accordance with WAC 197-11-400, the proposed adoption of this 2023 Flood Plan will go through the SEPA environmental review process. A programmatic draft EIS has been prepared to evaluate the affected environment, potential impacts and benefits, mitigation measures, and any significant unavoidable adverse impacts that may result from Pierce County's proposed adoption of this 2023 Flood Plan. The analysis in the Draft EIS, along with other considerations, will be used by agency decision-makers to decide whether to approve the proposal to adopt this 2023 Flood Plan, approve it with conditions, or deny the proposal. The SEPA applies to actions made at all levels of government within Washington. SEPA is intended to provide information to agencies, applicants, and the public to encourage the development of environmentally sound proposals. Comments from the public, agencies, and Tribes on the Draft EIS, and any have been considered in the development of a Final EIS.

1.10.2 SEPA and Future Projects

This programmatic EIS was prepared to consider the impacts of adopting and implementation of this 2023 Flood Plan and to provide the basis for later individual project review. Before individual projects in this flood plan are implemented, they will undergo a separate environmental review to evaluate potential effects. Under these reviews, potential impacts and mitigation measures that may result from specific projects will be evaluated.

2 Types of Flood Hazards in Pierce County

Flooding in general terms is defined as water on the ground surface where it normally is not experienced, along with associated impacts. This can include the shoreline of a lake or Puget Sound, active high flow channels of a stream or river, and water surfacing from regional aquifers.

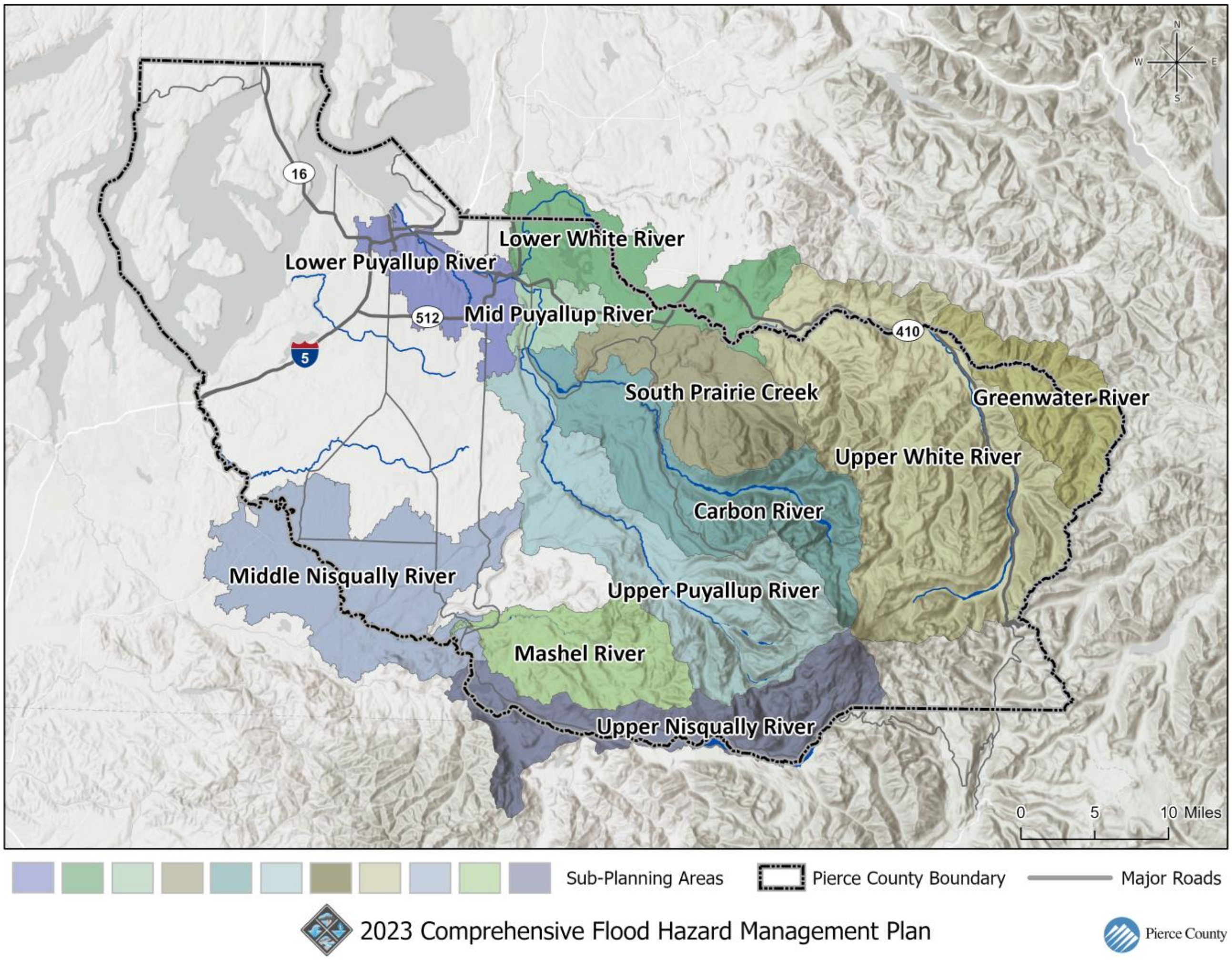
Flooding can have both positive and negative effects. Benefits might include the creation of complex ecosystems composed of wood and sediment, which benefit fish and wildlife. Flooding also recharges groundwater systems and lowers in-channel stream or river velocities by spilling over the bank and providing side channel refuge for juvenile salmon. The negative effects of flooding could include avulsions, which is the sudden cutting off of an area by flood, currents, or change in course of river. This can damage private property and infrastructure and separate salmon from their habitat. Overbank flows can also impact water quality and public infrastructure. Floods are measured by their impacts to humans, the built environment, and agricultural resources.

This 2023 Flood Plan encompasses all of Pierce County across multiple flood hazards: riverine, urban, groundwater, and coastal. Each of these hazards have unique characteristics that influence the way they flood an area and why it occurs. For some areas that flood, there may be overlap between flood sources. This 2023 Flood Plan strives to address the underlying issues of each type of flooding, while recognizing that at any one location the source of the flood hazard can be varied and mixed. This means that there may be several possible ways to mitigate flooding. Where this occurs, the plan will identify a preferred mitigation solution.

2.1 Pierce County River Systems

Pierce County's River systems includes the floodplains of the Puyallup River and the Nisqually River. Rivers in Pierce County behave differently than many other rivers in Western Washington. With a few exceptions, the major river systems of Pierce County originate from glaciers on the slopes of Mount Rainier. The planning area for this comprehensive flood hazard management plan has been divided into 11 sub-planning areas, as seen in Figure 2.1.

Figure 2.1. 2023 Flood Plan Sub-Planning Areas



2.1.1 Puyallup River Basin

The upstream end of the approximately 992 square mile basin begins at the top of Mount Rainier at an elevation of 14,411 feet above sea level and ends approximately 50 miles downstream where it discharges into Commencement Bay. The Puyallup River runs through the cities of Tacoma, Fife, Puyallup, Sumner, and Orting, and large areas of unincorporated Pierce County. This flood plan will focus on the two primary river systems within the Puyallup basin, the Puyallup River and the White River and its main tributaries where Pierce County manages flood risk reduction structures, public infrastructure and other community interests of concern related to flood risk management.

South Prairie Creek lies in the center of the Puyallup River Basin, east of Orting. South Prairie Creek has a drainage basin of 88 square miles and ranges in elevation from 285 feet above sea level to 5,933 feet at the summit of Pitcher Mountain. This 2023 Flood Plan concentrates on the lower floodplain area of South Prairie Creek (river mile [RM] 0.0 – RM 6.4), extending from the town of South Prairie to the confluence with the Carbon River near RM 5.8. There are no Pierce

County levees along lower South Prairie Creek, but there are isolated rock riprap revetments and earthen berms that have been constructed by agricultural and residential landowners and transportation agencies, such as near State Route (SR) 162 bridge crossings of the creek.

The description of the Puyallup River system in this 2023 Flood Plan is broken into its component managed reaches to describe specific characteristics associated with each river reach to provide context for the differences associated with each reach. The Puyallup River is broken into three managed reaches: the lower Puyallup, middle Puyallup, and upper Puyallup as shown in Figure 2.1. The reach upstream of RM 28.6 to Mount Rainier is not managed by Pierce County. The Puyallup River and its main tributaries are shown in Figure 2.2. Each reach is described in more detail in the following sections.

The lower Puyallup River reach conveys all waters received from every tributary area and stream. This reach begins at the confluence with the White River at RM 10.3 and flows in a westerly direction to its discharge point into Commencement Bay at RM 0.0. The land uses along this reach range from industrial near its terminus with Commencement Bay in Tacoma within the port area (including the Gog-le-hi-te wetland complex) to primarily urbanized areas adjacent to Puyallup and Sumner, along with scattered areas of agriculture in between.

The middle Puyallup River reach flows north from the confluence with the Carbon River at RM 17.4 north of Orting, then through the communities of McMillan and Alderton, proceeding along the edges of Sumner and Puyallup before meeting the confluence with the White River at RM 10.3. The land use in this reach is a mixture of agriculture, rural, and suburban, and acts as a transition zone between the more urbanized lower reach and rural upper reaches.

The upper Puyallup River reach flows in a generally northerly direction from the upper end of the managed system near RM 28.6 north of the community of Electron. The upper portion of this reach flows through primarily rural and agricultural lands until it encounters urban development in the southwest area of Orting. The reach proceeds northerly until it reaches the confluence with the Carbon River near RM 17.4.

The uppermost reach of the Puyallup River above RM 28.6 is not managed by Pierce County. This reach extends up to its point of origin on the west face of Mount Rainier. The river system is fed by the Puyallup, Emmons, Tahoma, and Mowich glaciers. Approximately 151 square miles of drainage area flows 27 miles downstream to the upper end of Pierce County's managed segments near RM 28.6. The majority of this river segment lies within rural unincorporated Pierce County. The primary land use in this part of the basin is dominated by managed timberlands. The uppermost portion of the basin lies within Mount Rainier National Park. From there, the river channel is confined to a relatively narrow valley corridor from the base of the glaciers down to approximately RM 29.0, where the floodplain starts to broaden as it begins to join the Puget Sound lowlands downstream of Electron.

Figure 2.2. Puyallup River System Schematic

2.1.2 White River Basin

The White River drains an area of approximately 494 square miles. It flows about 75 miles from its source on the Emmons Glacier on the northeast side of Mount Rainier. The river has several tributaries, including Huckleberry Creek, Greenwater River, and Clearwater River. It flows through the community of Greenwater; the Muckleshoot Indian Reservation; and the cities of Buckley, Auburn, Pacific, and Sumner before joining the Puyallup River near RM 10.3. Approximately 75 percent of the White River basin lies within Pierce County, and the remaining 25 percent is within King County. The White River forms a segment of the county line separating King and Pierce counties between the confluence of the Greenwater River and White River near RM 44.65 downstream to the southeast corner of Auburn. The Greenwater River lies in northeastern Pierce County and enters the White River at RM 44.65. The headwaters of the Greenwater River are on Castle Mountain in the Cascades (elevation of 6,700 feet), and it flows northwest for 21 miles to Greenwater. The Greenwater River forms another segment of the boundary between King County (north of the river) and Pierce County (south of the river) upstream of its confluence with the White River.

2.1.3 Carbon River Basin

The Carbon River, which drains an area of 142 square miles, originates on the north face of Mount Rainier at the Carbon Glacier. It flows 33 miles downstream before joining the Puyallup River north of Orting near RM 17.4. This flood plan concentrates on the lower 8.4 miles of the Carbon River. Most of this segment of the river lies within unincorporated Pierce County, but a portion of the left bank between RM 0.74 and 3.39 flows along the eastern boundary of the Orting city limits. Above RM 8.3, the river is contained within steep canyon walls up to the community of Fairfax at RM 17.5. Between RM 0.0 and RM 8.3, the channel corridor lies along the eastern flank of the Orting Valley and is confined within a relatively narrow trough-like corridor.

South Prairie Creek lies in the center of the Puyallup River Basin, east of Orting. South Prairie Creek has a drainage basin of 88 square miles and ranges in elevation from 285 feet above sea level to 5,933 feet at the summit of Pitcher Mountain. This 2023 Flood Plan concentrates on the lower floodplain area of South Prairie Creek (RM 0.0 to RM 6.4), extending from South Prairie to the confluence with the Carbon River near RM 5.8. There are no Pierce County levees along lower South Prairie Creek, but there are isolated rock riprap revetments and earthen berms that have been constructed by agricultural and residential landowners and transportation agencies, such as near SR162 bridge crossings of the creek.

2.1.4 Nisqually River Basin

The Nisqually River drains a watershed of approximately 568 square miles. The river originates from the Nisqually Glacier on the south slope of Mount Rainier and flows 81 miles to the estuary at Nisqually National Wildlife Refuge before flowing into Puget Sound. There are two major tributaries to the Nisqually River: the Mashel River and Muck Creek. Nearly 58 percent of the Nisqually River watershed lies in Pierce County, with the remainder in Thurston County (16 percent) and Lewis County (26 percent). There are two dams on the Nisqually River, the first near RM 41.2 (LaGrande Dam) and the second near RM 42.9 (Alder Dam). Alder Dam forms the 3,000-acre Alder Lake. The two dams are part of the Nisqually Hydroelectric Project owned and operated by Tacoma Power. According to Tacoma Power, the dams provide incidental reduction of flood flows, but there are no flood control requirements noted in the operating agreement (Nisqually Watershed Characterization 2008). The Mashel River is the largest tributary to the Nisqually River and drains an area of approximately 83 square miles. The headwaters of the Mashel River begin near Mount Rainier, then the river flows through Eatonville and joins the Nisqually River at approximately RM 38.2, which is 1 mile downstream of LaGrande Dam.

2.1.5 Pierce County Riverine Flooding History

Throughout Pierce County's history, flooding has been a natural characteristic of its streams and rivers. The river systems are relatively short, with steep gradients that can move large sediment and debris loads. As a result, these rivers are highly dynamic and difficult to manage.

In the relatively short period since European settlement began in the 1800s, the floodplains of Pierce County have been developed extensively along the lower reaches. From the late 1800s into the middle part of the 1900s, this development mostly focused on agriculture, with concentrations of development in and around nearby cities and towns. With development in the floodplains, there arose a need to provide some assurance from flooding to the farmers and business owners. Within the same period, there was also extensive development of the Port of Tacoma at the mouth of the Puyallup River. These low-lying areas, especially the fertile river valleys, have flooded periodically.

In December 1893, the river gauge near Buckley on the White River measured a flow of 28,000 cubic feet per second (cfs), the highest flow ever recorded on the White River at this gauge (Pierce County 1991). However, it was not until the great flood of 1906 that major changes occurred on the White River. These changes resulted in the permanent diversion of the White River from the Green/Duwamish River into the Stuck River valley. The diversion essentially doubled the tributary runoff area to the lower Puyallup basin, thus requiring a greater emphasis on flood control.

From 1916 to the early 1930s, efforts were made to reduce flood risk by straightening and confining the river within a system of levees, revetments, and other technologies. The 1933 flood was the highest recorded flood in the lower Puyallup River and destroyed much of the levee system. This led to the Congressional appropriation to construct Mud Mountain Dam on the White River. In 1948, Mud Mountain Dam was completed, with its primary purpose to minimize flooding in the lower Puyallup River. Further completion of work identified in the 1939 flood control plan for the upper Puyallup and Carbon Rivers' levee and revetment construction continued into the mid-1960s, with subsequent maintenance of the flood control system until 1990.

As a result of flooding and levee destruction in the mid-1980s, new management strategies were implemented in the 1990s. River maintenance managers made the decision that the current system was not sustainable. Strategies changed to accommodate the river by using approaches that emulate natural processes rather than trying to control the river. Pierce County began to purchase flood-prone properties in the floodplain and planning structural alternatives and developing regulations to guide future development in the floodplain.

Construction of levees and revetments along the county rivers in the early to middle 1900s helped reduce bank erosion and channel migration, which allowed agriculture to become a thriving industry in the river valleys. However, the use of the floodplains has evolved over the last 100+ years from primarily agricultural uses to more urbanized uses. As a result, floodplain managers are challenged to find solutions to complicated floodplain issues by seeking and implementing multi-benefit, holistic approaches. Such approaches balance the competing needs of flood risk reduction, benefit aquatic habitat, reduce maintenance impacts, and improves Pierce County's river corridors.

2.1.6 Disaster Declarations

The Robert T. Stafford Disaster Relief and Emergency Assistance Act, 42 United States Code (USC) Sections 5121–5207 (the Stafford Act), Section 401 states in part that "All requests for a declaration by the President that a major disaster exists shall be made by the governor of the affected state." The declaration authorizes the President to provide supplemental federal assistance.

Since 1906, there have been 16 Presidential Disaster Declarations and numerous flood events in Pierce County. Table 2.1 provides a summary of major and significant flood events in Pierce County.

Table 2.1. Significant Floods in Pierce County

Year	Presidential Declared Disaster
November 1906	No
December 1918	No
January 1919	No
December 1933	No
December 1946	No
December 1953	No
December 1955	No
November 1959	No
October 1962	Yes
December 1964	Yes
January 1965	No
February 1972	Yes
December 1975	Yes
December 1977	Yes
January 1984	No

Year	Presidential Declared Disaster
November 1986	Yes
January 1990	Yes
November 1990	Yes
December 1990	Yes
November 1995	Yes
February 1996	Yes
December 1996 to February 1997	Yes
October 2003	Yes
November 2006	Yes
December 2008	No
January 2009	Yes
January 2012	Yes
November 2014	No
December 2015	No
February 2020	No

2.1.7 Effects of Sediment on River Flooding and Channel Migration

2.1.7.1 Role of Excess Sediment in Flooding and Channel Migration

The conveyance capacity of a river is determined by the channel width, channel depth, and water velocity. The relationship with flow is shown in the following equation:

River Flow (cubic feet per second) = Water Velocity X (Channel Width x Channel Depth)

The ability of a river channel to carry floodwaters is increased if any of the three factors (channel width, depth, or velocity) are increased. The river's velocity and volume of water, the slope of the river channel, and the size and quantity of rock and sediment available determine the ability of the river to transport sediment. The faster and greater the volume of water, the larger the submerged rocks and overall sediment quantity can be moved. As channels flatten out and the water moves slower, the river can carry less material, resulting in deposition of rock and sediment (Ecology 2007). The inherent nature of a glacial river system is to balance its load of rock and sediment with its steepness and the volume of water it carries.

When steep river channels meet broad, flat valley floors, flow velocities decrease, and the ability of rivers to move sediment is reduced. This reduced ability to transport sediment results in the deposition of sand and gravel in the river channel (also known as aggradation). Under natural conditions, an unconfined river channel can migrate or flow around the deposited sediment and choose a new path. In confined rivers, between two levees or revetments, the channel cannot migrate and deposited sediment will usually lead to reduced flood conveyance capacity and greater potential to erode banks, including levees and revetments.

River channels in Pierce County provide for the conveyance of water, wood, and sediment (cobbles, gravel, and fine material) and habitat for various fish and animal species. Water, sediment, and wood form a dynamic interaction within the river channels, described as the "three rivers concept" (Wald 2009). Just as water flows from the upper reaches of a watershed downstream to the mouth of the river, sediment and wood also "flow" from various sources down the river channel and eventually discharge at the mouth of the river, or deposit along its reaches (Locke et al. 2008). This interaction affects river management, maintenance, and habitat formation.

Many rivers contain islands and gravel bars that accumulate sediments behind woody debris and logjams left after a previous flood or high-water event while serving as important habitat features. While it may take only days for water to move the length of a river, mobile sediment and wood may take years (or decades) to progress downstream from one reach to another, moving primarily during high flow events.

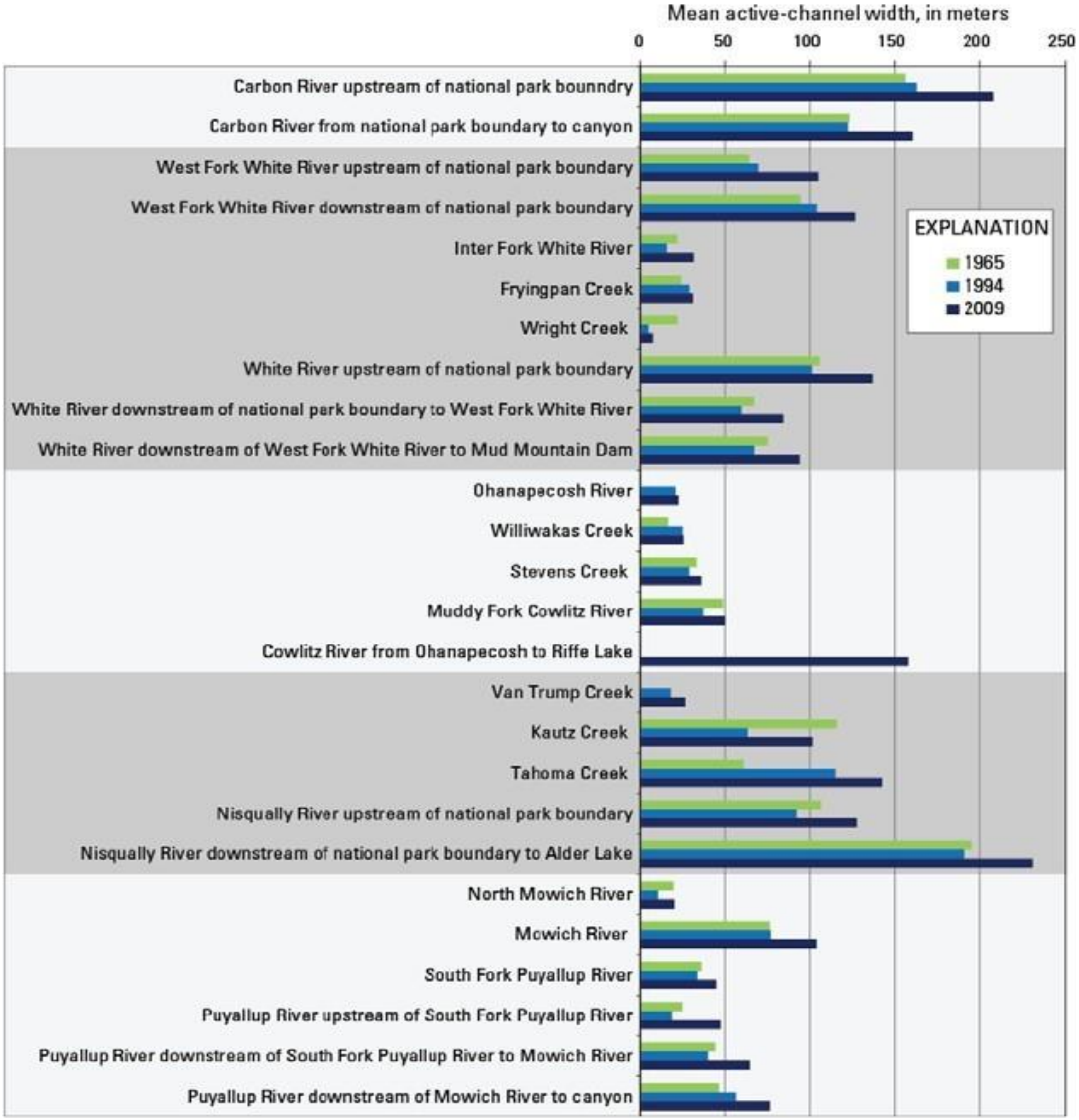
The transport of sediment and wood and the resulting habitat is a natural riverine process. However, the accumulation of sediment and large woody material in river channels can create an impediment to flood flow conveyance, raise water surface elevations during flooding, and sometimes redirect flows in a way that increases channel migration risks (King County 2007).

In 2010 and 2012, the United States Geological Survey (USGS) released two sediment studies for Mount Rainier and the lower Puyallup, White, Nisqually, and Carbon rivers. The 2012 report (USGS 2012) documents the following:

- Historical and current sediment loads in rivers draining from Mount Rainier
- Additional sources of sediment within the watershed
- Important sediment production and sediment delivery processes within the watershed
- Long-term trends of increasing discharge or sediment loads
- The anticipated magnitude of sedimentation 25 and 50 years into the future using public climate change predictions

As glaciers continue to recede on Mount Rainier, heavy rainfall, snow melt, and resulting floods can move more sediment materials down the system. More sediment can cause some upper river reach channels to widen. Figure 2.3, which was included in the 2012 USGS report, shows how some upper reaches of Mount Rainier river channels have widened over time.

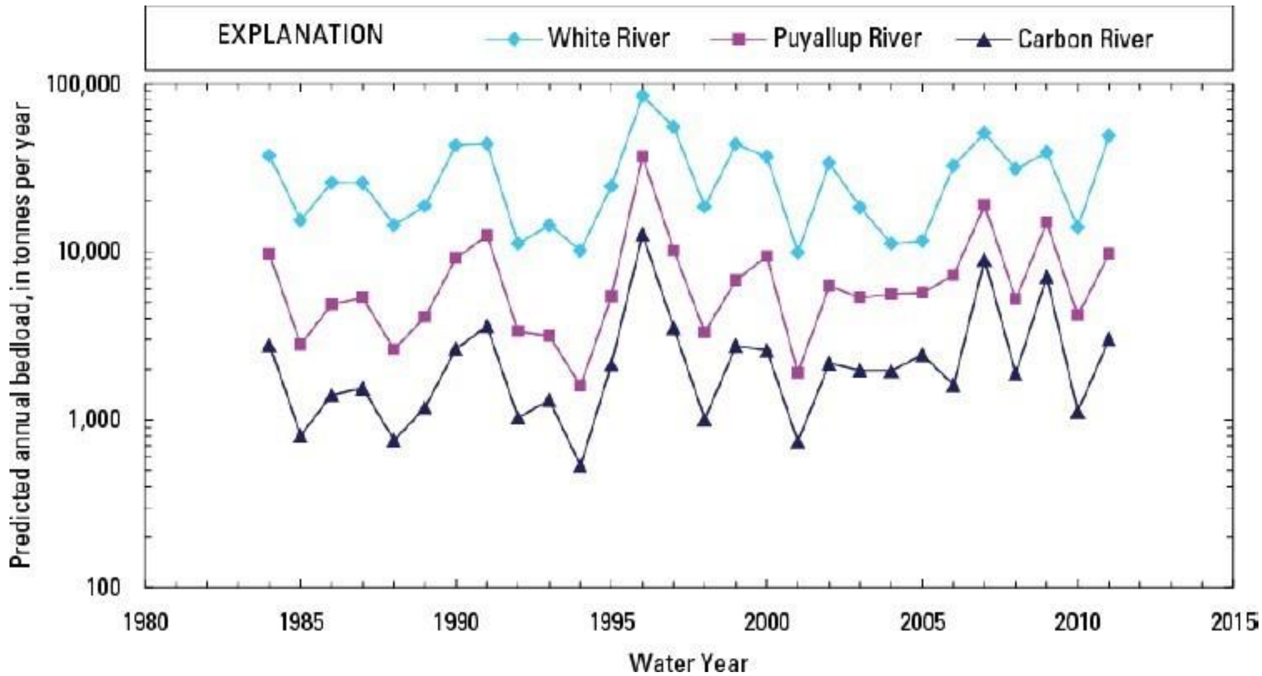
Figure 2.3. Mean Active Channel Width Over Time



The 2012 USGS report indicated that sediment is being transported from Mount Rainier to the Puget lowland through a sequence of glacial and fluvial processes that deliver material downstream. Studies found that the total sediment load for the upper Nisqually River from 1945 to 2011 was determined to be 1,200,000 (±180,000) tons per year (tons/yr). From 1956 to 1985, the total sediment load for the upper Nisqually River was determined to be 860,000 (±370,000) tons/yr, which is a significant decrease from 1945 to 2011 (USGS 2012). The lower Puyallup River was found to be 860,000 (±300,000) tons/yr between 1978 and 1994. Calculations for the White River at R Street carried a total load of 590,000 tons in 2011 with an annualized total load of

420,000 tons/yr from April 2010 to March 2012 (USGS 2012). Figure 2.4 shows the estimated annual bedload, which is the volume or mass of sediment being transported along the bed of a river for the White, Carbon, and Puyallup rivers from 1984 to 2011.

Figure 2.4. Sediment Transported between 1984 to 2011



The Puyallup River delivers about four times less bedload than the White River and will experience less severe aggradation, while the Carbon River will experience the least aggradation (USGS 2012). When sediment arrives and deposits in the Puget Lowland, there are limited structural methods for managing sediment to reduce flood risk. Potential sediment-management actions, including setback levees and gravel removal, would be most effective in reaches that tend to accumulate sediment naturally; these reaches were identified based on geomorphic conditions (USGS 2012).

In summary, rivers draining near Mount Rainier can assume to be in a general state of sediment surplus. As a result, future aggradation rates will be largely influenced by the underlying hydrology carrying sediment downstream. River management actions (such as setback levees and active sediment management) may be more effective in reaches of a river where sediment stays in the river for extended periods. Long-term river management decisions can be improved by monitoring suspended-sediment load, bedload, and aggradation in river reaches.

Another recent study completed by the USGS on behalf of King County in 2019 focuses on sediment transport within the White River. The study set out to better understand sources and pathways of sediment in the White River watershed with consideration to climate changes. Key points from the 2019 report (Anderson et al. 2019) include the following:

- Coarse sediment in the system is dominated by erosion of the lower watershed valley floor.
- Early 20th century avulsion augmented by subsequent dredging also contributed to lower watershed erosion.

- Major glacial and volcanic events have introduced more sediment into the system.

In summary, the 2019 report finds that primary sediment sources within the White River originate from erosion within the lower valley floor, rather than from glaciers, as initially thought. That erosion occurs in response to historic avulsion, exacerbated by more recent dredging within the new channel alignment. Sediment from glaciers is delivered in the river system in infrequent pulses, triggered by heavy rainfalls, causing sediment buildup to occur. Those areas of buildup then continually feed sediment into the system until another large rain event occurs, repeating the cycle. Because of sediment trapped behind Mud Mountain Dam, sediment sources upstream of the dam do not provide a significant source into the river. More generally, major watershed events have created persistent conditions in the system that are constantly changing, thus creating areas of repeated sediment buildup and loss.

2.2 Pierce County Streams

Streams are more sensitive to changes in their basins than larger riverine systems. Increased development pressures on their floodplains result in more dramatic changes in their runoff. While streams are more sensitive to development changes than a river (fluvial), they are still modeled with conventional riverine methods. Flooding begins to occur when stream channels receive more flow than can be conveyed by its channel as shown on Voight's Creek (see Figure 2.5).

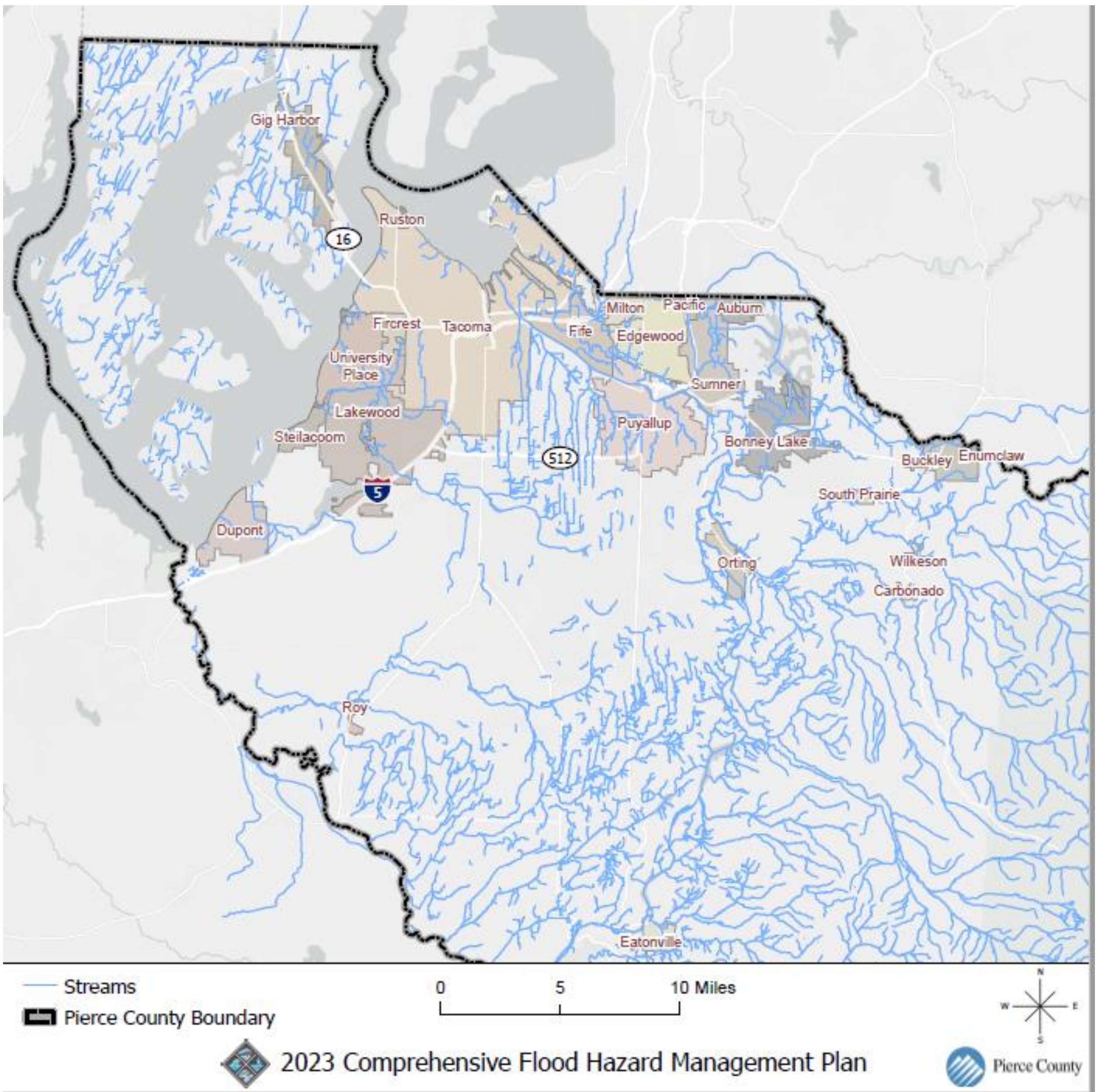
There is overlap with stream and urban flooding, primarily in and around urban growth areas. The defining feature of urban stream flooding is the source that is directly linked to flow leaving its normal channel and intermixing with urban sources. Urban flooding is typically associated with an urban developed environment. Flooding occurs when a storm drainage collection and conveyance system is unable to collect and convey surface water to prevent backflow and surcharge that results in flooding. Many urban streams within Pierce County have detailed flood studies from the early 2000s (refer to the Surface Water Management Library | Pierce County, WA - Official Website piercecountywa.gov).

Figure 2.5. Flooding on Voight's Creek, November 2011

2.2.1 Stream Flooding History

Since the development of the 2013 Pierce County Rivers Flood Hazard Management Plan, specific data have not been collected that reflects individual stream flooding within the county. The understanding of stream function has evolved since the early twentieth century. Previously natural streams were used as an extension of existing storm drainage systems. The streams were channelized and straightened to carry flows from the plateaus to the rivers system as quickly as possible. There is a better understanding of the importance of natural processes of streams and how they move sediment and provide critical ecological benefits. The goal for the updating this Plan is to evaluate and identify which urban flood events caused major stream flooding in the county. Figure 2.6 shows all major streams located within Pierce County.

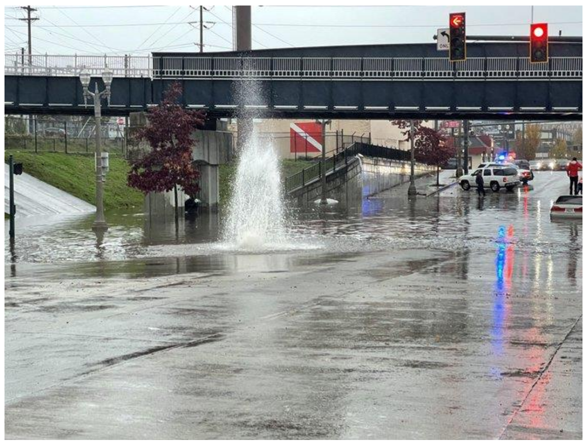
Figure 2.6. All Streams within Pierce County



2.3 Urban Flooding

Urban flooding is defined as overwhelmed drainage systems (such as municipal separate storm sewer system also known as "MS4") driven by localized rainfall events as seen in Figure 2.7. While these systems often discharge to a stream, they are considered a separate class of flooding because urban flooding can occur independently from stream flooding. All drainage networks around the county have not been mapped for this type of flooding due to the number of hydraulic controls that must be accurately surveyed in order to map a relatively small area. Flooding of this type can typically be seen throughout the county where the county MS4 systems have replaced natural drainage systems.

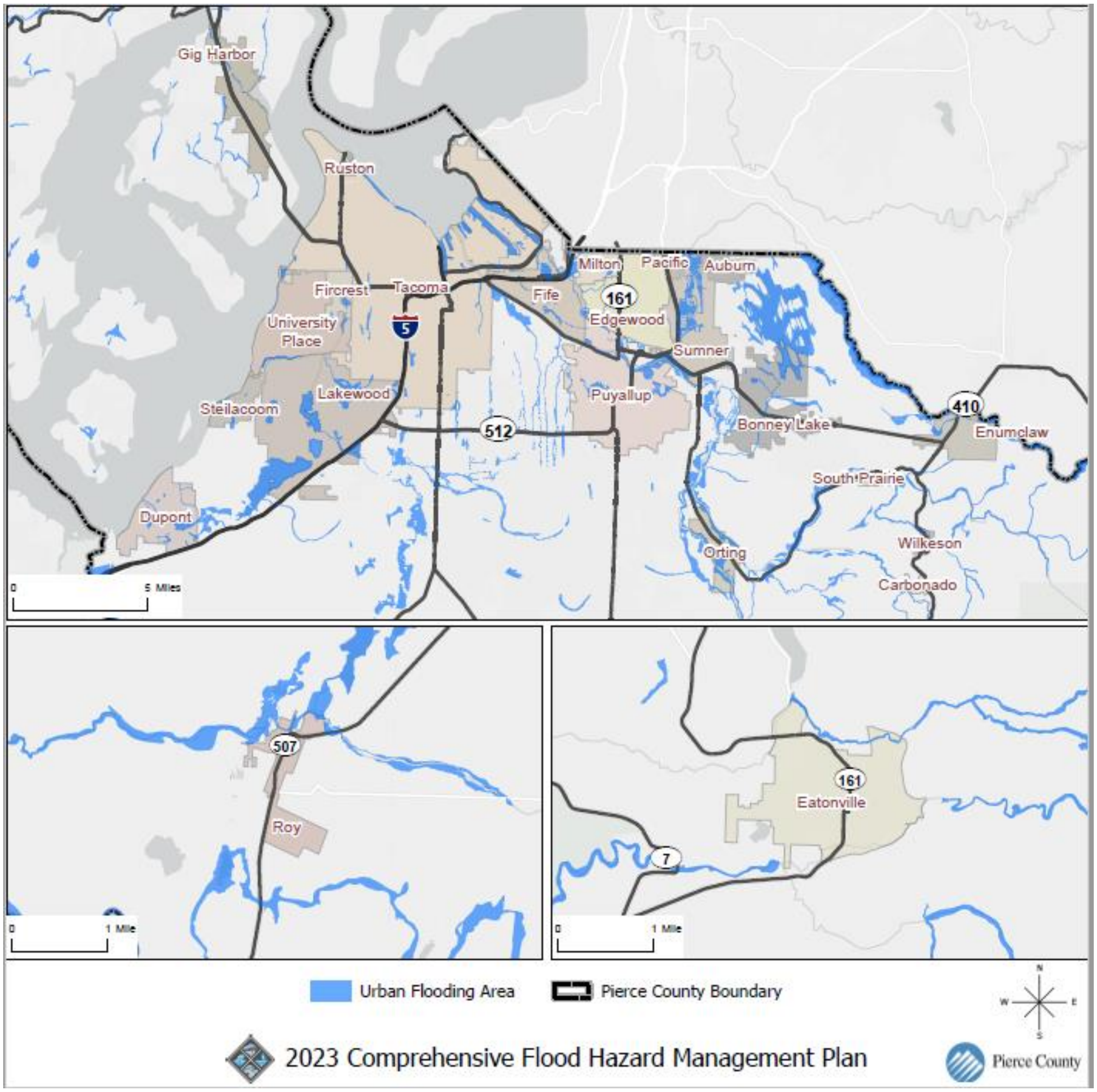
Figure 2.7. Urban Flooding during a Major Rain Event in Tacoma, October 28, 2021



Source: https://twitter.com/tacomafire/status/1453880462728855556

Storm drainage systems in Pierce County are typically designed to accommodate the 25-year flood event. Urban flooding can be made worse when the effects of streams, rivers, coastal, or groundwater inundation limit the stormwater systems from efficiently draining. Some systems are built with those external factors in mind. However, as hydrology and climate change occur, existing systems may be found to be undersized. Unless adjustments are made to accommodate anticipated increased rainfall due to climate change, the risk of urban flooding will continue to rise as the rain events grow larger and more frequent. Figure 2.8 shows where urban flooding has occurred in unincorporated Pierce County. Figure 2.8 does not include all urban flooding locations in Pierce County. Mapping of the urban flooding hazard is still being studied.

Figure 2.8. Urban Flooding Locations in Pierce County



2.3.1 Urban Flooding History

Since 1996, there have been five major urban flooding events observed in Pierce County that impacted county infrastructure and residential properties. Major urban flooding events occurred in the following years:

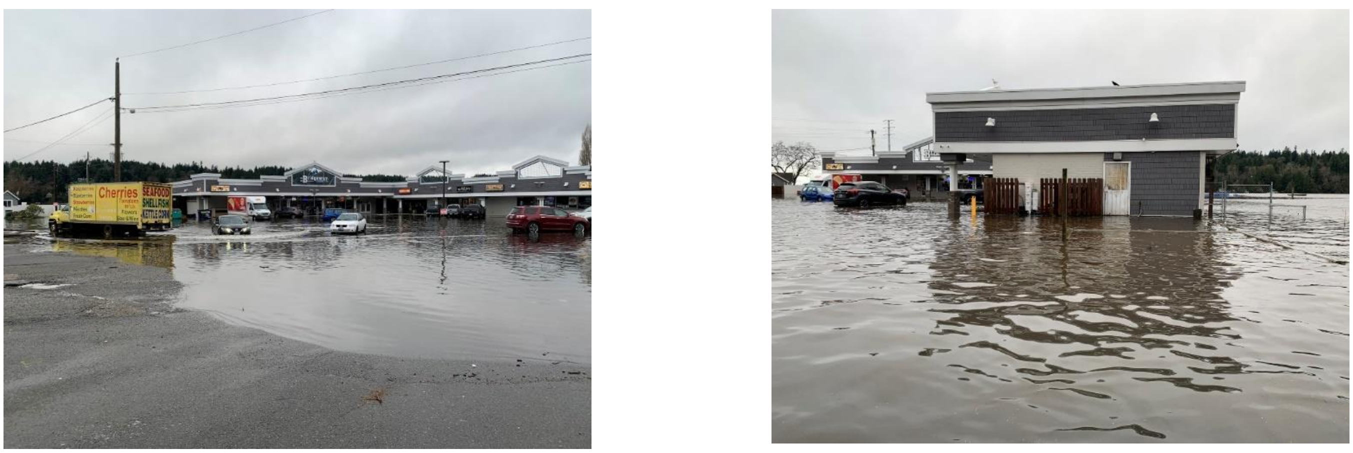
- 1996
- 1998
- 2001
- 2004
- 2019

2.4 Coastal Flooding

Pierce County has more than 120 miles of Puget Sound shoreline, but there has never been a declared disaster due to coastal flooding. The majority of the shoreline is steep with a small shoreline setback. Most homes were built on high ground beyond the reaches of coastal flood impacts. Coastal flooding is generally experienced in low bank areas typically formed by sand drifts or old landslides.

The tidal range in the south Puget Sound can fluctuate up to 18 feet between high and low tide. The highest of the high tides are commonly referred to as King Tides and coincide with astronomical forces when the earth is closest to the sun (perihelion) and a “spring tide” when the moon and the sun are in alignment. Tide tables are based on the astronomical forces, and local weather will suppress or amplify the forecasted tide, depending on if it is a high- or low-pressure system, respectively. It is common to see tides 1 to 2 feet higher than predicted when a low-pressure system is in the region. Winds are an additional risk to coastal flooding where the shorelines will be exposed to longer fetches of open water and the highest crashing waves surge onto the shore. The Puget Sound region can see high winds from any direction but the most extreme come from the north or south. All of these coastal amplifiers are additive. The greatest risk is in the winter when the King Tides occur for about one week each month from November to February; this is when winter storms bring low pressure systems with the strongest winds as shown in Figure 2.9.

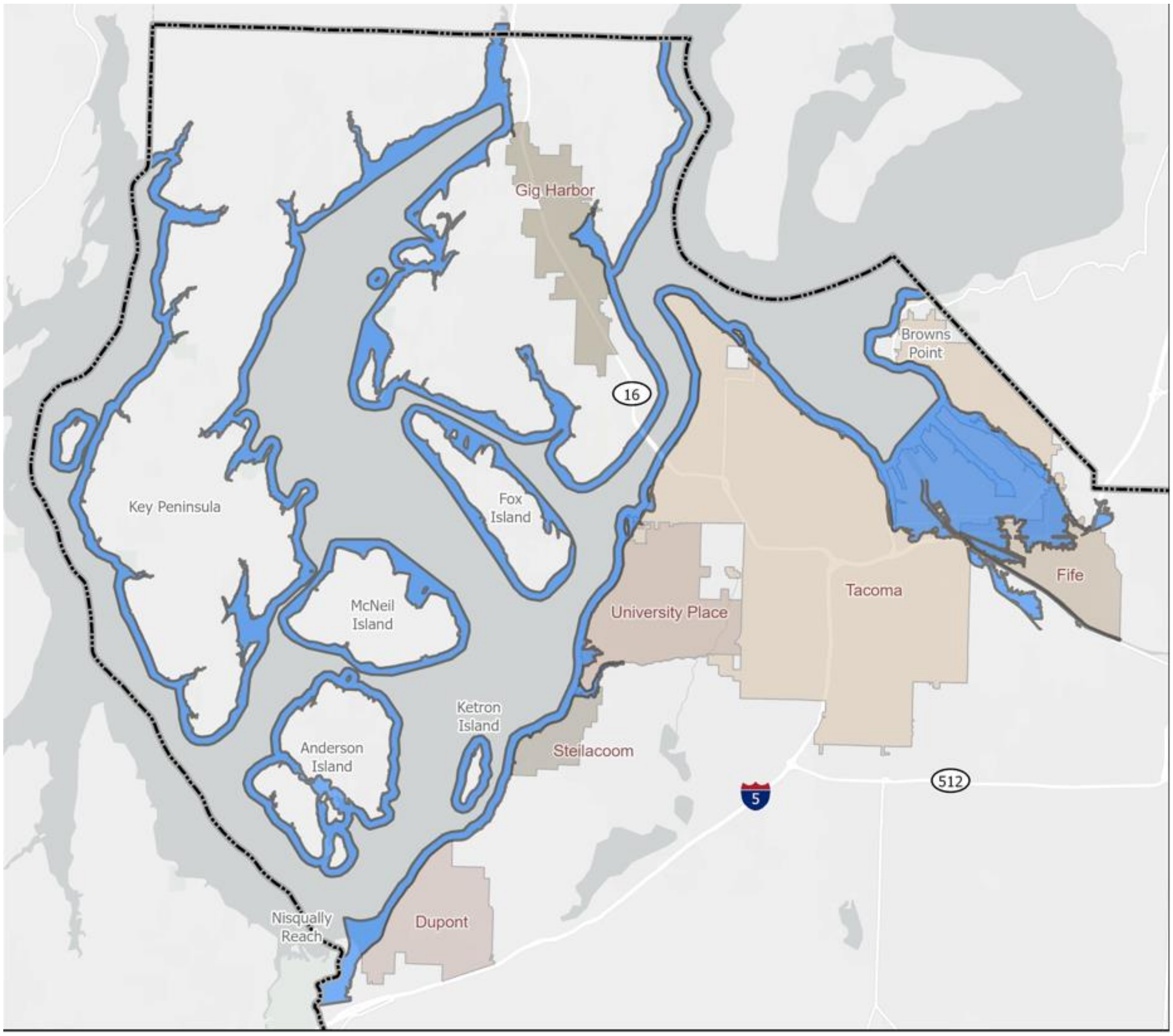
Figure 2.9. Coastal Flooding on January 11, 2022, Bridgeway Shopping Center, Purdy, Washington



2.4.1 Coastal Flooding History

Coastal flooding areas within Pierce County most prone to the coastal properties lie within the northwest portion of the county adjacent to saltwater sources associated with Puget Sound. Large portions of Pierce County shorelines are located in the Tacoma Tideflats where much of the region’s industrial economic activity takes place. The industrial properties in the Tacoma Tideflats / Port of Tacoma manufacturing/industrial center are some of the properties that are irreplaceable for the region and will have to adapt to sea level rise in the coming decades. The communities most affected by coastal flooding include the Key Peninsula, Gig Harbor, Puget Sound coastline stretching from Browns Point to the Nisqually Reach, and the island communities of Puget Sound, as shown in Figure 2.10.

Figure 2.10. Primary Areas Prone to Coastal Flooding in Pierce County



Based on the most up-to-date science research associated with climate change, current climate change projections range from several inches to over 57 inches of sea level rise in Puget Sound by 2100 (Climate Change Resilience Plan | Pierce County, WA - Official Website (piercecountywa.gov)). This will exacerbate the existing risk to coastal properties. Not only will predicted sea level rise impact coastal regions, but will also have an impact on riverine, stream and urban systems directly connected or in close proximity to saltwater sources. The rise in the sea level limits the ability of these systems to drain causing back water situations in urban systems and sediment deposition in riverine systems. Since the extreme high tide in 2012, there have been seven observed coastal flooding events observed in Pierce County that impacted coastal waterfront properties. Coastal flooding events occurred in the following months and years:

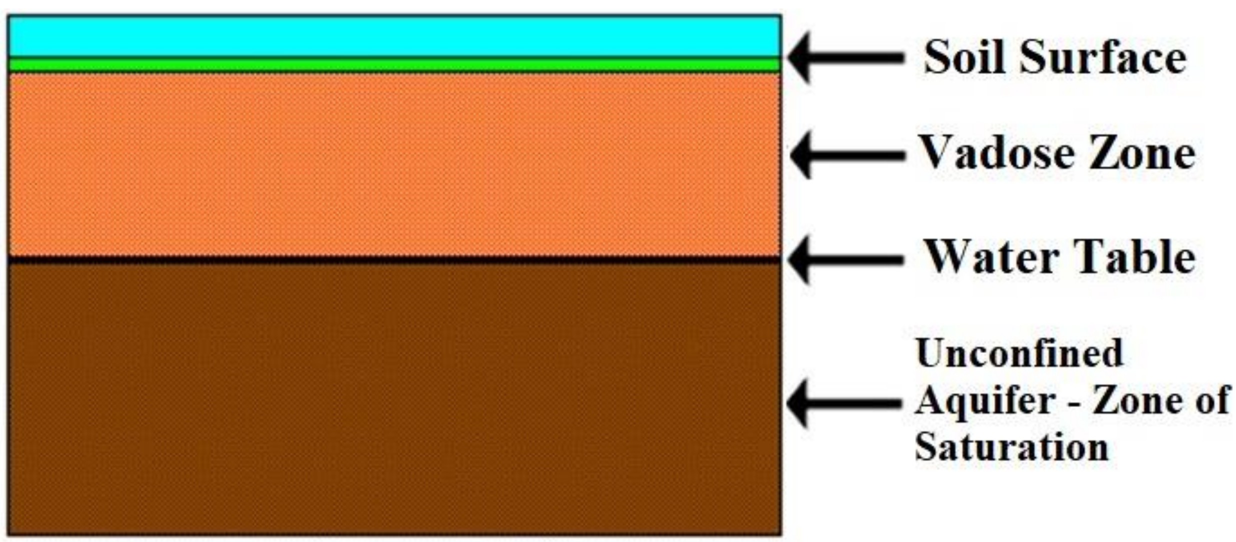
- December 2012
- December 2019
- January 2019
- January 2020
- November 2021
- January 2022
- December 2022

2.5 Groundwater Flooding

Groundwater flooding, also known as clear water flooding, is defined as water emerging from the ground. This happens when the underground water table exceeds its limits, thus causing the water to emerge from the ground and flow onto the surface, as demonstrated in Figure 2.11. There are many concerns with groundwater that are not included in this flood plan, including but not limited to, high groundwater tables that limit farming, infiltration facilities, and thin layer of permeable (porous) soils.

The *vadose zone* is the unsaturated part of the soil profile that extends from the ground surface down to the groundwater table, or zone of saturation.

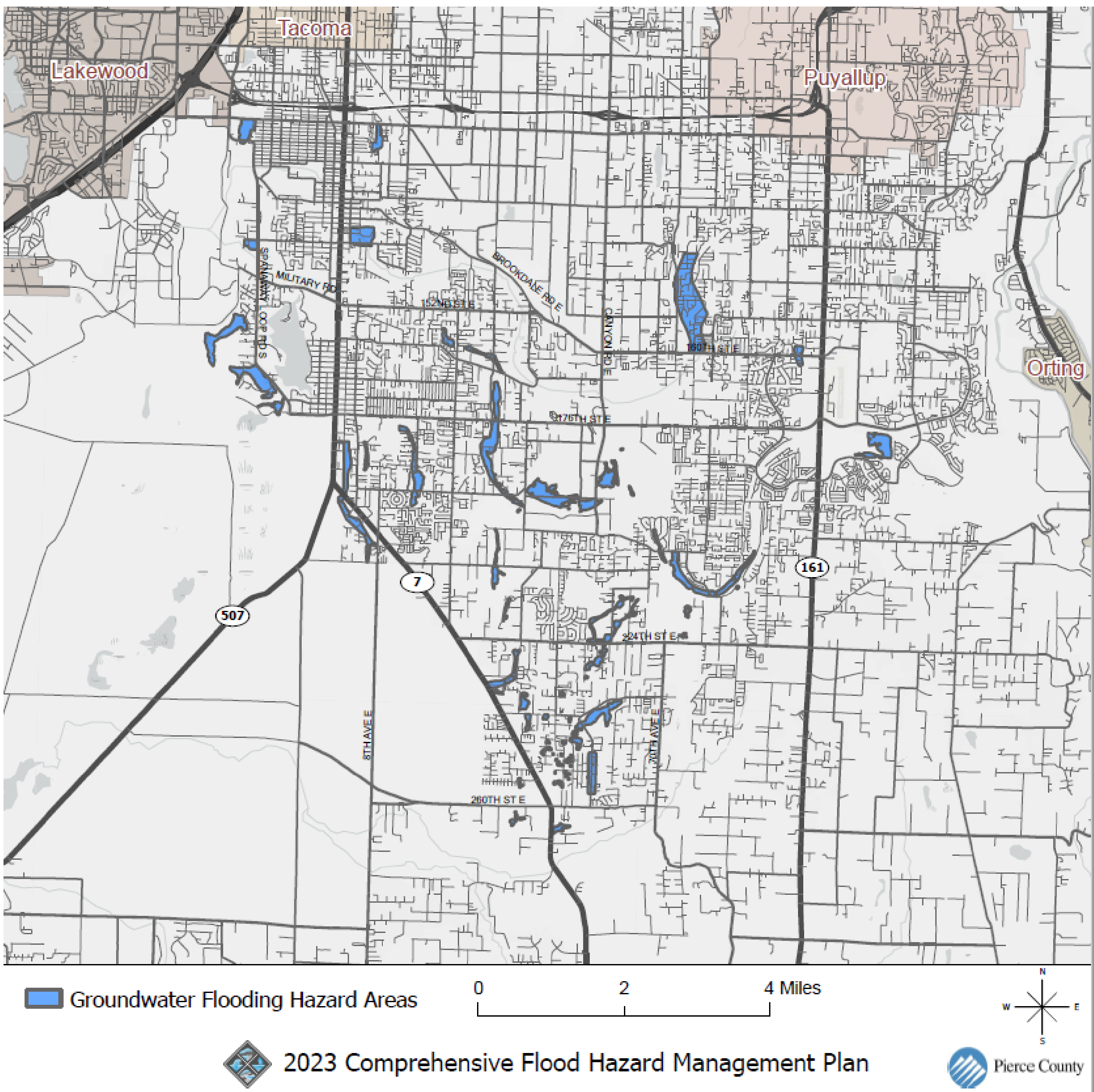
Figure 2.11. Cross Section of Underground Water Table to Soil Surface



Source: NRCS 2019

Groundwater flooding is a phenomenon that occurs predominantly in the south-central portion of Pierce County. Groundwater flooding typically happens when rainfall totals are high, and the flooding does not materialize until late winter and early spring. This area is geologically unique and has a high amount of glacial outwash soils. The flooding impacts small pockets of the communities of Graham, Frederickson, Spanaway, and Parkland. The general boundary prone to groundwater flooding is primarily isolated to west-central Pierce County. The area is generally bounded by 267th Street East to the south, 118th Avenue East to the east, 154th Street East to the north, and 40th Avenue South to the west. The communities affected include Graham, Parkland-Spanaway, South Hill, and the southwest communities of Frederickson and Pioneer Valley, as shown in Figure 2.12.

Figure 2.12. Primary Areas Prone to Groundwater Flooding in Unincorporated Pierce County



2.5.1 Groundwater Flooding History

Since the long-term road closure of 192nd Street East due to groundwater flooding in 1997, there have been 10 groundwater flood events observed in Pierce County that have impacted transportation and residentials properties. Figure 2.13 shows groundwater flooding at 192nd Street East in the spring of 2016. Groundwater flooding events occurred in the following years:

- 1997
- 1999
- 2011
- Spring 2012
- Spring 2014
- Fall 2015
- Spring 2016
- Spring 2017
- Spring 2019
- January 2021

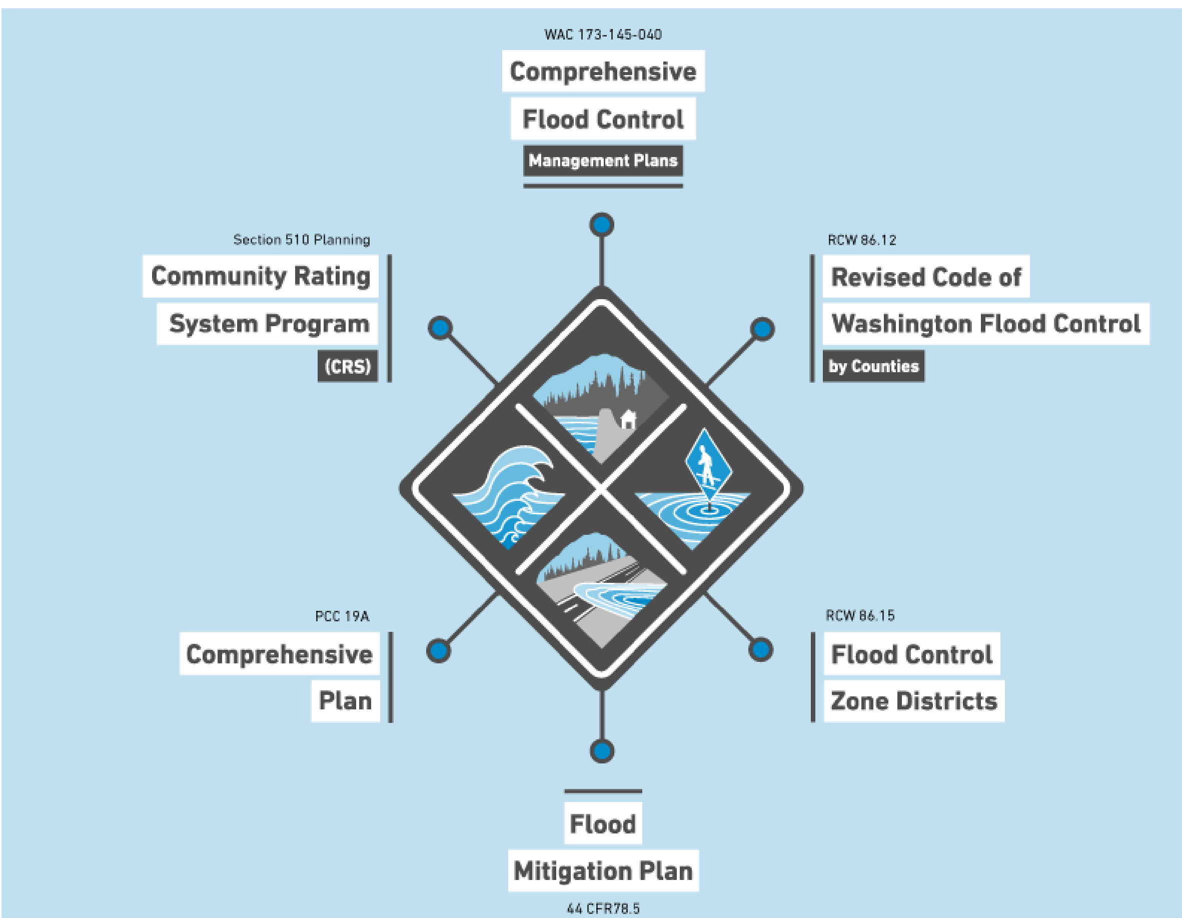
Figure 2.13. Groundwater Flooding, 192nd Street East, Spring 2016

3 Regulatory Commitments, Agreements, Drivers, and Other Considerations

3.1 Regulatory Requirements

This 2023 Flood Plan was developed to meet a variety of requirements: Washington Administrative Code (WAC) 173-145-040 Comprehensive Flood Control Management Plan, Revised Code of Washington (RCW) 86.12 Flood Control by Counties, RCW 86.15 Flood Control Zone Districts, 44 CFR (Code of Federal Regulations) 78.5 Flood Mitigation Plan, and Pierce County Code (PCC) 19A Comprehensive Plan. This plan is also a requirement of the National Flood Insurance Program's (NFIP) Community Rating System (CRS) program Section 510. The County will update this plan every five years as a requirement of the CRS program. Figure 3.1 outlines all relevant regulatory requirements that this flood plan meets. This chapter summarizes various regulatory requirements, obligations, and benefits that are all taken into considerations while developing capital projects and to enhance our environment.

Figure 3.1. Regulatory Requirements



3.2 General Practices

The practice contained within this flood plan encourages cooperative and consistent floodplain management among towns, cities, counties, and special districts, as advocated by Chapter 86.12 RCW. Actions taken by one jurisdiction can have adverse effects upon neighboring jurisdictions. Filling of the floodplain in one area frequently transfers the flood hazard risk to other areas and other jurisdictions and other members of the public. Consistent approaches to flood hazard management across jurisdictions can reduce such adverse effects.

The practices that follow are written to reflect the level of discretion local governments have in making floodplain management decisions. Use of the terms "shall" or "will" implies that the practice is to be interpreted as mandatory or nondiscretionary. The use of "should" or "may" in a practice indicates guidance and a greater level of discretion in making decisions based on the practice.

1. **Geographic Scope** – Pierce County will coordinate and supply regional flood hazard management services across the county for all flood hazards. Specifically for riverine flood hazards, Pierce County will provide flood management services on major rivers and tributaries with historical peak flows over 5,000 cubic feet per second (cfs). These rivers and streams include the Puyallup, White, Carbon, Nisqually, Greenwater, and Mashel rivers and South Prairie Creek.
2. **Flood and Channel Migration Risks** – The natural processes of flooding and channel migration become risks when human development is located within flood hazard areas. Flood and channel migration risks, and the consequences that would result, are generally prioritized in the following order: (1) threats to public safety; (2) impacts to the local and regional economy; (3) damage to public infrastructure; and (4) damage to private structures.
3. **Flood Hazard Management Approach** – Pierce County will implement projects and programs for river, urban, coastal, and groundwater flooding that result in multiple benefits, including the following non-prioritized objectives:
    1. Meet site and reach-specific flood and channel migration risk reduction needs;
    2. Achieve quantifiable benefits that exceed total costs of projects and programs, including long-term maintenance costs;
    3. Avoid creation of new flood and channel migration risks;
    4. Balance natural processes of river migration and flooding with protection of productive agricultural lands;
    5. Protect and improve aquatic and riparian habitat and ensure consistency with the Endangered Species Act (ESA) and salmon recovery programs; and
    6. Leverage flood hazard management revenues through partnerships with other agencies and stakeholders.
4. **Inter-Governmental Coordination and Cooperation** – Pierce County's flood and channel migration hazard management activities will be planned and implemented in close

cooperation with cities, counties, tribes, state and federal agencies (e.g., resource agencies, public agencies with infrastructure), and salmon recovery lead entities.

5. **Climate Change** – Project design and program management should reflect best available science regarding the anticipated changes in precipitation patterns and associated changes in flood flows and sediment transport as a result of climate change.

3.3 Project Practices

Projects can be structural, non-structural, or a combination of the two. The following project practices guide the project cycle, from initial concept through design and construction, to post-project monitoring and adaptive management. Structural projects consist primarily of construction of new and replacement setback of revetments, levees, and similar flood risk reduction structures. Non-structural projects include property acquisition, elevation of flood-prone homes, sediment and large wood management, and the removal of existing structures that no longer serve a flood management purpose.

1. **Prioritizing Flood Hazard Risks** – Pierce County should prioritize actions to address flood and channel migration risks using the following criteria in order of importance:
    1. The consequences that will result if no action is taken. Consequences should be prioritized as identified in the above General Practice #2 and in terms of probability of occurrence and severity;
    2. Legal responsibility and authority, as determined by a contractual relationship, between Pierce County and another agency or person(s) to maintain a flood risk reduction facility;
    3. Urgency, as measured by how quickly an action needs to be taken in order to prevent a risk from growing worse; and
    4. Readiness of the project in terms of funding, partnerships, resolved property issues, or permitting.
2. **Property Acquisition** – Property acquisition for flood risk reduction projects should be on a willing-seller basis. However, as risks are identified and prioritized, there will be circumstances when a compelling public interest makes condemnation necessary. Pierce County prefers acquisition over the use of easements.
3. **Easements** – New or additional easements necessary to construct, maintain, repair, or retrofit a flood protection facility should be sufficient to meet applicable Pierce County design and construction standards and federal and state technical guidelines.
4. **Management of Pierce County Properties** – Pierce County will manage its public lands and easements within flood hazard areas in accordance with the policies in this 2023 Flood Plan. Public access to publicly owned flood risk reduction facilities should be allowed on a case-by-case basis, provided that such access does not interfere with the performance of any infrastructure and after evaluating issues such as public value, cost, and public safety.

5. **River Flood and Channel Migration Risk Reduction** – Flood risk reduction facilities designed to contain floodwaters (e.g., levees) or reduce channel migration (e.g., revetments) should be designed to be consistent with the adopted river reach management strategy. The following are the four levels of design for levees:
    1. 200-year design, plus 3 feet of freeboard
    2. 100-year design, plus 3 feet of freeboard
    3. Maintenance of existing (2009) conveyance capacity
    4. Maintenance of existing levee prisms

Following are the two erosion protection levels for revetments:

1. Channel migration prevention design
2. Channel migration resistance design

Deviations from the level of design shall be approved by the Pierce County manager of the Surface Water Management Division.

6. **Urban, Groundwater and Coastal** – Pierce County intends to develop a better understanding of urban, groundwater, and coastal flooding. This will be accomplished with additional studies, monitoring, and analysis.
7. **Facility Design and Maintenance** – Pierce County should construct new flood risk reduction facilities and maintain, repair, or replace existing facilities in such a way as to achieve each of the following:
    1. Minimize maintenance costs over the life cycle of the facility;
    2. Ensure that flood or channel migration risks are not transferred to other sites; and
    3. Protect and improve aquatic and riparian habitat.
8. **River Management Facility Setbacks** – Pierce County will identify opportunities to set back existing river management facilities farther from the river edge and associated buffers to increase flood conveyance and storage, reconnect previously disconnected floodplain, improve aquatic habitat, and allow natural riverine processes to occur.
9. **Pierce County Sponsored Projects** – Pierce County-sponsored projects located in flood hazard areas shall be consistent with policies in this 2023 Flood Plan and meet or exceed the standards adopted in the Pierce County Code to implement those policies.
10. **Adaptive Management** – Flood hazard management projects shall be monitored to assess the degree to which they function relative to their stated purpose, performance, goals, and objectives. Adaptive management principles shall be used to manage projects over time, identify needed changes, and inform the design and implementation of future projects. Pathways planning can also be a resource during the planning phase to identify multiple potential solutions when a single solution is not clearly evident. This can help with uncertainty associated with climate change, shifts in public support, politics, and policy changes.

11. **Large Woody Material** – Naturally occurring accumulations of large woody material may be repositioned, relocated, or removed for flood hazard management purposes if one or more of the flood and channel migration risks in the above mentioned General Practice #2 is present, all reasonable flood and channel migration risk reduction alternatives have been considered, and there is an imminent threat. Repositioning, relocation, or removal of large woody material should be done in a manner that does not create new flood or channel migration risks and can be accomplished using techniques that result in the least disturbance to the river channel and aquatic habitat while preserving the function of the large woody material.
12. **Comprehensive Sediment Management** – Comprehensive sediment management in Pierce County shall be informed by technical sediment transport studies and consider the highly variable nature of sediment transport to achieve a balance between flood risk reduction and ecological health.

3.4 Floodplain Land Use Strategies

Pierce County floodplains contain a complex matrix of lands governed by Pierce County, cities, and towns. Because the actions of one jurisdiction have the potential to adversely affect the frequency, duration, or magnitude of flood hazards in downstream, upstream, or adjacent jurisdictions, the strategies listed below are intended to promote greater consistency of regulations across floodplain jurisdictions.

- **Consistent Regulatory Standards** – Pierce County supports consistency in flood hazard regulations across jurisdictions. Cities and towns are strongly encouraged to adopt policies and regulations that are consistent with Pierce County critical area regulations for flood hazard areas, and regulate according to the best available data, such as updated flood studies.
- **National Flood Insurance Program** – Pierce County and cities and towns with floodplains should participate and maintain good standing in the National Flood Insurance Program and its Community Rating System in order to better protect public safety, reduce the risk of flooding and channel migration hazards to existing public and private property, and achieve flood insurance premium discounts.
- **Urban Growth Area Expansion** – Prohibit expansion of urban growth areas into 100-year floodplains of any river or river segment within the geographic scope of this flood plan, except as allowed by RCW 36.70A.110.
- **Development in the Floodway** – Prohibit new residential and non-water-dependent non-residential structures within the Federal Emergency Management Agency (FEMA) floodway, severe channel migration zone (CMZ) floodway, and deep and fast flowing (DFF) water floodway, except as allowed by local land use codes. Definitions for these floodways should be consistent across jurisdictions.

- **Zero-Rise** – The placement of structures or fill is allowable in the floodplain if it can be proven that it would not cause an increase in elevation of the 100-year flood by more than 0.001 foot. This regulation should be consistent across jurisdictions.
- **Compensatory Storage** – Preserve the existing flood storage volume of the floodplain by replacing floodplain storage volume that is eliminated by structures or fill by excavating to provide live storage volume equal to or greater than that which is displaced. Options to achieve this could include removing or relocating existing structures and associated fill, or by setting back levees. Provide the live storage volume between corresponding 1-foot contour intervals that are hydraulically connected to the floodplain through their entire depth.
- **Critical Facilities** – Locate critical facilities outside of the 500-year floodplain unless no other possible alternative exists. If no alternative exists, elevate critical facilities to or above the higher of the 500-year flood elevation or three feet above the 100-year base flood elevation and locate to allow for planned future levee setbacks.

3.5 Agreements, Drivers, and Other Considerations

This flood plan outlines the local and federal obligations Pierce County must meet and identifies a level of design the county will provide as new projects are constructed. Surface Water Management (SWM) constructs capital projects to meet current and projected future local, state, and federal legal regulatory obligations. Obligations such as the National Pollutant Discharge Elimination System (NPDES), the Clean Water Act (CWA), Total Maximum Daily Load (TMDL), the ESA, United State Army Corps of Engineers (USACE), floodplain management obligations through the NFIP, and Pierce County Code. As new capital projects are designed, SWM works to ensure that projects include as many primary benefits as possible. These primary benefits include water quality improvements, habitat improvement, flood risk reduction and agricultural operations improvements.

3.5.1 Water Quality

3.5.1.1 Total Maximum Daily Load

TMDL is a regulatory term from the 1972 CWA (Public Law, 92-500). TMDLs are a unique type of planning process specifically designed to bring a polluted water body back into compliance with its water quality standards. You can think of TMDLs as a pollution diet developed to guide a watershed back to health. The TMDL identifies the maximum amount of a particular pollutant a waterbody can accept while still complying with the applicable water quality standards. It then assigns numeric limits to each pollution source in the watershed, so they all add up to a number below the total allowable limit for that waterbody. If the TMDL is calculated correctly and the numeric targets are achieved for each pollution source, the water body should return to a healthy condition over time.

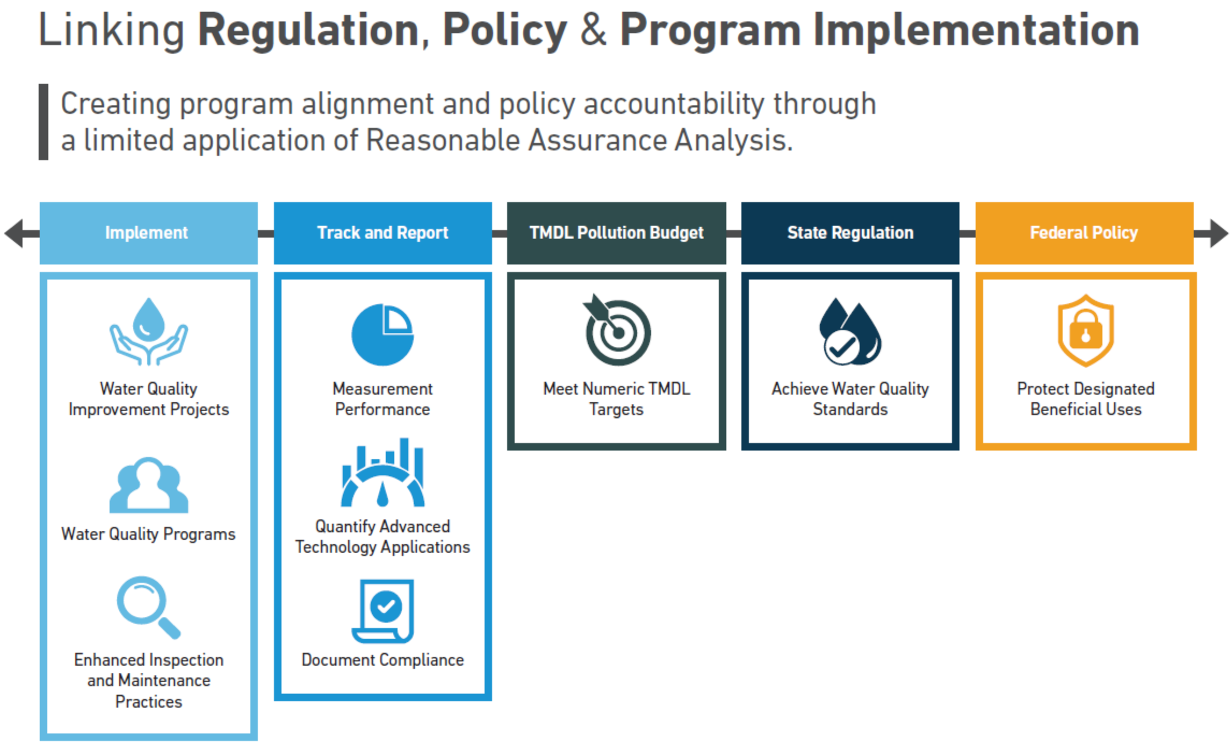
TMDL analysis attempts to establish the appropriate levels of pollutant loading an aquatic system can tolerate by quantifying and adding up all the discernable sources of pollution it receives. This means using monitoring data and water quality modeling to itemize the natural background load and all distinguishable point source and nonpoint sources of pollution, including a margin of safety and a reserve capacity for future development (EPA 1991). TMDLs are primarily informational tools the state uses to proceed from the identification of waters requiring additional planning to the development of the plans deemed necessary for their restoration. As such, TMDLs serve as a link in an implementation chain, which includes federally regulated point source controls, state or local plans for point and nonpoint source pollution reduction, and an assessment of the impact of such measures on water quality, all to the end of attaining the statutory water quality goals established for the nation's waters.

Identifying a water body's maximum pollutant loading or absorption capacity is central to developing a TMDL. Loading capacity is defined as the highest amount (e.g., concentration, mass, or volume) of a pollutant a receiving waterbody can accept without violating its assigned water quality standards. The loading capacity provides the reference point for calculating the amount of pollutant reduction required to bring a stream into compliance with standards (EPA 1991).

*The term **303(d) list** is short for a state's list of impaired and threatened waters (e.g., stream/river segments, lakes). States are required to submit their list for EPA approval every 2 years. For each water on the list, the state identifies the pollutant causing the impairment, when known.*

In Washington, TMDLs are developed and administered by the Washington State Department of Ecology (Ecology). The U.S. Environmental Protection Agency (EPA) then reviews and certifies the TMDL or develops and issues their own revised version. TMDLs may include any number of water bodies and pollution types. Ecology then uses a numerical or narrative standard that is established by law to protect water quality. These standards are based on the designated uses assigned to a water body by Ecology. Designated uses are designed to protect waterbodies for important societal values such as, human recreation, aquatic life habitat, or aesthetic quality. Section 305(b) of the CWA directs Ecology to assess water quality for all regulated water bodies in the state. When standards are not being met, the water body is assigned to the 303d impaired waters list. When a water body is assigned to the 303d list, the designated uses are considered impaired, and applicable water quality standards must be restored through a TMDL. Figure 3.2 is a graphic representation of the TMDL Quantifiable Alignment of Policy, Regulation, and Program Implementation, upon which Pierce County's TMDL Implementation Plan's Strategy relies.

Figure 3.2. TMDL Quantifiable Alignment of Policy, Regulation, and Program Implementation



For example, Clarks Creek is classified as an impaired water body for two pollutants—sediment, and dissolved oxygen. These impairments are based on water quality standards (criteria) developed by the state to protect beneficial uses such as core summer salmonid habitat, primary contact recreation (swimming), and domestic water supply. Numerical water quality standards do not yet exist for fine sediment, but Ecology determined there is excessive fine sediment in Clarks Creek when compared to other reference streams. Instream monitoring data also indicated dissolved oxygen fell below standards during both summer and winter. Consequently, Pierce County was issued two numeric Waste Load Allocations or TMDL Clean Water Targets to establish its responsibilities for pollution reduction.

For additional information on the Clarks Creek TMDL, please visit Clarks Creek (TMDL) Project | Pierce County, WA - Official Website (piercecountywa.gov).

3.5.1.2 National Pollutant Discharge Elimination System

Flooding incrementally increases as humans build impervious surfaces that prevent rainwater from soaking into the soils beneath. Precipitation drains off imperious surfaces with increased volume and speed, thereby increasing erosion and drawing in pollution from human-influenced sources in the flow. Climate change has the potential to increase storm intensity and subsequently flood events.

The NPDES program was created to address harmful effects of human development by the EPA. In Washington, permit administration is delegated to the state, except in cases when the discharges are to or from federally controlled lands, such as military bases and tribal lands. The goal of this permit system is to apply regulations to stormwater discharges that will result in improvement in the downstream natural streams, rivers, estuaries, and marine waters, collectively called waters of the state, so those waters will meet the state's Water Quality Standards.

As populations increase, impervious surfaces increase and human's need for high quality water that can support natural systems, drinking water needs, irrigation, and recreational use by humans also increases.

The NPDES permitting system requires owners or operators of potential sources of polluted runoff to gain coverage under a permit to discharge their stormwater to waters of the state. The permittees must apply best management practices, educational programs, flow controls, and treatment to reduce or eliminate the pollutants contained in their stormwater discharges.

Municipal permittees must implement a structural stormwater program that includes a capital program to design and build projects to control flow and pollutants in areas without adequate stormwater controls.

Pierce County has an NPDES permit for discharges from its Municipal Separate Storm Sewer System (MS4) called a Phase I Municipal Stormwater Permit (permit). The permit conditions are revised every five years to incorporate new information regarding practices that protect surface water quality. The programs mandated by the permit and more information about the County's NPDES programs can be found at our current NPDES webpage: Managing Stormwater Runoff | Pierce County, WA - Official Website (piercecountywa.gov).

3.5.1.3 Water Quality Monitoring

Pierce County has a Watershed Health Monitoring program to evaluate water quality in the County's streams. This program involves collecting samples from about 50 stations in streams throughout the area. Pierce County SWM measures or analyzes 21 parameters from each monitoring site, every month. Eight of the 21 parameters are used to calculate an annual Water Quality Index score, which can be found at Watershed Health | Pierce County, WA - Official Website (piercecountywa.gov). Starting in 2008, the county began collecting macroinvertebrate samples and produces an indexed biological score (the Biotic Index of Biological Integrity, or BIBI) that provides additional information on stream health. Detailed information can be found at Puget Sound Stream Benthos Monitoring and Analysis. These two scores complement each other and allow a quick comparison of the water quality across years and within watersheds throughout the county, and guide future monitoring and management decisions. Both scores are reported each year on the County's Watershed Health website.

3.5.2 Incidental Take

Flood hazard management activities can adversely affect habitat of fish, but they are crucial to public safety. Violating "take" prohibitions of the federal ESA may result in civil or criminal penalties, loss of federal funding on a broad scale, potentially extensive legal expenses, and injunctions to stop operations. However, the ESA also provides for authorizing take that is incidental to and not intended as part of an action when in compliance with an incidental take statement or permit. Long-term cumulative adverse effects of some flood hazard management activities cannot be mitigated adequately through on-site mitigation. The only way to mitigate these adverse effects is through off-site mitigation and long-term programmatic efforts.

The ESA prohibits the take of species listed as threatened or endangered. Take is defined as "harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or any such conduct." Harass means an intentional or negligent act that creates the likelihood of injuring wildlife by annoying it to such an extent as to significantly disrupt normal behavior patterns such as breeding, feeding, or sheltering (50 CFR 17.3). Harm means an act that actually kills or injures a protected species (50 CFR 222.102). Harm can result from habitat modification or degradation that kills or injures protected species by significantly impairing essential behavioral patterns, including breeding, spawning, rearing, migrating, feeding, or sheltering.

Sections of the ESA provide protection from a finding of "take" in three ways: (1) through a Section 4(d) exemption, (2) an incidental take statement as part of a biological opinion in accordance with Section 7 (see Section 7 Incidental Take Statements, below), and (3) an incidental take permit (ITP) in accordance with Section 10 (see Section 10 Incidental Take Permits, below).

3.5.2.1 Section 4(d) Rule

Section 4(d) of the ESA authorizes the National Marine Fisheries Service (NMFS) to customize regulations to conserve threatened species, and it also applies to Section 9 take prohibitions. A 4(d) rule "excepts" activities or programs deemed by NMFS to "conserve" listed species from ESA restrictions. The rule may adopt local or regional programs, thus providing protection for program activities from "take" prohibitions. The program or activities become part of the species recovery plan. An example of this is the Regional Road Maintenance Program in which Pierce County uses coverage for roadway maintenance.

3.5.2.2 Section 7 Incidental Take Statements

Section 7 of the ESA directs federal agencies to ensure the actions they take, including those they fund or authorize, do not jeopardize the existence of any endangered or threatened species. Section 7 applies to projects requiring a federal permit or seeking federal funding.

The process usually begins as an informal consultation with U.S. Fish and Wildlife (USFWS) Service for terrestrial species, the NMFS for marine species, and affected Tribes. If it appears that the proposal may affect a listed species, the federal agency prepares a biological assessment to assist in determining the degree of effect on a species. When the federal agency determines that its action is likely to adversely affect a listed species, formal consultation is requested. The respective Service (USFWS or NMFS) prepare a biological opinion on whether the proposed activity will jeopardize the continued existence of a listed species. Jeopardy occurs when an action is reasonably expected, directly or indirectly, to diminish a species' numbers, reproduction, or distribution so that the likelihood of survival and recovery in the wild is appreciably reduced. When the Service finds that an action may adversely affect a species but not jeopardize its continued existence, the Service prepares an incidental take statement. The statement includes the amount or extent of expected take, reasonable and prudent measures to minimize the take, and terms and conditions that must be observed when implementing the measures.

3.5.2.3 Section 10 Incidental Take Permits (10.a.1(b))

In contrast, an ITP (as discussed in Section 10 of the ESA) contains all the conditions that must be implemented in order to be exempt from the take prohibition and provides an explanation of the evidence that the Services have considered in reaching their conclusions about issuing the permit. An application is filed with the Services along with a habitat conservation plan (HCP). After public review and comment, the Services must find that the habitat conservation plan and proposed actions (1) involve a taking of an endangered species that will be incidental to an otherwise lawful activity; (2) the permit applicant will minimize and mitigate the impacts of the taking "to the maximum extent practicable"; (3) the applicant has ensured adequate funding for its conservation plan; and (4) the taking will not appreciably reduce the likelihood of the survival of the species.

At the heart of ITPs is an HCP, which starts with a group of activities with potential adverse effects, frequently those with long-term direct and indirect cumulative adverse effects. Adverse effects are quantified to the extent possible. Next, the range of programs, projects, methods, and activities that can overcome the adverse effects are identified. If the permit applicant adopts a plan that the Services and Tribes agree will not appreciably reduce the likelihood of the survival and recovery of the species in the wild, the applicant can file for the ITP. Federal funding of up to 75 percent of the cost of preparing an HCP, 90 percent for multi-sponsors, is available for qualifying applicants. The ESA also provides federal grants to implement HCPs.

A successful HCP starts with a clear focus on activities with incidental take not covered by Section 7 consultations. For SWM, that means repair and maintenance activities and other activities that benefit water quality and aquatic habitat (such as floodplain acquisition or setback levees). This broadens the dialogue between stakeholders to maintenance and repair within the context of the whole SWM system.

3.5.2.4 Habitat Conservation Plan

Since the publication of the 2013 Flood Plan, Pierce County has continued its pursuit of an ITP for Public Works' flood risk reduction maintenance and operations activities. The HCP, which is needed to obtain an ITP, describes anticipated effects of proposed maintenance and operations activities along rivers and streams and how county staff and contractors will minimize or mitigate the impacts to habitat and species. Those activities include managing vegetation along levees for inspection and maintenance, flood fighting or other emergency work on levees, conducting imminent threat projects, and routine levee and revetment maintenance. The ITP will allow Pierce County to conduct routine maintenance activities along segments of the Puyallup, White, Carbon and Nisqually rivers that might result in incidental takes, without violating the ESA.

Pierce County is working closely with the USFWS and NMFS in the development of the HCP. Several draft versions of the HCP have been reviewed by the USFWS, NMFS, and Tribes. Issuance of an ITP is a federal action subject to National Environmental Policy Act (NEPA) compliance. The USFWS and NMFS are preparing a joint NEPA environmental assessment (EA) that will analyze the potential impacts of USFWS and NMFS each issuing an ITP to Pierce County. The EA does not address the impacts of the county's flood risk reduction activities, which necessarily would take place with or without the issuance of an ITP. Pierce County has also continued coordination with federal, state, and local agencies, Tribes, and other stakeholders throughout the development of the HCP. Publication of the final draft HCP and draft EA is anticipated to occur later in 2023. Following publication, Pierce County, USFWS and NMFS will solicit public comments during a 45-day comment period before issuing the ITP. Updates on the project and materials can be found on the project webpage at Habitat Conservation Plan | Pierce County, WA - Official Website (piercecountywa.gov).

3.5.3 System-Wide Improvement Framework

The System-Wide Improvement Framework (SWIF) Plan represents Pierce County's local approach to improving the system of levees enrolled in the USACE Public Law (PL) 84-99 Rehabilitation and Inspection Program. This SWIF Plan was accepted by the USACE on June 8, 2017, and expires in 2037. It is intended to be a "living" document for a 20-year period and will be amended over time to address evolving river conditions that may affect levee integrity and associated level of flood risk. The SWIF addresses identified levee deficiencies, including the correction of unacceptable inspection items in a prioritized manner to optimize flood risk reduction.

The SWIF is an implementation plan where actions are phased over a period of time. The categories of actions are characterized as near-term, mid-term, long-term, programmatic, and monitoring actions. Near-term actions are typically those that will be addressed within the current budget cycle, such as routine maintenance or response to deficiencies that pose a high level of risk. Mid-term actions are generally those of moderate-high risk and more extensive in scope and cost, including capital improvement projects scheduled to coincide with the county's capital improvement program 6-year budget cycle. Representative mid-term actions include capital maintenance projects to correct extensive or chronic deficiencies by building resiliency into the levee repair to better withstand changing river conditions. Long-term actions may include projects already listed in the 2013 Flood Plan, but not yet included in the current six-year capital improvement plan or whose funding source has not yet been identified or programmed into the overall budget.

Programmatic actions are ongoing over the course of the 20-year planning horizon. Programmatic actions, such as the SWIF levee vegetation management strategy, the levee asset management program, and the levee capital maintenance/ preservation program, are important components of the SWIF that will be ongoing through the 20-year course of SWIF implementation necessary to maintain as well as improve the system of levees over time. Monitoring actions are intended to ensure that the objectives in the SWIF are met, levee deficiencies do not worsen, and programmatic actions are successful. The SWIF Action Plan describes interim risk reduction measures to apply while the SWIF is being implemented. This strategy relies upon the various programs already in place, coordinated between Pierce County SWM and Emergency Management.

For additional information on the SWIF, please visit SWIF (piercecountywa.gov).

3.5.4 Channel Migration Zone Regulations

Pierce County experiences two major types of hazards associated with riverine flooding: flood inundation and channel migration. The CMZ refers to the geographic area where a stream or river has been and is susceptible to channel erosion and/or channel occupation (Rapp and Abbe 2003). CMZ delineations help reduce risks to communities by making homeowners and potential home buyers and builders more aware of risks. As shown in Figure 3.3, a home that was more than 150 feet from the mapped floodplain was damaged due to channel migration. The CMZ risk is also reduced by regulations guiding development in and along river and stream systems that are away from areas of severe risk of lateral channel erosion. Pierce County only regulates the severe CMZ as a floodway under PCC Title 18E.70. For example, the severe CMZ on the Puyallup River is where the river has a high probability of lateral migration within the next five years. Title 18E.70.020 (Flood Hazard Areas) notes that CMZs on regulated watercourses (South Prairie Creek and Carbon, Puyallup, White, Greenwater, Nisqually, and Mashel rivers) will be regulated when CMZ studies are completed, accepted, and adopted by Pierce County, except for the lower Puyallup River (downstream of the confluence on the White River), where the default CMZ shall be the regulated FEMA floodway.

Figure 3.3. Damage from Channel Migration

3.5.5 Inter-County River Improvement Agreement

The Inter-County River Improvement Agreement (ICRI) was a 105-year agreement approved in 1914 to settle a legal dispute between Pierce and King counties. The ICRI agreement between the counties was developed in response to the permanent diversion of the White River from King County into the Stuck River (lower White River) in Pierce County following a catastrophic storm and flood event in 1906. For this agreement to be possible, state law had to be changed to allow counties to jointly fund and operate flood control facilities. The RCW 86.13 was passed by state legislators in 1913. The ICRI agreement jointly funded the construction and maintenance of flood facilities on the lower White and lower Puyallup rivers to protect the communities of Sumner, Puyallup, Tacoma, and the Port of Tacoma. These facilities were constructed between 1914 and the early 1930s. Many of these facilities continue to exist today. While the agreement has now expired, the necessity for joint flood planning and response remains on the White River. Pierce County and King County continue to develop new facilities within their jurisdictions to reduce the impacts of flooding. A new agreement documenting this continued joint effort is needed to memorialize this effort.

3.5.6 Salmon Recovery

3.5.6.1 Fish Habitat/Spawning

Chinook, steelhead, and bull trout species are listed as threatened species under the ESA. The Puget Sound Chinook Recovery Plan lists White River Spring Chinook as a Primary Stock for recovery, and therefore integral to the recovery of the Evolutionary Significant Unit (ESU).

All rivers in this 2023 Flood Plan study area, except for the upper Nisqually River, are used by salmon for one or more of their life stages (migration, rearing, and/or spawning). The upper Nisqually River is inaccessible to salmon due to existing dams. Specific habitat needs for salmon vary by species and life stage, but important factors for salmon habitat broadly include water quality and quantity, in-stream woody debris, riparian vegetation, varying sizes of gravel substrate, and diversity of in-stream conditions such as fast flowing riffles and deep pools.

For spawning and rearing, Chinook and steelhead prefer the large side channels and stable main channel areas near large pools with wood. Coho, chum, and cutthroat trout occupy smaller side channels or along the margins of the main channel. Prime spawning and rearing habitat contains abundant high-quality spawning gravel and a pool-riffle configuration (Marks et. al 2009).

While any fish-bearing water is important potential habitat for salmon species, there are several areas that are critical remaining habitat. These include the following:

- Tributaries to the Puyallup, Carbon, and White rivers provide important spawning habitat for Puyallup River fall Chinook salmon, especially South Prairie Creek.
- Particularly important is the stock of White River spring Chinook, which were on the brink of extinction in the mid-1980s.
- The upper White River reach is particularly important ecologically because it provides spawning habitat for all three ESA-listed species in the Puyallup River watershed, which are bull trout; Chinook salmon, including spring Chinook; and steelhead.
- The Greenwater and Clearwater rivers are the principal tributary stream for spawning spring Chinook in the White River watershed.

- Boise Creek provides important spawning habitat for steelhead trout and Chinook salmon.
- The middle reach of the Nisqually River serves as a migration corridor for all species of salmon in the river and provides spawning habitat for chum, coho, pink, and Chinook salmon and steelhead. There is abundant spawning gravel just downstream of the Centralia diversion dam.

3.5.6.2 Temperature/Shading

Pre-modern time river systems in Pierce County were complex, braided, and vast, with extensive floodplains. Riparian areas and surrounding forests comprised of conifers, hardwoods, and shrubs are a part of the riverine ecosystem. As part of this same riverine ecosystem, salmonid populations rely on the environmental conditions created by this landscape. One such vital condition for anadromous fish is cool water temperatures produced from shade, groundwater inputs, snow and glacial melt, and climate conditions.

Modern development and population growth in Pierce County have significantly disrupted the historical functioning of the established ecosystem. A subsequent change is the increase in water temperatures within natural water systems, which negatively impacts anadromous fish. Warm water temperatures can alter the timing of migration and spawning, negatively affect growth and survival, increase salmonid stress levels and susceptibility to disease (Lead Entity, 2018), promote predator survival, and create thermal barriers to migration routes to spawning and rearing habitat.

Chinook salmon are most frequently observed spawning in waters between 4 and 14 degrees Celsius (°C) (39 to 57 degrees Fahrenheit [°F]) and bull trout below 9 °C (49 °F) (Behnke 2002; EPA 2003;). Rearing of juvenile Chinook salmon usually occurs in water with temperatures ranging from 10 to 17°C (50 to 63 °F) (EPA 2003). In some cases, Chinook salmon, coho salmon, and steelhead trout have long freshwater rearing requirements, and warmer stream temperatures may heavily impact their populations. To promote cool water, intact forested areas near waterways and riparian areas should remain intact. Vegetation along riverine corridors is essential to provide shading and habitat opportunities for a variety of fish and wildlife species. Extra precautions for maintaining shade should be considered on the southerly bank of river channels to keep water temperatures cool (avoid reductions of trees in riparian area) (Lead Entity, 2018).

A recent study completed through the Floodplains for the Future partnership used Thermal Infrared Technology to measure the thermal landscape of the Puyallup River Watershed (South Puget Sound Salmon Enhancement Group, 2019). This work flagged multiple high temperature areas, helping to pivot and concentrate cold water refuge restoration work in these vicinities.

3.5.6.3 200-Foot Riparian Buffer

Forested riparian buffers provide important habitat for salmon because they shade and cool streams and produce large woody material (LWM) that support instream habitat-forming ecological processes. A mature forested riparian buffer with a full complement of ages, sizes, and species of native trees and vegetation, and of a width equal to the site-potential tree height (about

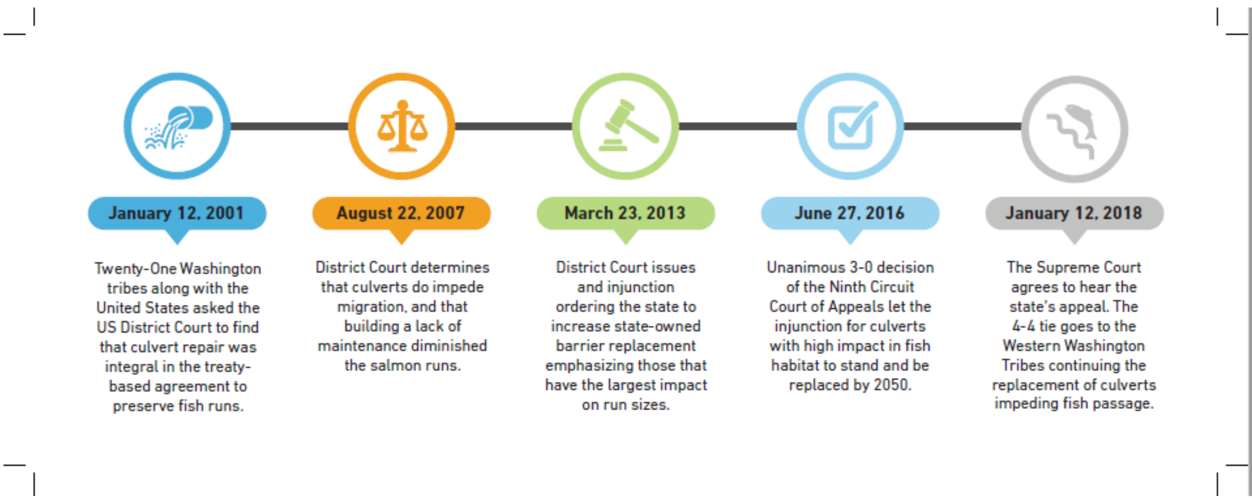
200 feet in Western Washington) will provide adequate LWM to create functional salmon habitat (Knutson and Naef 1997).

The Salmon Habitat Protection and Restoration Strategy for Puyallup and Chambers Watersheds recommends applying a 200-foot forested riparian buffer to the Digital Flood Insurance Rate Map (DFIRM) 100-year floodplain maps or the CMZ severe hazard area, whichever is greater in width, to best support salmon habitat-forming processes. Extra attention should be focused on the southern bank of river channels, where the forested buffer creates shade and keeps water temperatures lower. For additional information on the 200-foot riparian buffer, visit Focus on Riparian Buffers for Salmon Protection (wa.gov).

3.5.6.4 Culverts

Within Pierce County, many streams pass through culverts across a variety of land ownership types, including private landowners, the state, local cities and towns, and unincorporated Pierce County. Passage of anadromous fish through these culverts is paramount to salmon recovery, and an obligation to Tribal Treaty Rights as determined by the U.S. Supreme Court in 2018 (United States v. Washington, 2016). Figure 3.4 provides a timeline overview of the culvert case milestones.

Figure 3.4. Timeline of the United States vs. Washington Case



As salmon migrate upstream from Puget Sound, they most often pass through cities, towns, and private lands before entering unincorporated Pierce County. To truly connect salmon to habitat, fish passage improvements must occur on a watershed scale through collaboration and partnerships. Particularly important to the effort is the partnership with the local Tribal governments. Pierce County recognizes the importance in addressing county-owned culverts, while acknowledging that the best use of public funds for fish passage projects is to coordinate efforts throughout the county to restore fish accessibility to creeks and streams.

Pierce County Planning and Public Works manages county infrastructure, such as culverts and bridges. Each division intersects with fish passage infrastructure in different ways. The Office of the County Engineer implements road projects that occasionally cross streams; Maintenance and Operations and Parks and Recreation both maintain existing infrastructure such as culverts and bridges; Planning and Land Services perform permitting for those activities and SWM assists with culvert replacements for the benefit of fish passage and stormwater. Coordinating and streamlining work efforts across Pierce County divisions is fundamental to achieving the larger vision of improving fish passage to rivers and streams in a timely manner.

3.5.6.5 Orca Restoration Plan

Governor Jay Inslee established the Southern Resident Orca Task Force through Executive Order 18-02 in March 2018 after recognizing the urgency of the threats facing the Southern Resident orcas and the unacceptable loss extinction would bring.

While other killer whale populations prey upon a variety of marine mammal or shark species, Southern Residents have uniquely evolved to prey upon salmon—with Chinook making up about 80 percent of their diet. Many Chinook populations across the Pacific Northwest have declined to a fraction of their historic abundance and are listed as either threatened or endangered under the ESA. In addition, Chinook are returning younger and smaller than they have historically. These significant shifts in abundance and size are making Chinook less available and less nutritious for Southern Resident orcas.

Climate change is another important consideration that is already exacerbating existing stresses on Southern Residents and the ecosystems upon which they depend, including salmon and forage fish. As temperatures continue to rise, Southern Residents will be affected primarily through their food web. Higher temperatures will impact salmon habitats and populations at each life stage. In response, Pierce County can help mitigate the impact of a changing climate by accelerating and increasing action to increase the resiliency and vitality of salmon populations and the ecosystems on which they depend.

Listed below are some recommendations from the task force work that are relevant to the multi-benefit projects and work Pierce County does within river corridors.

- Increase fish access to cold water habitats and refugia.
- Significantly increase the scale and scope of investment in habitat protection and restoration projects that focus on habitat diversity and complexity.
- Increase the diversity and resiliency of wild and hatchery salmon stocks.

For additional information on orca restoration, visit Southern Resident Orca Task Force Final Report and Recommendations, November, 2019.

3.5.6.6 Salmon Recovery Plan

Several Puget Sound salmonid species are listed as threatened or as species of concern under the federal ESA, and critical habitat has been designated for some species. In addition to ESA requirements, there are Tribal treaties and state regulations addressed in the Hydraulic Project Approval legislation, Growth Management Act, and Shoreline Management Act that identify salmon as a protected species and require land use and recovery planning to protect salmon species and their habitats. There are recovery plans at the state, regional, and sometimes watershed level, such as watershed chapters of the Puget Sound Chinook Recovery Plan, which was adopted by the NMFS. Local Tribes as well as the Northwest Indian Fisheries Commission are involved in decision making and co-manage the resources along with the Washington State Department of Fish and Wildlife.

The Salmon Recovery Planning Act (RCW 77.85) provides the framework for salmon recovery in Washington State. It established the Governor's Salmon Recovery Office, the Salmon Recovery Funding Board, and delegates recovery of habitat to watershed-based Salmon Recovery Lead Entities, which put the local stakeholders in the driver's seat to develop recovery strategies and identify, prioritize, and fund restoration projects. The Recreation and Conservation Office manages the Lead Entity process for the state, and the Puget Sound Partnership (PSP) is the Puget Sound regional organization that coordinates the Puget Sound Lead Entities.

Salmon Recovery Efforts

One important flood control strategy is to either remove or set existing levees back closer to the edge of floodplains. This provides more room for floodwaters to occupy a river, which also provides important opportunities for salmon to escape fast-flowing floodwaters into the reconnected floodplain, where there is also more habitat and prey available.

All of this demonstrates the need to coordinate any flood reduction and floodplain management strategy with salmon recovery efforts. It will also help salmon recovery to consider climate resilience; temperature reduction; and efforts that help protect habitat, such as strengthening and enforcing critical area regulations and making sure all actions achieve a net ecological benefit.

For additional information on salmon recovery in the Puget Sound, visit the Puget Sound Salmon Recovery Plan at Recovery Plan for Puget Sound Chinook Salmon | NOAA Fisheries.

3.5.6.7 Puget Sound Action Agenda

The Puget Sound basin in Washington is the southern portion of the Salish Sea. The collaborative effort to recover Puget Sound is directed by the PSP, a state agency. The PSP is responsible for coordinating recovery efforts and distributing the EPA's National Estuaries Program grant dollars, along with other state agencies that take the lead on one of three Strategic Initiatives: stormwater, habitat, and shellfish.

Puget Sound Vital Signs are agreed upon indicators that identify quantifiable measures of progress toward recovery. The Vital Signs underwent significant revision in 2020-21. Implementation Strategies are plans for achieving specific ecosystem targets for the Puget Sound Vital Sign indicators. These indicators describe the sequence of steps, activities, and results needed to move closer to a recovery goal. With regard to flooding, the Vital Signs most relevant are streams and floodplains, estuaries, salmon, forests and wetlands, beaches, and marine vegetation.

To guide the implementation, every five years the PSP produces the Puget Sound Action Agenda of shared priorities for recovery. The basis of the Action Agenda is science. It is also informed by

Ecosystem Recovery Plans developed by local experts and stakeholders from among 10 Local Integrating Organizations (LIO) across the Puget Sound basin.

There are three LIOs within (and beyond) Pierce County's jurisdictional boundaries:

- Alliance for a Healthy South Sound (South Sound LIO)
- West Sound Partners for Ecosystem Recovery (formerly West Sound LIO)
- Puyallup-White River LIO

Prior to the 2022-2026 Action Agenda, organizations were invited to submit projects they deemed necessary to recovery efforts, which they termed Near Term Actions (NTA). If accepted, the NTAs became eligible to receive National Estuary Program NEP funding annually in a competitive process. The next Action Agenda is expected to have a different model for prioritizing and funding projects.

The local Ecosystem Recovery Plans, along with the Puget Sound Action Agenda, are good sources of information to inform local priorities and future projects that will influence recovery of Puget Sound. Aligning projects with these plans will serve to achieve priorities and leverage dollars. It is worth noting that only projects that are accepted and align with these plans are eligible for the NEP funding dedicated to Puget Sound estuary recovery.

3.5.7 Community Rating System

3.5.7.1 Pierce County Participation in the National Flood Insurance Program and the Community Rating System

The CRS is an incentive program for jurisdictions who practice comprehensive floodplain management with standards that exceed the minimum requirements of the NFIP. The incentive comes in the form of discounts on flood insurance, which allows residents more affordable insurance and the ability to recover faster after a flood. Pierce County has participated in the NFIP since 1987 and in the CRS since 1997.

The NFIP was created in 1968 to address the rising cost of taxpayer-funded disaster relief. The goal of the program is to decrease the amount of money the federal government pays in post-flood disaster relief by encouraging jurisdictions to reduce the risk to property owners through floodplain mapping, regulations, education, and other programs. The NFIP is administered by the Federal Insurance Administration, which is part of FEMA. While participation in the NFIP is technically not required under federal law, it is highly impractical for Pierce County and other local governments to not participate in the program because federally backed mortgage loans require the purchase of flood insurance if the structure is in the mapped floodplain. Participation in the NFIP allows for federal assistance under the Stafford Act when there is a Presidential Declared Disaster as well as Small Business Administration loans and Community Development Block Grants.

The CRS was launched in 1990 to be an incentive program to reward communities that exceed the NFIP minimum standards. The CRS program has three primary goals: reduce flood losses, support the federal flood insurance program, and support comprehensive floodplain management.

The CRS program scale begins at a Class 10, and for every 500 points a community is credited, it goes up a class and receives an additional five percent insurance discount. For instance, a Class 10 community receives no premium reduction, but a Class 1 community receives a 45 percent discount. CRS is divided into four major sections (Public Information, Mapping and Regulations, Flood Damage Reduction, and Warning and Response) that represent 19 major activities that are scored based on 95 individual elements. To move between classes, it is also necessary to meet certain prerequisites.

Pierce County has done quite well in the CRS program because the County's mission, expressed throughout this 2023 Flood Plan, aligns with the goals of the CRS program. Pierce County began as a Class 7 community in 1995, and since 2009, the county has been a Class 2 community. This gives a 40 percent discount on flood insurance to unincorporated Pierce County residents. For additional information on Pierce County's CRS program, please visit the following link: Community Rating System Program | Pierce County, WA - Official Website (piercecountywa.gov).

Table 3.1 shows a breakdown of Pierce County's 2018 CRS points. Pierce County continues to strive to improve its program and rating under the CRS program. This will be aided by implementation of this 2023 Flood Plan.

Table 3.1. Summary of CRS Activities and Points

Activity	2017 Manual Maximum Possible Points[a]	2018 Pierce County Points Earned[b]
Elevations Certificates	116	77
Map Information Service	90	90
Outreach Projects	300	227
Hazard Disclosure	80	25
Flood Protection Information	125	53
Flood Assistance	110	
Flood Insurance Promotion	110	
Floodplain Mapping	850	141
Open Space Preservation	3,720	1,303
Higher Regulatory Standards	3,782	682
Flood Data Maintenance	222	187
Stormwater Management	755	530
Floodplain Management Planning	622	291
Acquisition and Relocation	2,250	437
Flood Protection	1,600	204

Activity	2017 Manual Maximum Possible Points[a]	2018 Pierce County Points Earned[b]
Drainage System Maintenance	470	115
Flood Warning and Response	395	275
Levees	235	
Dams	160	45
Total	15,992	4,682
Growth Adjustment	1.08	227
Total Points		**4,909**

[a] Maximum possible points based on 2017 CRS Coordinators Manual.

[b] Blanks indicate that Pierce County did not seek credit for these activities.

3.5.8 Tribal Agreements

3.5.8.1 Settlement Agreement between Puyallup Tribe of Indians and Federal Government, State of Washington, Local Governments of Pierce County, and Private Interests

In 1990, a Settlement Agreement was reached between the Puyallup Tribe of Indians (Puyallup Tribe), local governments in Pierce County, the State of Washington, the United States of America, Port of Tacoma, and certain private property owners. Key provisions of this agreement that affect flood hazard management planning efforts include:

1. Numerous additions to the Tribe's land base, including the submerged lands below the mean high water line (riverbed) within the Puyallup River within the 1873 survey area (approximately RM 1.4 to RM 7.2);
2. Provisions for substantial restoration of the fishery resource, allowing for future development while lessening impacts on fisheries;
3. Resolution of conflicts over governmental jurisdiction; and
4. Establishment of a consultation process. All actions in this area need approval of the Puyallup Tribe.

The agreement also specifically affects vegetation management, gravel removal, and flood control activities to the extent to which they affect fisheries habitat. The agreement calls for the partners and stakeholders involved in development of this flood plan to work closely with the Puyallup Tribe to ensure that the draft and final recommendations are consistent with the agreement. A more complete summary of the agreement is found in Appendix B.

3.5.8.2 Vegetation Management Agreement with Puyallup Tribe of Indians

Adopted in 1985, the Puyallup River Vegetation Management Program was the result of an agreement between Pierce County and the Puyallup Tribe to settle a legal dispute about vegetation on the county's flood control facilities. The United States District Court issued a stipulation that acknowledged the vegetation management program and enabled the lawsuit to be cancelled. The program specifies allowable vegetation removal for maintenance activities, sediment berm and gravel removal, and levee/revetment reconstruction in the Puyallup River Basin. Recommendations in this 2023 Flood Plan must be consistent with or specify changes to the agreement for consideration by the two parties to the agreement.

3.5.9 United States Army Corps of Engineers Mud Mountain Dam Operational Agreement

The primary control on the magnitude of flood flows in the lower Puyallup and lower White rivers is Mud Mountain Dam, which was completed in 1948 at RM 29.6 on the White River. The dam flood control project was authorized by an Act of Congress in 1936. The authorized project purpose of the dam is to prevent flood damages in the lower Puyallup River valley below the mouth of the White River. The dam was developed for the single purpose of flood storage to reduce downstream flooding and is operated as a run-of-river facility. (A run-of-river facility allows the river to flow freely during normal non-flood conditions.) Most other federal dams are multipurpose, with a permanent pool for irrigation or conservation flows to support in-stream flows downstream.

The dam is owned and operated by the USACE and provides storage of up to 106,000 acre-feet of floodwaters. It was originally operated to maintain flows on the lower Puyallup River below 45,000 cfs at the U.S. Geological Survey (USGS) Puyallup River gauge in Puyallup (#12101500). Under the initial water control plan, water stored in the dam was discharged to the White River at up to 17,600 cfs (USACE 2002). Channel capacity of the White River downstream of the dam was estimated to be at least 20,000 cfs. However, field observations in the 1970s indicated that flooding in the White River downstream of the dam was occurring at discharges as low as 12,000 cfs. The reduced flood-carrying capacity of the river was attributed to multiple factors, including encroachment of development along the channel, accretion of sediments in the channel, and limitations on channel dredging (USACE 2002). The Water Control Manual for the dam was updated in 2004 to reflect a revised operating procedure (USACE 2004). The primary objective (i.e., restrict flood discharges in the lower Puyallup to a maximum of 45,000 cfs) remains intact, but a new secondary objective was added to limit dam discharges to 12,000 cfs, when feasible.

4 Project Considerations

4.1 Climate Change Projections for Pierce County

Climate change in the Pacific Northwest is predicted to have significant effects on flooding and channel migration within Pierce County river systems. Appendix C discusses in more detail the effects of the background of climate projections as well as past trends and projected changes for warming air, precipitation, shrinking snow and glaciers, sea level rise, groundwater flooding, and river flooding.

As a result of climate change, flood events may be more frequent and longer in duration. It is necessary to account for these changes as part of project and program implementation throughout the county.

Pierce County completed a Climate Change Resilience Strategy for Pierce County SWM along with other departments. This study can be found at: https://www.piercecountywa.gov/5558/Climate-Change-Resilience.

4.1.1 How Climate Change Will Affect Flooding in Pierce County

Floods in the Puget Sound region are becoming larger and more frequent due to the combined effects of declining snowpack, intensifying rain events, and rising sea levels. For example, one recent study projects a 25 percent to 44 percent increase in the volume of the 100-year flood by the 2080s for the lower Puyallup River (on average, for a low and a high greenhouse gas scenario, respectively; Chegwidden et al. 2019).

Given that the FEMA (2002) calculation of the 100-year flood discharge in the lower Puyallup River was 48,000 cfs and as of 2022 the calculated discharge (based on observations) is now 59,500 cfs, the estimated discharge of 60,000 to 69,000 cfs for the future 100-year flood in the 2080s appears understated. These discharge estimates represent dramatic changes in flooding, especially given the severe consequences of major floods under current conditions. Additional flooding impacts, such as potential consequences of groundwater flooding, wildfire, and channel aggradation in response to higher sediment loads, could be important but have not yet been sufficiently studied. For additional information on Climate Change projections for Pierce County please see Appendix C.

4.1.2 Climate Change and Pierce County Capital Projects

Climate change affects all types of capital improvements projects. The potential impacts of climate change on a marine floodwall will be substantially different than impacts on a setback levee, a fish passage culvert, or a water quality treatment facility. The climate science currently available in these different environments varies widely. Because sea level rise is a global issue, it has received more scientific investigation and modelling than localized changes on precipitation patterns and their effects on rainfall intensity and hydrology within Pierce County.

With many capital projects having an expected life span of up to 100 years, acknowledging climate change during the design process is prudent. Concrete structures, such as fish passage culverts, have a design life of approximately 100 years. The U.S. Army Corps of Engineers (USACE) uses a design life of 50 years when designing new levees but acknowledges that the facilities could continue to meet level-of-service expectations for longer. Future conditions, that is, changes in land use and changes in channel morphology (sediment transport) during the expected life of a project, are already being factored in during project design, so precedent exists for factoring in climate change as well. The challenge is determining when climate change forecasts are sufficiently accurate for use during the design process.

The Washington Department of Fish and Wildlife (WDFW) has issued guidance on incorporating climate change into the design of fish passage structures (Wilhere et al. 2017), which Pierce County implements on an “as feasible” basis. The Washington State Department of Transportation also provides guidance for the design of bridges and stream crossings in Section 7-4.4.6, “Climate Resilience,” in the 2022 Hydraulics Manual.

Design of new setback levees and the analysis of large regional storm control facilities all attempt to quantify climate change in some way. Water quality treatment facilities, which are designed for the very frequent “water quality event” specified by the 2019 Western Washington Stormwater Design Manual (Ecology 2019), are not currently designed to accommodate climate change. In this instance, definitive guidance from Washington State Department of Ecology (Ecology) or others would be helpful.

4.2 Adaptive Management/Pathways

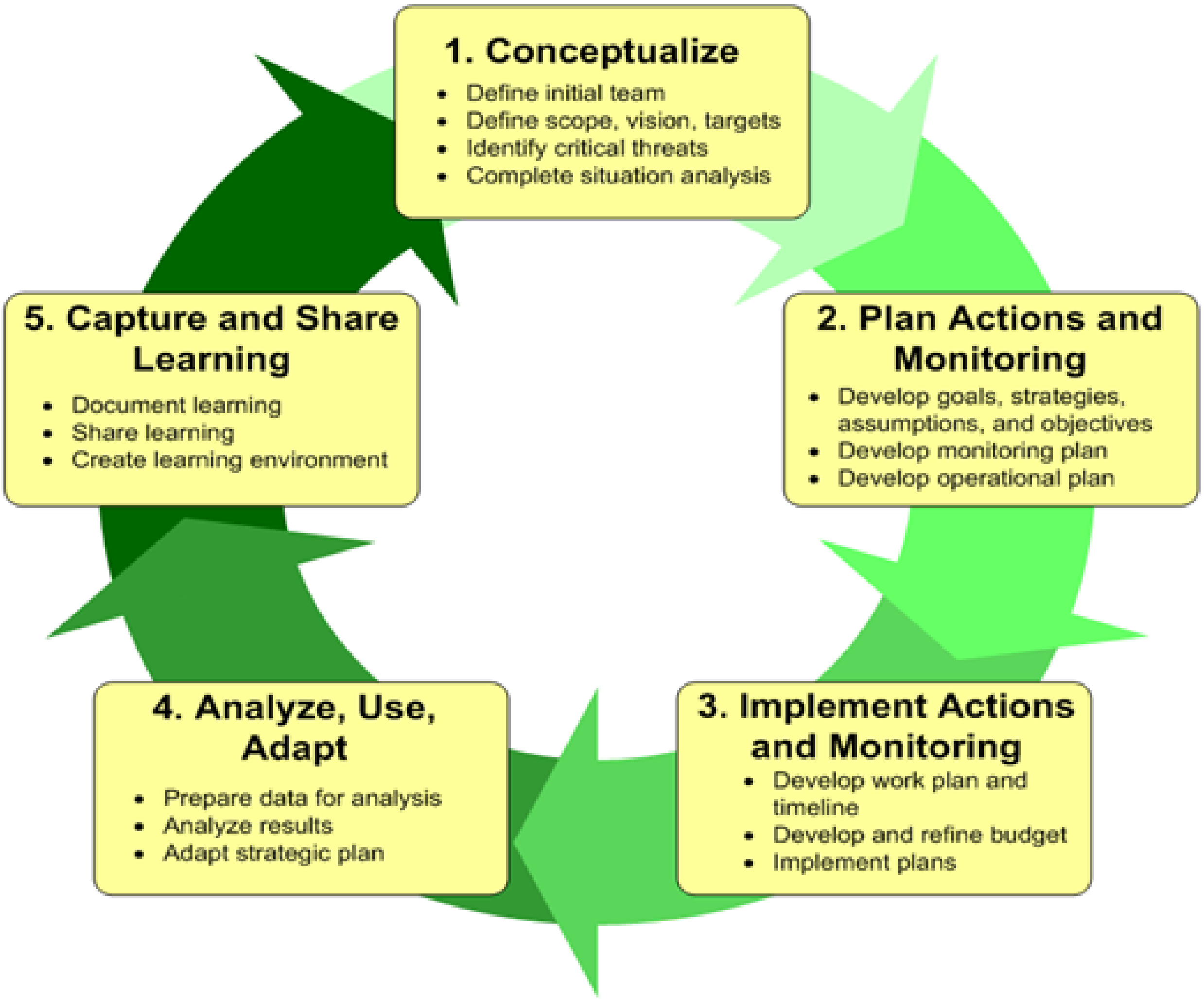
When permits are issued for maintenance, repair, or replacement of flood risk reduction facilities, the permits often require monitoring to ensure the facility is functioning as designed. Post-project monitoring of selected indicators can provide valuable information on the effectiveness of project types and how to improve the design and construction of future projects. Pierce County should use this information to modify and adjust design approaches and construction and maintenance practices to ensure that the most appropriate methods and materials are used. This information may also be used to communicate progress achieved toward reaching flood hazard management project and reach level goals over time. Adaptive management approaches to plan implementation require a commitment to an ongoing coordinated information management system.

4.2.1 **Adaptive Management**

The 2023 Flood Plan contains recommendations and capital projects to guide Pierce County's flood hazard reduction over the next 10 to 20 years. The plan reflects the best available information at the time of plan completion, but there remains much to be learned through implementation. Several of the recommendations in this Plan include future evaluation and/or monitoring. Without a well-designed approach to determine the effectiveness of strategies and actions in meeting project objectives, learning opportunities are lost for improving future actions. Adaptive management offers a framework and systematic approach for understanding the effectiveness of individual projects as well as to measure progress made towards meeting stated project goals and objectives. This information may be used to make adjustments to projects over time as well as to continually improve the effectiveness of new management policies and practices. Adaptive management leads to improved outcomes and more comprehensive ways to communicate results to technical and non-technical audiences.

Adaptive management frameworks provide a strategic approach to problem solving and decision-making in the face of ongoing uncertainty. The Puget Sound ecosystem recovery process has adopted the Open Standards for the Practice of Conservation (Open Standards), as the adaptive management framework for the region. The Open Standards framework was developed by the Conservation Measures Partnership and has been deployed nationally and internationally in support of conservation and resource management projects and initiatives. In addition to the Puget Sound Partnership's deployment of the Open Standards, other regional applications of the Open Standards include regional salmon recovery implementation, the Hood Canal Watershed Protection Initiative, the Pilchuck Watershed Protection Project, Port Susan Conservation, and Snohomish Basin Watershed Protection Plan. The Open Standards is a simple five-step process, as identified in Figure 4-1 and described below.

Figure 4-1. Open Standards Framework to Adaptive Management



Step 1 involves defining the extent of the problem and examining potential opportunities for taking action. Step 2 involves developing goals, strategies, and theories of change associated with primary strategies as well as selecting indicators to monitor the effectiveness of the chosen action. Step 3 involves implementation of the project or program and monitoring to determine how effective the actions are in meeting project goals and management objectives. This sometimes involves formal hypothesis testing. Step 4 involves evaluating data, comparing actual outcomes to forecasted outcomes, and adapting a strategic plan, as necessary. Step 5 involves sharing information and knowledge with all interested stakeholders to reflect new understanding from results of Steps 1 through 4 in a continual cycle of improvement.

Adaptive management is an integral component of implementation. An adaptive management framework includes an institutional structure that, in combination with monitoring and evaluation, can be used to judge progress in achieving this 2023 Flood Plan goals and objectives. The framework also lays out how information from monitoring and evaluation efforts will guide decisions about future flood risk reduction measures.

4.3 Pathways Approach

With uncertainty and limited known information about some of the flood hazards presented in this 2023 Flood Plan, such as groundwater, coastal, and urban flooding, Pierce County is adopting a pathways approach to adaptive management. The pathways approach promotes adaptive management, which enables adaptation plans to be ongoing by incorporating flexibility and adaptability into the decision-making process. Not all decisions must be made immediately, and options can remain on the table. This prevents decisions from being made now that lock decision-makers out of other options in the future.

An adaptation pathway is a decision-making strategy that is made up of a sequence of manageable steps or decision points over time. This approach helps to deal with the deep uncertainty associated with climate change, shifts in public support, politics, and policy changes. These uncertainties make it difficult to develop specific plans for future flood hazard management projects, particularly when little is known about the hazard, and instead highlight the need for plans that are flexible and responsive to changing conditions over time. The concept of adaptation pathways has emerged to address these challenges. The adaptation pathway approach has been successfully applied around the United States and the world.

As presented in this 2023 Flood Plan, pathways were prepared for groundwater, coastal, and urban flood hazards. These pathways illustrate Pierce County actions, in coordination with cities, intended to take place over the course of the implementation of this plan and beyond. Additional pathways were created for specific problems and projects for Pierce County, Bonney Lake, Puyallup, and South Prairie. Chapter 6 provides more information on each flood hazard pathway.

4.4 Integrated Work and Coordination

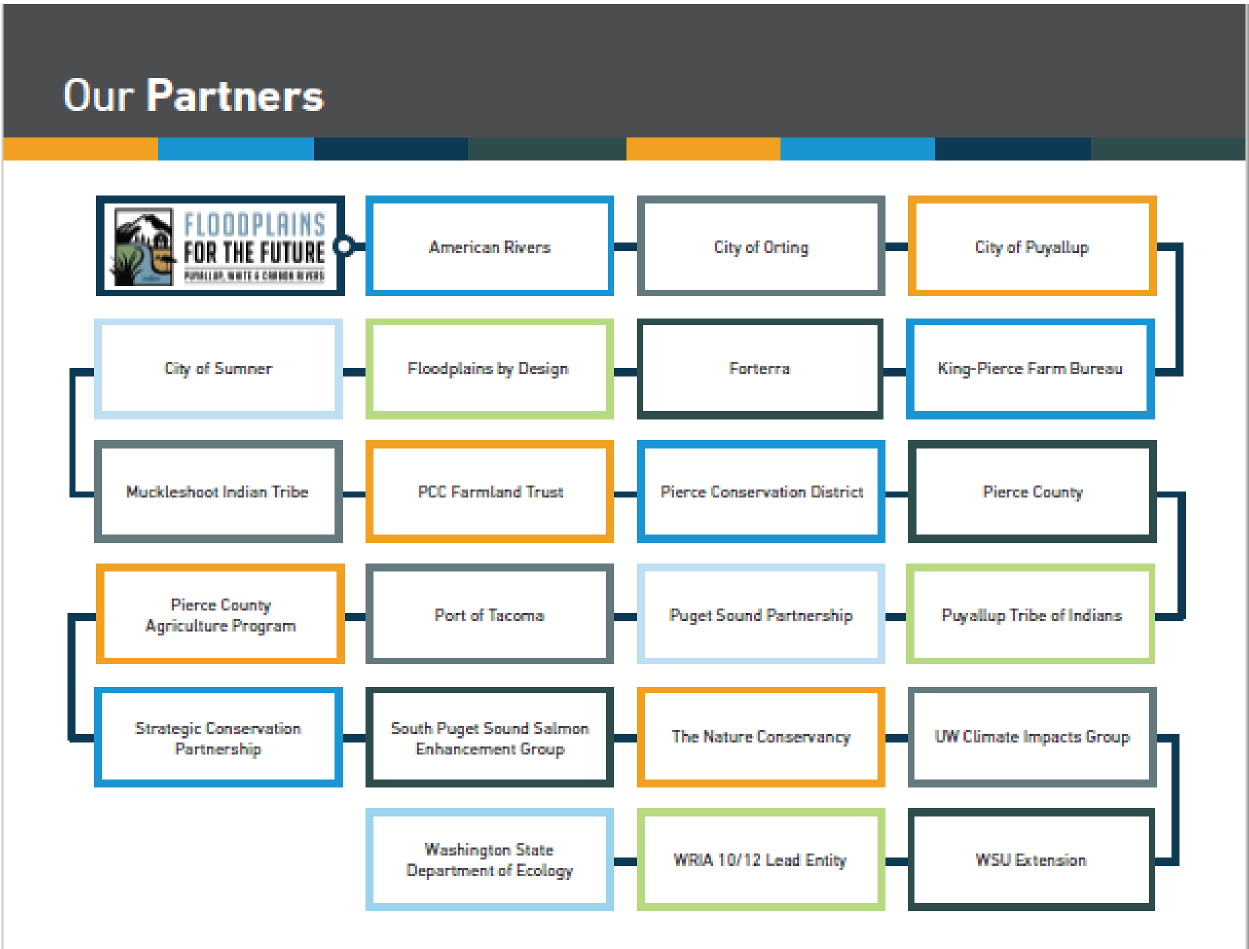
Pierce County works with multiple federal, state, and local partners on flood risk reduction policies, plans, and projects. The inclusion of diverse stakeholders in Pierce County's work collaboratively improves floodplain health, beginning with actions that address flood risk reduction, agricultural viability, and habitat restoration/creation. Pierce County will continue to strengthen partnerships with stakeholders through completing an array of projects that provide significant flood control and ecological lift to the system. Pierce County's approach is to complete an array of integrated projects across all communities within and adjacent to the county, that combined, will provide significant flood control and ecological benefits to the entire river system. This approach ensures increased consistency in floodplain management approaches across all jurisdictions.

4.4.1 Floodplains for the Future

Floodplains for the Future is a cross-sector and inter-organizational partnership in the Puyallup River Watershed. Twenty-two partner organizations meet to plan, fund, and implement floodplain projects to attain the shared vision of restored connections between rivers and land to improve habitat for salmon and protect communities and infrastructure from flooding while preserving agricultural lands. Figure 4-2 outlines all the partners in the Floodplains for the Future group.

Floodplains for the Future works on projects across the Puyallup Watershed, including Orville Road Protection Project, Clear Creek Floodplain Reconnection Project, Neadham Road Acquisition and Revetment, South Prairie Creek Restoration Project, Alward Road Acquisition and Floodplain Restoration, Pacific Point Bar, Ball Creek, White River 24th Street Point Bar, and South Fork Side Channel Reconnection Project. For additional information, please visit https://floodplainsforthefuture.org/.

Figure 4-2. Floodplains for the Future Partner Organizations



4.4.2 Coordination with Cities, Towns, and Counties

Coordination with the cities and towns of Pierce County has been imperative during the development of this 2023 Flood Plan. The cities and towns met during the summer of 2021 to update and modify the Problem and Project Ranking Criteria used to score and prioritize flood projects included in this plan. The cities and towns worked diligently to add two new categories to the ranking criteria (Partnerships and Opportunities and Best Management Practices) and create a more detailed description of some of the existing criteria that were already in the ranking criteria. The Problem and Project Ranking Criteria can be found in Appendix D.

Most cities and towns within Pierce County also participated in Flood Plan Advisory Committee and Disappearing Task Groups (DTGs) that discussed topics such as urban, groundwater, and coastal flood hazards. These meetings were held throughout the development of this plan where the cities and towns provided critical information on the additional flood hazards in this plan. Not only did the cities and towns take part in those specific DTG meetings to address urban, groundwater, and coastal flooding, but they also took part in an additional set of DTG meetings to create programmatic recommendations and actions to work on over the next 10 years. These recommendations can be found in Appendix E.

Given the variety of jurisdictions and stakeholders in the floodplains of Pierce County's major rivers, it is critical to continue to coordinate with neighboring counties. Pierce County shares jurisdiction with Lewis and Thurston counties along the Nisqually River and with King County along the White River, respectively. Coastal flooding is experienced by surrounding counties including Thurston, Mason, Kitsap and King. Throughout this planning process, neighboring counties also participated in the Flood Plan Advisory Committee as well as some of the DTG meetings. Pierce County will continue to coordinate and work with partner counties as part of plan implementation.

4.4.3 Federal/State Coordination

Joint Base Lewis-McChord (JBLM) and Camp Murray are military installations located within Pierce County in the Chambers-Clover Creek Watershed, which is in a hydrologically well-connected surface water and groundwater system. Management of surface and groundwater resources and base operations have impacts on creeks, groundwater, and communities in jurisdictions of unincorporated Pierce County, as well as Tacoma, Lakewood, Roy, DuPont, and Steilacoom.

PFAS (per- and polyfluoroalkyl substances) are widely used, long-lasting chemicals, components of which break down very slowly over time. Scientific studies have shown that exposure to some PFAS in the environment may be linked to harmful health effects in humans and animals.

Most recently, the emergency culvert replacements to a re-designed bridge under the McChord airfield on JBLM diverted a portion of Clover Creek on the base and carried out dewatering along the section of the creek during construction. The construction affected the stream flow downstream and off the base to the west and may have drained some areas upstream and off the base to the east.

Historical operational practices on base, such as using perfluoroalky and polyfluoroalkyl substances (PFAs) for fire suppression at the airfield have polluted nearby creeks in the past and has led to groundwater contamination off the base that still persists today. This affects local water purveyors and consumers.

A better understanding of groundwater levels and quality in this highly permeable system is needed to address known water quality and quantity issues in Section 303d stream reaches and nearby Spanaway Lake. Since much of this land mass in the area is within federal jurisdiction, it is important to continue to work with JBLM to have a coordinated approach to future issues as they arise.

4.4.4 Tribal Coordination

Tribal coordination has been essential during the development of this 2023 Flood Plan. In 2019, prior to developing the outline for this plan, Pierce County Surface Water Management (SWM) held a meeting with Puyallup Tribe of Indians (Puyallup Tribe) and Muckleshoot Indian Tribe (Muckleshoot Tribe) fisheries staff to scope the plan outline. During that meeting, SWM staff were able to collect suggestions from the Tribes on ways to improve the Flood Plan. Since the 2023 Flood Plan kickoff, the Puyallup Tribe, Muckleshoot Tribe, Nisqually Indian Tribe, and Squaxin Island Tribe have been active participants in the Flood Plan Advisory Committee and/or the DTG meetings.

Ongoing coordination between Pierce County and the Tribes will continue in order to minimize the likelihood of impacts of flood hazard management projects on cultural and historic resources, habitat, and treaty fishing rights. Tribal cultural and fisheries staff are consistently consulted both formally and informally in the development of capital improvement projects, plans, and studies. As mentioned earlier, the Puyallup Tribe and the Muckleshoot Tribe participate in the Floodplains for the Future group that collaborates on projects along the Puyallup, White, and Carbon rivers. Currently, the Puyallup Tribe is a partner on projects such as the thermal refugia project on South Prairie Creek in collaboration with the South Puget Sound Salmon Enhancement Group; the Clear Creek Habitat restoration project in collaboration with Pierce County (Clear Creek Habitat Restoration), and Swan Creek Channel Restoration at 64th Street project, which is also in coordination with Pierce County (Swan Creek Channel Restoration at 64th Street). Partnerships like these are key in assisting Pierce County achieve long-term habitat improvements through improved flood risk reduction and mitigation efforts.

When the Pierce County Flood Control Zone District (FCZD) was created in 2012, the Pierce County Council also created a 15-member countywide advisory committee. This advisory committee provides policy advice to the FCZD Board of Supervisors and recommends an annual capital budget for the district. Chapter 11.06.030C (Ch. 11.06 Pierce County Flood Control Zone District) in the Pierce County Code outlines the specific locations and/or organizations the 15 members should represent on the advisory committee. According to county code, the Puyallup Tribe or a representative from either a recognized organization representing agriculture and/or forestry interests would have a seat on the advisory committee. Since this code went into effect in 2012, the Puyallup Tribe has had held that position on the advisory committee. Having the Puyallup Tribe serve on this committee has allowed for continued coordination between the county and the Tribe while constructing, operating, and maintaining flood control projects in the county. For additional information on the Pierce County Flood Control Zone District, visit Pierce County Flood Zone District, WA.

5 Programmatic Recommendations

This chapter focuses on programmatic recommendations and non-structural actions to increase understanding of flood risks in Pierce County, encourage partnerships with other agencies, and improve the services offered by Pierce County to further reduce the associated risks of flooding and channel migration. Once the programmatic recommendations are adopted, they will also provide guidance for how floodplain management is implemented throughout Pierce County over the next 10 years. The programmatic recommendations include a wide array of programs and projects such as environmental justice, hazard mapping, technical assistance, public education and outreach, flood warning and emergency response, and studies such as sediment management in small streams as well as salmon habitat and monitoring.

Each of the programmatic recommendations is presented with supporting information for the recommendation or action. Each programmatic recommendation is listed in a table format that includes timeframe, programmatic recommendation, lead department, and partners. For this flood plan, the timeline is described as follows:

Ongoing: This recommendation is actively being worked on at this time.

Near Term: Completed within a 2-year timeframe

Mid Term: Completed within a 2- to 6-year timeframe

Long Term: Completed within a 10-year timeframe

During the planning process, Pierce County also identified lead departments that would work to accomplish the recommendations/actions and listed partners who could assist with accomplishing the programmatic recommendations.

The costs of implementing the programmatic recommendations vary due to the number of full-time staff to implement a program element; lump sum costs; and whether costs are annual, one-time, or, for example, once every five years or during/following a flood event.

5.1 Environmental Justice

Pierce County Surface Water Management (SWM) Division projects and programs do not affect everyone similarly. By not considering equity, some responses may even lead to unintended disparities in "overburdened communities. " Overburdened communities are those that experience disproportionate environmental harms and risks due to exposures, greater vulnerability to environmental hazards, or cumulative impacts from multiple stressors. One example is the Valley Brook mobile home park, as shown in Figure 5.1. This may relate to impacts to sustainable agriculture, aging infrastructure, affordable housing, water-dependent employment locations, access to resources like public transit, recreation and childcare, and dependence on social networks when relocation is an option or necessity.

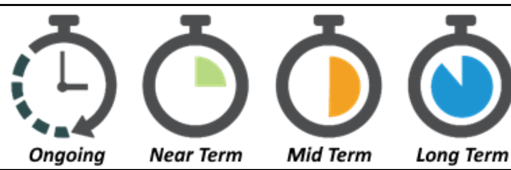
Figure 5.1. Valley Brook Mobile Home Park Flooding in 2009

In 2020, Pierce County partnered with the City of Tacoma and the Tacoma-Pierce County Health Department to implement a countywide Equity Index. This new Equity Index (which combines values for livability, accessibility, education, environmental health, and economy by geographic areas within the county) was launched to the public in 2021.

Pierce County completed a Flood Risk Assessment and Economic Analysis in March 2022. Included in this analysis are the demographic and socioeconomic characteristics of people living within the Pierce County floodplain areas compared to those living outside of the floodplain. The data collected to write this study will assist Pierce County with pursuing the programmatic recommendations listed in Table 5.1.

Table 5.1. Environmental Justice Programmatic Recommendations

Timeline	Action	Lead Department	Partners
	Hire an Environmental Justice consultant to do the following: • Conduct a review of past acquisition projects to identify strategies that effectively address equity concerns.	Planning and Public Works—SWM	Pierce County Planning and Land Services
	Establish an Environmental Justice working group to advance and track the implementation of the listed Programmatic Recommendations.	Planning and Public Works—SWM	
	Implement and create a tool that will help assess progress: e.g., Programmatic, Capital Projects Assessment Schedule.	Planning and Public Works—SWM	Consultant
	Incorporate an equity screening tool into Capital improvement project prospectus phase and evaluate how this tool might fit into the Project Delivery Manual.	Planning and Public Works—SWM	Other Pierce County Public Works departments
	Identify and develop language and culturally appropriate outreach guidelines, methodologies, outreach materials, and literature for capital projects.	Pierce County Communication Department	Pierce County Surface Water Management



(This list is not ranked or prioritized.)

5.2 Floodplain Management

The most effective way to reduce risks and costs associated with flood hazard areas is to minimize incompatible land uses and human activities. In addition to acquisition, capital projects, and other structural solutions, a combination of regulations and programmatic actions also support this goal.

5.2.1 Flood Hazard Areas Regulations

Implementation of flood hazard area regulations are one of the most effective ways to reduce future risks and property losses. The PCC Chapter 18E.70 (Flood Hazard Areas) is a section of the critical areas development regulations that is the primary tool for regulating land use in the floodplain.

The Washington State Growth Management Act (GMA) requires the protection of five types of critical areas: wetlands, critical aquifer recharge areas, frequently flooded areas, geologically hazardous areas, and fish and wildlife conservation areas. Frequently flooded areas as defined by GMA are the same as “flood hazard areas” in the PCC and city municipal codes entitled, for example, “flood damage prevention,” “flood damage protection,” or “flood control.” Flood hazard areas along rivers in Pierce County include floodplains and floodways (Federal Emergency Management Agency [FEMA] regulatory floodway, deep and/or fast flowing water floodway, and channel migration zone floodway).

Pierce County and other jurisdictions use the following FEMA products for determining flood hazard areas:

- FEMA Flood Insurance Rate maps (FIRM)
- FEMA Flood Insurance studies (including preliminary studies)
- FEMA Flood Insurance Rate maps (including preliminary maps)
- FEMA Letter of Map Change

Pierce County uses the best available data sources to determine a flood hazard area, including the following:

- Critical Area reports and maps
- Channel Migration Zone maps and studies
- Deep and/or Fast Flowing Water Floodway maps
- Historical flood hazard information (aerial photos and high-water marks)
- Superior mapping data including light detection and ranging (LiDAR) topography and stream locations
- Site-specific flood studies

A floodway is an extremely hazardous area due to the depth and/or velocity of floodwaters and has severe erosion potential. Washington Administrative Code (WAC) 173-158-070 prohibits the construction of new residential structures or the substantial improvement of existing structures in the floodway. In unincorporated Pierce County, any development encroachment, filling, clearing, grading, new construction, and substantial improvement is prohibited within the floodway. There are a few exceptions in specific circumstances, such as agricultural activities, structures that do not require a building permit and repairs, reconstruction, replacement, and improvements to existing structures that do not have any associated fill and are not substantial improvements (i.e., improvements values are less than 50 percent of the pre-work value calculated over a five-year running period).

The following areas are regulated by Pierce County as floodways:

- **FEMA Floodway:** A FEMA Floodway is defined as the channel of the river or stream and any adjacent land area that will allow floodwaters to pass without increasing the water surface elevation by more than one foot. The state (WAC 173-158) does not allow residential structures or development to occur within a regulated floodway. Additionally, because of the severity of the danger during a flood, as homes become substantially damaged for any reason, they are not allowed to redevelop.
- **Deep and/or Fast Flowing Water Floodway:** As exemplified in Figure 5.2, deep and/or fast-flowing (DFF) water floodway are areas where persons and/or property can be exposed to great risks during the 1 percent annual chance flood. The DFF is defined as water moving at least 3 feet per second or water at least 3feet in depth or a combination of the two, which is plotted in Chapter 18E.120 of the Pierce County Code. The 1988 study on the Downstream Hazard Classification Guidelines (U.S. Department of Interior, Bureau of Reclamations 1988) on dam failures and downstream hazards calculated the depths and velocities that are dangerous to structures and persons trying to walk through the flow. Pierce County selected the DFF water floodway threshold at which it is a life safety threat to children and small adults. The 3 feet of depth and 3 feet of velocity are also referenced in WAC 173-158-76, which establishes minimum criteria for rebuilding residences in a floodway. Pierce County has regulated the DFF water floodway since joining the National Flood Insurance Program (NFIP) in 1987, and the burden of providing the data is placed on the permit applicant. In 2006, Pierce County commissioned the mapping of DFF water floodway using data from detailed flood studies completed by FEMA and the county (2002-2006). The mapping of the DFF water floodway was for 125 river miles on 19 rivers and streams.
- **Channel Migration Zone Floodway:** A channel migration zone (CMZ) floodway occurs only in the areas determined to be a severe channel migration zone risk. A severe channel migration hazard is determined to be areas where erosion can occur in the near future and an area can become part of the river channel. For this reason, severe channel migration areas are regulated under Pierce County's floodway codes. Unlike other types of floodways, the CMZ floodway allows for homes that are beyond the reach of the deep and/or fast-flowing waters or FEMA floodways. No new structures are allowed within a severe channel migration zone once the channel migration zone study for a river reach has been adopted.

Flood hazard regulation programmatic recommendations are listed in Table 5.2.

Figure 5.2. Impacts of Deep and Fast-Flowing Water

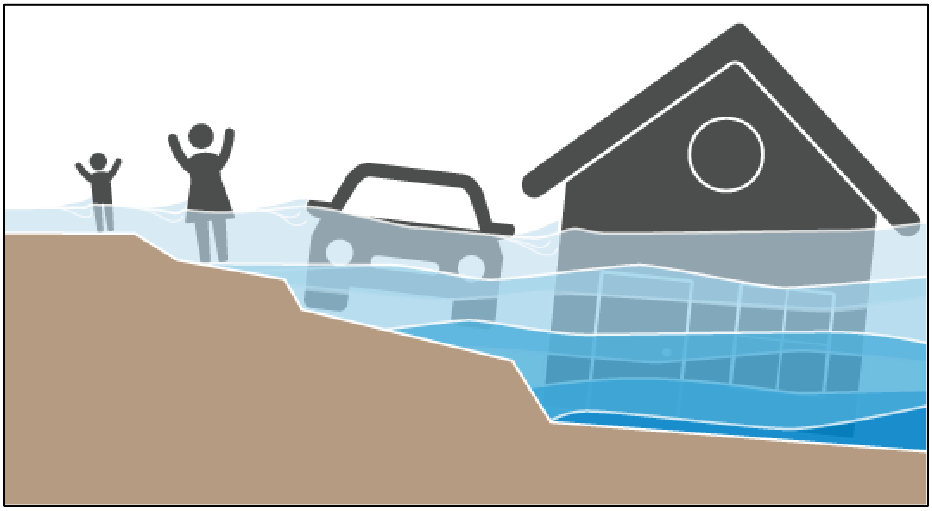
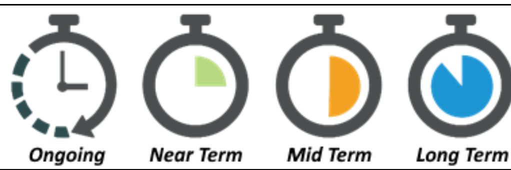


Table 5.2. Flood Hazard Regulation Programmatic Recommendations

Timeline	Action	Lead Department	Partners
	Update the PCC to include additional design guidance for coastal flood structures within the shoreline environment.	Planning and Public Works—SWM	Other Planning and Public Works Departments; Tacoma Pierce County Health Department; Pierce Conservation District



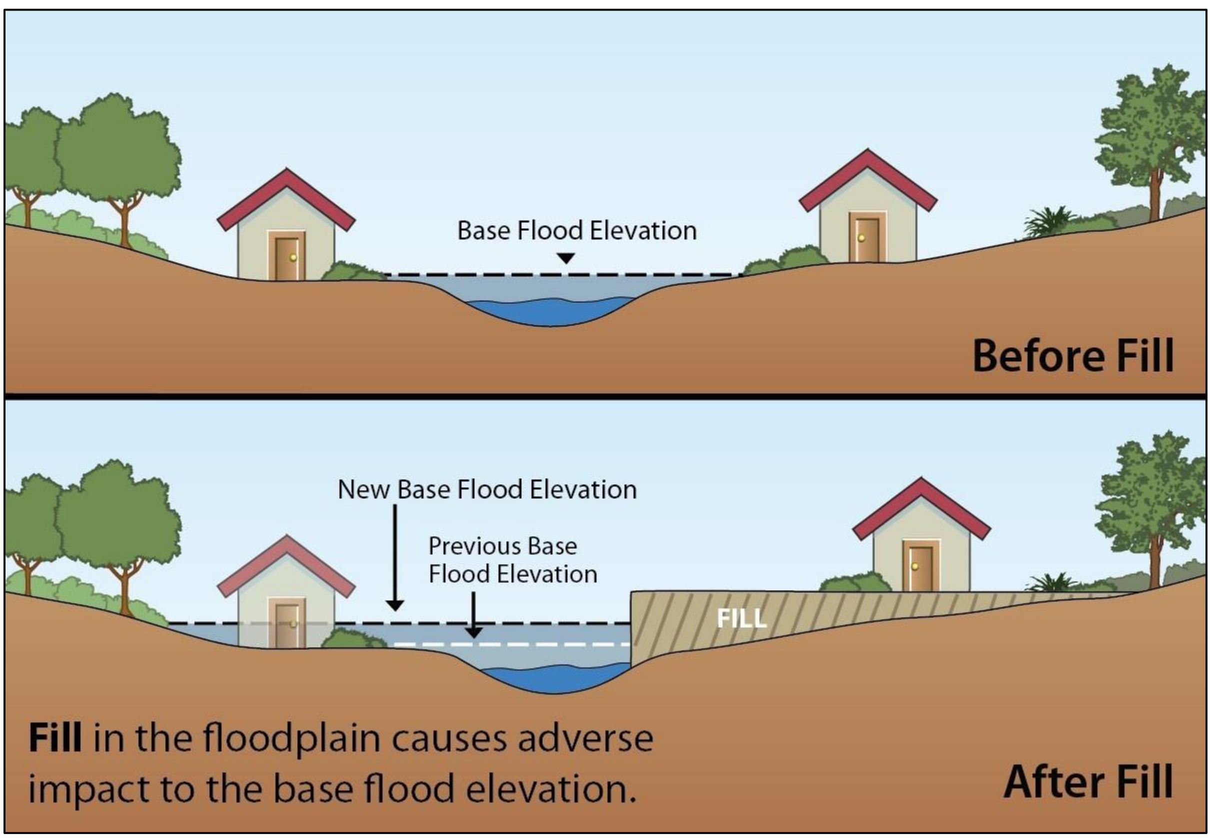
Development in the Floodplain

The standards contained in PCC Chapter 18E.70 (Flood Hazard Areas) provide criteria for regulated activities within flood hazard areas. Regulations are intended to keep people from harm and allow the community to quickly recover from flooding. Development in flood hazard areas is required to be located above the Base Flood Elevation, which is the elevation (to the tenth of a foot) that has a 1 percent chance of flooding each year, or a 26 percent chance of flooding over 30 years. Due to potential inaccuracies in floodplain mapping and the impacts that occur when fill is improperly placed in the floodplain (shown in Figure 5.3), Pierce County requires a site-specific review—and at times a floodplain boundary survey—when any regulated activity is proposed within 150 feet of a mapped flood hazard area. This is intended to ensure that the proposed activity is out of the flood hazard area.

When Pierce County concludes that a proposed project cannot be located outside of a flood hazard area, a zero-rise analysis may be required to determine and ensure that no increase in the base flood elevation or flow conveyance reduction will occur as a result of the development. When development is permitted and designed to achieve the zero-rise standard, it must also meet the following requirements:

- **Compensatory Storage:** New excavated storage volume shall be equivalent to the flood storage capacity eliminated by filling or grading within the flood fringe; equivalent shall mean that the storage removed shall be replaced by equal live storage volume between corresponding one-foot contour intervals that are hydraulically connected to the floodplain through their entire depth.
- **Flow Conveyance:** Post-development conveyance capacity shall be equivalent to existing conveyance capacity.
- **Erosion Protection:** Development shall be protected from flow velocities greater than two feet per second through the use of appropriate bank protection methods determined by an engineering study.
- **Elevation:** When avoidance is not possible, a structure must be elevated above the base flood elevation. Different foundation construction types have different flood risk, so the point of compliance elevation will vary.
- **Critical Facilities** should be located outside of the 500-year floodplain unless there is no feasible alternative. If no feasible alternative exists, the facility must be elevated three feet above the base flood elevation.

Figure 5.3. Improperly Placed Fill in the Floodplain



Development in Coastal Flooding Areas

Pierce County regulates development in coastal flood hazard areas. New development should be located outside of these hazard areas whenever possible. Coastal flood hazard areas are the one hazard that is regulated beyond the base flood elevation; this is an acknowledgement of the greater risks that occur at the shoreline. Other development requirements include the following:

- Unobstructed pier or pile foundations are required on ground below the base flood elevation.
- A structural engineer is required to certify the design, including a scour analysis.
- No construction is allowed beyond the reach of mean tide, approximately 9.5 feet NAVD (North America Vertical Datum).

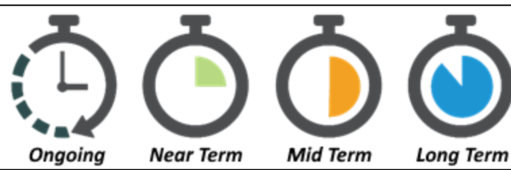
Development in the Groundwater Flooding Areas

Predicting when and where groundwater flooding will occur can be difficult. Groundwater flooding areas have expanded as development has occurred and impacted subsurface conditions. More studies are needed to better understand these impacts. Development in groundwater flooding areas is regulated the same as other non-coastal flood hazard areas. In certain limited situations, the requirement for compensatory storage may be waived.

Table 5.3 presents the county's programmatic recommendations for development in floodplains.

Table 5.3. Development in the Floodplain Programmatic Recommendations

Timeline	Action	Lead Department	Partners
Near Term	Update DFF Floodway on new riverine studies (for Nisqually River and Muck Creek).	Planning and Public Works—SWM	TBD
Near Term	Update coastal flood risk at the parcel scale and for future conditions.	Planning and Public Works—SWM	U.S. Geological Survey (USGS)
Mid Term	Review and update PCC 18E.70 to ensure coastal development is regulated in a similar manner as other flood hazards and seek to avoid development in coastal floodplain when possible.	Planning and Public Works—SWM	Muckleshoot Tribe Puyallup Tribe Nisqually Tribe



Notes:
TBD = to be determined

5.3 Management of Land Use

5.3.1 Consistent Floodplain Development Regulations

Having a set of consistent regulatory standards focused on avoidance of adverse impacts in the floodplain creates a more equitable and resilient community. These standards often consist of the following topics:

- Zero rise (no measurable rise in the base flood elevation)
- Channel migration
- Deep and fast-flowing waters
- Compensatory storage
- Best available data
- Development restrictions (no new subdivisions or lot creation within the floodplain)

Higher regulatory standards for development within the floodplain allows communities to recognize the unique characteristics of floodplains and the inherent risks associated with them. These standards meet or exceed the national standards and allow Pierce County to continue to be in good standing in the NFIP.

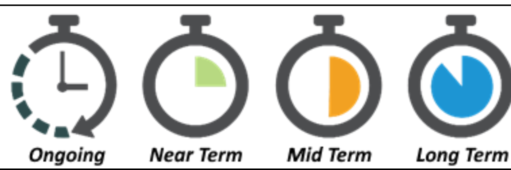
Flood hazard development regulations are the basic regulatory tool to practice sound floodplain management related to development. Currently, individual jurisdictions have different approaches to regulating development in a floodplain. Having consistent regulations in floodplains across jurisdictions results in less confusion and lower flood risk for all development in a floodplain. In keeping with a principal goal of reducing risks in floodplains, communities within Pierce County have agreed to establish a working group to discuss floodplain regulations. This group would work toward establishing consistent floodplain regulations throughout the county. For more information on this working group and other programmatic recommendations the cities within Pierce County have developed, please see Appendix E.

Federal requirements are primarily found in 44 Code of Federal Regulations (CFR) 59, 60, and 65 and meet the Endangered Species Act (ESA) requirement as defined in the National Marine Fisheries Service 2008 Biological Opinion. State floodplain management regulations are primarily found in WAC 173.158, but there are other additional state rules that may affect development in the floodplain, such as restricting expansion of an Urban Growth Area (UGA) into the floodplain (Revised Code of Washington [RCW] 36.70A.110.8), Sediment Dredging (RCW 77.55.271), Shoreline Management (WAC 173.18), and Clean Water Act through the National Pollutant Discharge and Elimination System (NPDES) permit (phase I and phase II).

Table 5.4 presents the county's programmatic recommendations for floodplain development regulations.

Table 5.4. Consistent Floodplain Development Regulations Programmatic Recommendations

Timeline	Action	Lead Department	Partners
	A regulatory working group should be established to support development of more consistent regulations across jurisdictions and to meet the goals and objectives of this 2023 Flood Plan. The group should promote a regional discussion about residual flood risks.	Planning and Public Works—SWM	Cities and Special Districts in Pierce County
	Pierce County will provide technical assistance to cities and towns within the 2023 Flood Plan planning area in support of aligning their flood hazard regulations with unincorporated Pierce County critical area regulations for flood hazard areas.	Planning and Public Works—SWM	Pierce County cities
	Develop a zoning map overlay that consistently supports the goals of the 2023 Flood Plan.	Pierce County Planning	Pierce County SWM, Cities and Special Districts within the county
	Cities and towns in the 2023 Flood Plan planning area should adopt policies and regulations that are consistent with unincorporated Pierce County critical area regulations for flood hazard areas, including regulating based on the best available data, such as updated flood studies. Regulations should address development in the floodway, zero-rise, compensatory storage, and critical facilities. Other important considerations include locating development out of the floodplain as feasible, elevating above the base flood elevation, substantial damage limits and improvement calculations, and non-residential flood-proofing.	Planning and Public Works—SWM	Cities and Special Districts in Pierce County



5.4 Urban Growth

The floodplains of Pierce County's major rivers have a high probability of flooding, which results in risks to public safety and property damage. If currently zoned resource lands, public facilities, or open space areas located in the 100-year floodplain are converted to more urban land uses, more people and property associated with higher density land uses will be put at risk. This recommendation proposes limitations on expansion of UGAs into river floodplains in the study area of the 2013 Pierce County Rivers Flood Hazard Management Plan. The RCW 36.70A.110 established the threshold of 1,000 cubic feet per second (cfs) mean annual flow, and several rivers and reaches in the plan are below this threshold.

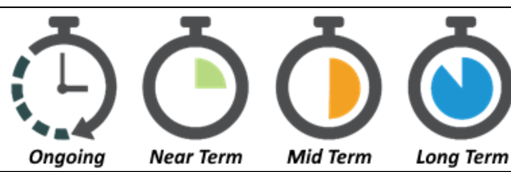
Effective June 2010, Chapter 19A.30.010 (Comprehensive Plan – Urban Growth Areas) of the PCC was amended to prohibit the expansion of the UGA into the 100-year floodplains of rivers or river segments above 1,000 cfs of mean annual flow. In Pierce County (in accordance with the Washington State Department of Ecology) this includes (1) the Puyallup River below the confluence with the Carbon River, (2) the Nisqually River below the confluence with Mineral Creek, and (3) the White River below the confluence with the Greenwater River. However, significant floodplains included in this plan are not covered. The UGAs along the Carbon River, Greenwater River, Mashel River, Nisqually River, South Prairie Creek, and the upper Puyallup River could be expanded, or new urban growth areas could be created in the floodplain without this change.

5.4.1 Comprehensive Plan – Periodic Update

As part of the periodic review of the Pierce County Comprehensive Plan, the GMA requires that the policies and regulations of the county are in alignment with the best available science for frequently flooded areas and are in compliance with RCW 36.70A.110. Pierce County has hired a team of experts to help determine the best available science for critical areas. Based on their findings, the county will update the policies and rules as necessary. Table 5.5 presents the programmatic recommendations for the comprehensive plan with regards to floodplain management.

Table 5.5. Comprehensive Plan Programmatic Recommendations

Timeline	Action	Lead Department	Partners
	Update comprehensive plans, policies and PCC to require the use of best available science in floodplain management.	Long Range Planning	Pierce County SWM



5.5 Flood Information/Mapping/Technical Assistance

5.5.1 Reduce Impacts from Flooding

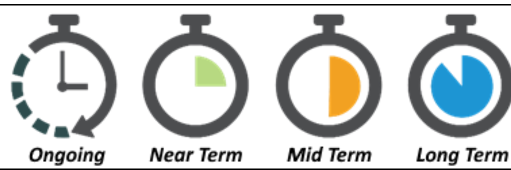
Riverine Flooding

River flooding happens when rivers are filled above their capacity from excessive rainfall and snowmelt, which causes rivers to overflow their banks. River flooding is exacerbated by sediment and debris loads transported down the river. Higher flows typically result in more sediment and debris being moved through the river system. When transported and deposited, sediment and debris reduce the carrying capacity of a river channel, thus resulting in an increased risk of flooding, which is a natural phenomenon. However, flood damage is a result of structures built in the floodplain.

In the early 2000s, Pierce County worked with FEMA as a Cooperating Technical Partner to update the 1980s FEMA Flood Insurance Study. This work only covered the major rivers and streams in the UGA, and a large percentage of county rivers and creeks were not studied. Because there have been significant changes in river and creek flows, another update is needed. With more comprehensive topography data based on LiDAR studies since then, it is evident that the flood hazards drawn in the rural areas with 5-foot contours do not accurately reflect flood risk at the parcel level. These areas should be redrawn and updated on the FIRM. In 2019, FEMA completed a levee analysis and mapping approach (LAMP) report of the Puyallup River near Orting. This study should be shown on the FIRM and the companion LAMP for the Carbon River near Orting should be completed and mapped. The DFF Floodway is based on the 2002–2006 flood mapping and 2004 LiDAR; because these source data sets are updated, the DFF Floodway should also be updated. Table 5.6 presents the county's programmatic recommendations for riverine flooding.

Table 5.6. Riverine Flooding Programmatic Recommendations

Timeline	Action	Lead Department	Partners
Mid Term	Remodel and remap the floodplain to be used as best available science.	Planning and Public Works—SWM	FEMA
Mid Term	Update the DFF water floodway mapping to be used as best available science.	Planning and Public Works—SWM	TBD
Mid Term	Rectify the flood maps to reflect current topography of the floodplain to more accurately reflect the actual flood hazards.	Planning and Public Works—SWM	TBD
Long Term	Map new streams/creeks that were not mapped before, e.g., Lacamas, Horn, Brighton, and Voight.	Planning and Public Works—SWM	TBD



Notes:
TBD = to be determined

Urban Flooding

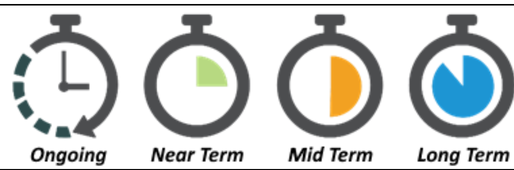
Urban flooding happens when intense rainfall overwhelms the capacity of streams and stormwater systems ability to accommodate the stormwater. Street intersections, low-lying bowl-shaped areas, and lands adjacent to natural wetlands and streams are the most likely areas to be inundated by urban flood waters.

Localized urban flooding does not typically result in widespread structural damages but does result in a disruption of peoples' daily activities, transportation, and commerce. Urban flooding can also result in measurable environmental degradation of water quality and natural systems that support fish and wildlife. Large-scale urbanized flooding risk is highest within the valley floodplain, associated with the Puyallup River system and Nisqually River system.

Efforts to manage urban flooding in Pierce County has evolved with urbanization, mostly over the last 50+ years. Most of what was once a rural undeveloped landscape of forests and farmlands, served by localized rural roadways, has been consumed by urban and suburban-level development with limited stormwater controls to manage the rain runoff. Infrastructure systems within Pierce County are typically designed to carry water for a 25-year event. As hydrology changes and more data are collected, the understanding of what the magnitude of a 25-year event is will also change. In the future, existing infrastructure may not be adequate.

Today, urban infill development is challenged with a patchwork of stormwater control systems and reduced natural areas to contain the stormwater, resulting in urban flooding impacts to roadways, homes, and fish habitat. Table 5.7 lists the programmatic recommendations to address urban flooding in Pierce County.

Table 5.7. Urban Flooding Programmatic Recommendations

Timeline	Action	Lead Department	Partners
	Develop urban flood hazard working group with the cities to solve urban flooding throughout Pierce County.	Planning and Public Works—SWM	Cities in Pierce County; Pierce County Department of Emergency Management
	Reassess regional county ponds – current and future capacity and treatment.	Planning and Public Works—SWM	Pierce County Engineering Services
	Develop resident assistance program for private drainage and flooding issues.	Planning and Public Works—SWM and Maintenance and Operations	Pierce County Human Services
 	Expand network analysis program to the remainder of the Water Resource Inventory Areas 10/12.	Planning and Public Works—SWM	Cities in Pierce County
@			

Coastal Flooding

Coastal flooding is defined as damaging impacts associated with marine waters. In Pierce County, this means Puget Sound shorelines. Coastal floods are caused by extreme sea levels, which arise as combinations of four main factors: waves, King Tides, storm surges, and relative mean sea level. Each of these four components of sea level exhibits considerable natural variability, which influences the frequency of flooding on inter-annual and multi-decadal time scales and makes isolating changes due to climate change difficult.

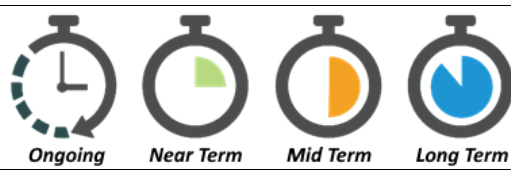
Pierce County has 223 miles of marine shoreline. The effects of coastal flooding can occur during high tide events and storm events. High tide events are predictable and occur over a three to five day period, usually twice a year. Each event can last from two to four hours. However, sea level rise predictions indicate that these events are expected to become more severe over time. Tidal events can aggravate stream, river, and upland flooding by backing up water into those channels and into nearshore drainage pipes and infrastructure. Likewise, wind events can increase the impacts from wave action and exacerbate damage from high tide events, which is often referred to as "storm surge."

There are several features of coastal flooding that differ from riverine flooding. Development along coastlines is often concentrated. Development types include parcels that are small in size and of relatively high monetary value, as well as large regionally significant and water-dependent industrial uses such as the Port of Tacoma. Shoreline flood control structures need to be designed for both drainage and backwater effects. They also need to tolerate saltwater and wave action. Another feature of coastal areas is the potential for slope failures. High tides and storm surge can weaken the toes of slopes, while stormwater infiltration, on-site sewage systems, and irrigation systems can destabilize slopes from above. Poorly designed and maintained stormwater conveyance systems can cause slopes to incise or scour at their outlets. Additionally, buildings were historically constructed close the shoreline and vegetation removed to provide for views. These practices allowed for little flexibility in accommodating natural processes and little room for engineered solutions, and projects costs were and remain typically higher than in other locations. For these reasons, coastal flooding requires different approaches than other types of flooding.

Table 5.8 presents programmatic recommendations to address coastal flooding in Pierce County.

Table 5.8. Coastal Flooding Programmatic Recommendations

Timeline	Action	Lead Department	Partners
	Conduct a Sea Level Rise Risk Assessment for coastal areas.	Planning and Public Works	TBD
	Prepare and publicize maps showing predicted coastal flood hazard areas.	Planning and Public Works—SWM	USGS
	For coastal properties that are prone to unsafe conditions due to flooding or slope failure, expand existing funding sources to either acquire, elevate, or flood-proof flood prone properties.	Planning and Public Works—SWM	TBD
	Map, monitor, and analyze coastal flood events.	Planning and Public Works—SWM	TBD
	Survey coastal property owners about preferred level of service/information gathering.	Planning and Public Works—SWM	TBD
	Establish coastal hazard working group to continue solving coastal flooding issues as they relate to zoning and land use. • Develop a Coastal Flooding Response Plan. • Develop coastal structure elevation initiative. • Develop a retrofit plan for public infrastructure in coastal flood hazard areas.	Planning and Public Works—SWM, Planning and Public Works	Cities, Special Districts, Puyallup Tribe, Muckleshoot Tribe, Nisqually Tribe, Squaxin Island Tribe
	Educate and provide technical assistance to nearshore property owners, builders, landscapers, and real estate professionals on vegetation management, erosion control, slope stabilization, ESA compliance, septic systems, and stormwater management.	Planning and Public Works division	Tacoma Pierce County Health Department; Pierce Conservation District



Notes:

TBD = to be determined

Groundwater Flooding

Groundwater flooding occurs when the soil's inability to accept rainfall causes the water table to rise and persist above the ground surface. Groundwater flood risk management poses a unique set of technical and environmental problems that differentiate it from other types of flooding (e.g., riverine and coastal). Groundwater flooding does not typically occur after short, intense storms, which sometimes causes flooding in smaller streams and rivers. Instead, it is often the accumulation of continuous rainfall over a period of weeks or months that determines the severity and duration of groundwater flooding when it occurs. This condition can create a significant hazard for many communities and neighborhoods, and its increased frequency in recent years has increased the county's commitment to reducing its impacts through better planning and an enhanced ability to forecast this condition before it occurs.

Groundwater flooding in Pierce County can be thought of as the surface-breaching manifestation of a shallow aquifer toward the end of a wetter than normal winter. There are significant areas in Pierce County that are impacted by this seasonal phenomenon; these areas are often dominated by glacial outwash soils, which are very porous and have a high capacity to infiltrate water. These types of soils occur around Graham, Frederickson, and throughout significant parts of the Clover Creek watershed.

Some depressional areas and potholes flood on an annual basis due to normal winter rainfall and the shallow, subsurface perching of a seasonally high groundwater table. During prolonged rainfall, the underlying soils are often unable to drain quickly enough to prevent the aboveground flooding of low-lying topographic areas. The magnitude and duration of this type of flooding can last several weeks before the water table finally drains and retreats below the ground surface. The best management options under these circumstances are to avoid and minimize to the greatest extent possible because typical flood control remedies offer little relief. Groundwater flooding can create major impacts on the transportation corridors that experience this condition for an extended period of time. This type of flooding also creates a nuisance in subsurface structures such as basements and the surrounding foundations of houses or buildings.

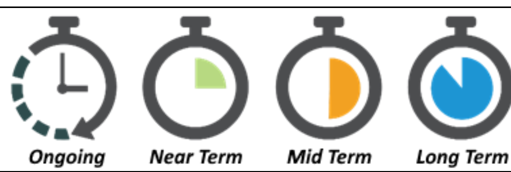
Pothole

In this context, a pothole is a sizable rounded, often water-filled depression in land.

Table 5.9 presents programmatic recommendations to address groundwater flooding.

Table 5.9. Groundwater Flooding Programmatic Recommendations

Timeline	Action	Lead Department	Partners
	Conduct a groundwater study to map, monitor, and analyze groundwater flood locations, soil capacity, and historical groundwater flood events.	Planning and Public Works—SWM	City of Lakewood, and Joint Base Lewis McChord; Tacoma Pierce County Health Department
	Continue education and outreach efforts that specifically target groundwater issues.	Planning and Public Works—SWM	USGS, Pierce County Communications
	Develop guidance for groundwater flood locations for future development building.	Planning and Public Works—SWM	Pierce Conservation District, USGS, Natural Resources Conservation Service, Port of Tacoma, Pierce County Land Use and Environmental Review
	Create an early warning sentinel well program to alert public to potential groundwater flooding.	Planning and Public Works—SWM	USGS, Pierce County cities and towns, Pierce County Department of Emergency Management, Water Purveyors, Port of Tacoma, Joint Base Lewis McChord
	Expand the existing Surface Water Management acquisition program to include structures impacted by groundwater flooding.	Planning and Public Works—SWM	TBD
	Revisit groundwater flooding model.	Planning and Public Works—SWM	USGS, Cities and Towns, Pierce County Department of Emergency Management, Water Purveyors, Port of Tacoma, Joint Base Lewis McChord
	Establish groundwater working group to continue understanding of groundwater flooding issues.	Planning and Public Works—SWM	Department of Ecology, Thurston County, City of Lakewood, USGS



Notes:

TBD = to be determined

5.5.2 Mapping

Floodplain and Hazard Mapping

Flood hazard studies and associated mapping provide critical baseline information for flood hazard management and flood risk reduction planning in Pierce County. Modeling of watershed hydrology and river channel hydraulics are essential first steps in characterizing river channel conditions, delineating flood hazard areas, and developing floodplain maps. This information is then used to develop floodplain management tools to manage flood risk. The tools may be used to inform land use decisions, create regulations to guide existing and proposed floodplain development, and to evaluate and design flood hazard management projects.

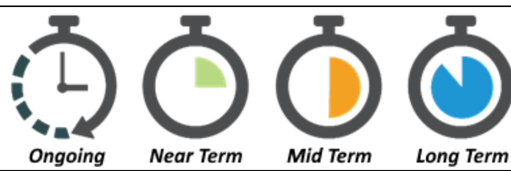
Knowledge of flood hazard and channel migration risks is critical for landowners and property developers to make informed decisions about new construction or re-construction. In addition, local jurisdictions and other agencies with infrastructure need better information to make informed decisions. Therefore, the need to maintain and manage current technical data is an important factor in managing risks associated with county floodplains.

Pierce County obtained current flood hazard maps in the early 2000s, but much of the county has not been studied or updated since the 1970s. As urban development has increased, mapping will need to be continually reassessed and updated.

Table 5.10 presents programmatic recommendations for floodplain and hazard mapping.

Table 5.10. Floodplain and Hazard Mapping Programmatic Recommendations

Timeline	Action	Lead Department	Partners
	FEMA and Pierce County should update flood studies and floodplain maps for the lower and upper White and Greenwater Rivers.	FEMA	Pierce County SWM
	Conduct a detailed flood study on the Greenwater River to include DFF mapping.	FEMA	Pierce County SWM
	When Pierce County updates this Comprehensive Flood Hazard Management Plan, the floodplain mapping should be evaluated and updated as needed.	Planning and Public Works—SWM	FEMA



Channel Migration Zone Mapping

Channel migration zone studies and maps provide critical baseline information necessary to understand the effects of potential river migration on hazards in river valleys and their associated floodplains. While most of the major rivers in Pierce County are confined by levees and revetments, there are many river reaches that are still subject to potential channel migration. Levees or revetments on major rivers continue to be damaged by erosion associated with channel migration. Because of the risks to public safety and the high cost associated with construction and maintenance of flood risk reduction facilities, the county's approach in severe channel migration hazard areas is to restrict development. Channel migration hazard mapping and the adoption of land use regulations to prevent development in these areas aids in the reduction of risks associated with migrating river channels and can lead to improved environmental health.

Channel Migration Zones

Channel migration zones are areas in a floodplain where a stream or river channel can be expected to move naturally over time in response to gravity and topography. In addition, geology can affect how susceptible the floodplain is to erosion. Rivers in Pierce County are geologically young, carry a high sediment load, and have short and steep courses. These factors increase the potential erosion that leads to the river changing location. Channel migration is not necessarily tied to a flood event. While high flows have a greater risk of avulsion (the sudden separation of land from one property and its attachment to another, especially by flooding or a change in the course of a river) with the added stream power, erosion occurs every day.

Pierce County has used many methods to mitigate for channel migration risks over the last 100 years. Early in the twentieth century, the county actively removed wood and sediment from the floodplain with the hope that the river would flow in an orderly manner. The removal actions were supported with low levees and wood fencing built to encourage the river to a designated flow path but not to contain a large flood. The actions by the county tend to encourage greater development behind these new structures, where people had a perceived level of protection that exceeded the design. Flood insurance is an economic mitigation tool to help recover after damage occurs. Channel migration-incurred damages are not always covered by flood insurance because erosion can occur without the river overflowing its channel. Since the 1990 Flood Plan, the county's preferred mitigation strategy has been non-structural solutions.

Channel Migration Zone Studies in Pierce County

To address concerns about channel migration, geomorphic evaluations, and channel migration zone analyses, and CMZ mapping has been carried out on all six of the major riverine systems with upland risk. The Mashel River is primarily in a canyon in the unincorporated part of the county, so the erosion hazard has not been mapped. Mapped reach areas are as follows:

- Puyallup River from river mile (RM) 10.0 to RM 28.8
- White River from RM 0.0 to RM 5.5 and RM 46 to RM 52

- Carbon River from RM 0.0 to RM 8.3
- South Prairie Creek from RM 0.0 to RM 5.8
- Upper Nisqually River from about RM 50.5 to RM 68.6
- Greenwater River from RM 0.0 to RM 2.4

The CMZ reports have identified severe, moderate, and low channel migration potential . The approach to identifying the channel migration zone potential areas (severe, moderate, and low) involve four major elements: (1) data collection and review, (2) geographic information system (GIS) data preparation, (3) geomorphic evaluation, and (4) migration potential delineation. In preparing these studies and maps, Pierce County used information on historical channel locations (primarily aerial photography), geology, basin hydrology, current channel conditions, sediment transport, composition of bank and bed material, potential avulsion sites, and channel migration rates to characterize the channel migration zones.

The CMZ maps for the Puyallup, White, and Carbon Rivers were completed and accepted in 2003 and adopted by the Pierce County Council in 2005. The CMZ maps in South Prairie Creek and upper Nisqually River were completed and accepted in 2005 and 2007 and adopted in 2017. The upper White and Greenwater Rivers were completed and accepted in 2019-2020 and adopted in 2021. For additional information on these CMZ studies, which are listed in Table 5.11, please refer to the Pierce County Channel Migration Zone (CMZ) website. The programmatic recommendations for CMZs in the county are provided in.

Table 5.11. Channel Migration Zone Studies

Study – Reach	Completed	Adopted	Reference Documents
Puyallup-Carbon-Lower White	2003	2005	Puyallup-Carbon-Lower White
South Prairie Creek	2005	2017	South Prairie Creek
Upper Nisqually	2007	2017	Upper Nisqually
Greenwater	2019	2021	Greenwater River
Upper White	2020	2021	River Channel Migration Zone

Table 5.12. Channel Migration Zone Programmatic Recommendations

Timeline	Action	Lead Department	Partners
	Pierce County should pursue a mechanism for notifying existing and potential future property owners about channel migration hazards.	Planning and Public Works—SWM	TBD
	Develop a policy for accepting levees/revetments constructed by others and proposed work on flood risk reduction facilities.	Planning and Public Works—SWM	Pierce County Office of the County Engineer, Pierce County Maintenance and Operations, U.S. Army Corps of Engineers, Muckleshoot Tribe and the Puyallup Tribe of Indians
	Pierce County should develop river reach-specific design standards and evaluate existing levees and revetments to assess the level of resistance the facility provides against rivers processes.	Planning and Public Works—SWM, Maintenance and Operations	TBD
	CMZ mapping should be revised on a 20-year timeframe to reflect significant changes in risks as they are identified. Changes in risk could include decreased risk based on an evaluation of a levee or revetment that limits channel migration or an increased risk based on new geomorphic or geological information that was not known at the time of the original study.	Planning and Public Works—SWM	TBD

Notes:

TBD = to be determined

Current and Recent Mapping Efforts

The FEMA remapping of the Nisqually River watershed is anticipated to be completed prior to the adoption of this 2023 Flood Plan. The lower/mid Nisqually is being modeled to allow for mapping as a Zone AE with a FEMA defined floodway. The upper Nisqually watershed is being mapped with base engineering methods that will show the area as a Zone A with no base flood elevation (BFE)s listed, but there will be a work map that shows an approximate BFE that will be used to draw the flood zone boundary and can be used to meet regulatory needs. The area from Kernahan Bridge to Mount Rainier National Park is not being restudied and will remain an unstudied Zone A. The Nisqually River FEMA mapping is expected to be effective in early 2023. FEMA is also updating Muck and South Creek with detailed and base engineering studies; that map revision should be effective in late 2023 or in 2024.

Zone AE

AE zones are areas inundated by the 1 percent annual chance flood, including areas with the 2 \ percent wave runup, elevation less than 3 feet above the ground, and areas with wave heights less than 3 feet.

The new Nisqually River flood study by FEMA is showing the 1996 flood of record to be less than the 1 percent-annual-chance flood. The model does not show the Tacoma Public Utilities (TPU)-owned dams as flood control facilities. This assumption is confirmed by the response in 1996 and the recently updated Federal Energy Regulatory Commission license. The 1 percent annual chance flood discharge at the McKenna river gauge is now set at 52,000 cfs, whereas the 1996 flood was estimated to be 50,000 cfs.

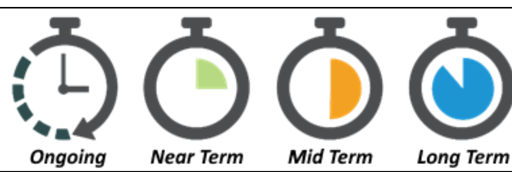
Zone A

Zone A areas have a 1 percent annual chance of flooding; such a flood is also called the 100-year flood.

Table 5.13 presents the programmatic recommendations for FEMA mapping for Pierce County river basins.

Table 5.13. FEMA Mapping Programmatic Recommendations

Timeline	Action	Lead Department	Partners
	FEMA and Pierce County should update flood studies and floodplain maps for the Nisqually River.	FEMA	Pierce County SWM
	Develop grant applications for the Cooperating Technical Partners grant for technical studies to convert unstudied flood hazard areas to Special Flood Hazard Areas.	Planning and Public Works—SWM	FEMA



Levee Analysis and Mapping Procedures

Levee Analysis and Mapping Procedures (LAMP) for Non-Accredited Levee Systems is FEMA's analysis and mapping procedures for showing risk behind non-accredited levees FIRMs. The areas behind levees that meet 44 CFR 65.10 are mapped as having a lower risk of flooding. In locations where a levee has little or no impact in a large flood, the area is mapped as if the levee is not there. Along the lower Puyallup River where there are significant levees, neither of these mapping options tell a complete story of risk. With LAMP, FEMA and the communities can assess the optimal risk analysis for an individual levee. There are five main approaches:

- Natural valley
- Sound reach
- Freeboard deficient
- Overtopping
- Structural-based inundation

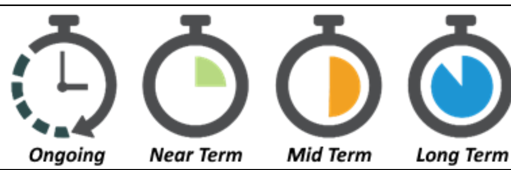
> **Freeboard**
>
> **Freeboard is the added capacity above the design flood to account for dynamic variables and uncertainties. Freeboard is typically reported as additional elevation above expected water surface elevation.**

All areas that were "secluded" in the 2017 issue of the FIRMs will need their own individual LAMP process. At the time this 2023 Flood Plan was prepared, only the Orting reach of the Puyallup River had been studied. The Orting reach of the Carbon River is the next planned mapping effort and upon completion, the FIRMs will be updated. There are currently no plans to restudy the lower Puyallup River levees. For additional information on the FEMA LAMP process, visit the FEMA Local Level Partnership Team website.https://www.starr-team.com/starr/RegionalWorkspaces/RegionX/Documents/archive/LAMP Final Approach Document/FactSheet_LLPT.PDF

Table 5.14 shows the programmatic recommendation for related to the LAMP process.

Table 5.14. LAMP Programmatic Recommendations

Timeline	Action	Lead Department	Partners
	Complete the LAMP process with FEMA for the Puyallup and Carbon Rivers.	FEMA	Pierce County, City of Orting



5.5.3 Technical Assistance

Knowledge of flood hazard and channel migration risks is critical for landowners and property developers to make informed decisions about new construction. In addition, local jurisdictions and other agencies with infrastructure need better information to make informed decisions.

Without technical assistance, there is a higher risk of decisions being made without updated or complete information.

Floodplain Technical Assistance and Consultation

Pierce County SWM can help public and private entities make informed land use decisions to reduce flood- and channel migration zone-related risks with a range of technical assistance and consultation. This includes sharing expertise in hazard identification techniques; interpreting flood hazard data, maps, and regulations; and by reviewing and coordinating planning and design efforts that are adversely affected by flood hazard areas.

Pierce County has worked closely with FEMA, the United States Geological Survey (USGS), and consultants to expand the coverage and improve the accuracy of flood- and CMZ-related studies and maps that delineate flood hazards and CMZs along the major rivers in Pierce County. Sharing this knowledge with other jurisdictions in Pierce County, agencies, Tribes, and private individuals can reduce the public cost of flooding and CMZ impacts and improve the consistency in the management of flood hazards. Completed and published flood and CMZ studies and maps are located at Pierce County SWM and on the Pierce County Surface Water Management website.

Review and Coordination in Flood Hazard Areas and Multiple Beneficial Uses

Functioning river and floodplain systems provide vital ecosystem services and values to society, including but not limited to recreational opportunities, clean water, wildlife habitat, scenic values, and clean air. Portions of Pierce County's rivers and floodplains also support a variety of land uses and human activities with varying degrees of compatibility and associated risks. For example, roads and bridges are often unavoidably located within flood hazard areas. Residential, commercial, and industrial developments historically occurred in flood hazard areas, particularly in the lower Puyallup River, lower White River, and Orting areas. Agricultural uses, open space, and trail corridors are also common in floodplain valleys and along rivers. In the absence of human activities and land uses, rivers and floodplains support habitat-forming processes for aquatic and terrestrial fish and wildlife, some of which are protected by state and federal endangered species legal mandates.

To minimize impacts from human activities and land uses to the natural functions of rivers and floodplains, it is often desirable to consult with local officials to coordinate in decisions related to zoning and planning. This ensures that public safety is achieved and beneficial public uses and values are preserved to the greatest extent possible for current and future generations.

Roads, Bridges and Railways

Many state highways and some arterials cross or parallel rivers in floodplain valleys. Sometimes roads and railways are built atop river levees, such as along River Road and North Levee Road adjacent to the lower Puyallup River. In other cases, roads parallel the rivers, such as Orville Road along the upper Puyallup River. When the roads are built too close to the rivers, the natural process of bank erosion and channel migration can threaten or undermine the road, thus requiring extensive armoring of the stream banks and ongoing maintenance. Where feasible, consideration should be given to setting back the levee or revetment, and in some instances align the road itself, to achieve more conveyance capacity, extend project design life, and improve aquatic and riparian habitat.

Pierce County can provide technical assistance during design for flood conveyance, changes in channel conditions, and bridge clearance requirements. Those who design new or replacement roads, railways and bridges should consider these conditions and look for opportunities to minimize future flooding and channel migration concerns by designing the facilities to accommodate riverine processes. Design of road, railway and bridge projects should be reviewed with these considerations in mind.

Residential, Commercial, and Industrial Development

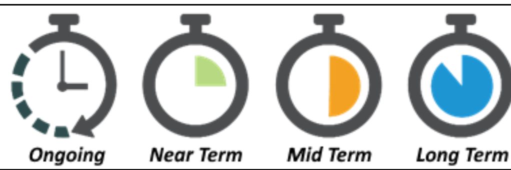
The construction of residential, commercial, and industrial structures in a floodplain puts people and properties at risk during flood events. Many such structures already exist, and new development may occur in floodplains and floodways if allowed by local governments. It is important that new or improved structures be designed to minimize flood risk while protecting other uses of the floodplain. Pierce County provides technical assistance to private property owners which can include review of new development proposals, provision of information about specific flood hazards on private parcels, and guidance or review of private bank stabilization projects.

Programmatic recommendations for technical assistance for reducing flood risks and hazards in Pierce County are presented in Table 5.15.

Table 5.15. Technical Assistance Programmatic Recommendations

Timeline	Action	Lead Department	Partners
	Pierce County SWM should continue a high level of technical training for staff to remain subject matter experts and a regional resource for local communities in flooding and channel migration issues.	Planning and Public Works—SWM	Pierce County Development Engineering Land Use Environmental Review Building Department
	Pierce County SWM will continue to provide information and technical assistance to help public and private entities, and local jurisdictions make project and land use decisions that minimize flood-related risks.	Planning and Public Works—SWM	N/A
	Pierce County SWM will continue to work with those involved in the use and management of agricultural, recreational, and open space lands in floodplains and river corridors to ensure that land uses remain compatible with the natural storage and conveyance of flood waters.	Land Use Environmental Review	Pierce County SWM

Timeline	Action	Lead Department	Partners
	Bridges should be designed with consideration of scour and freeboard above the base flood event. The most current and/or best available data needs to be used including assessments of future peak discharge flows and backwater effects.	Planning and Public Works—SWM	Office of the County of Engineer
	Create a coordination working group within Planning and Public Works to discuss capital planning projects to better meet the priorities of the communities.	Planning and Public Works—SWM	Pierce County Office of the County Engineer, Pierce County Sewers
	Pierce County Surface Water Management will continue to conduct development review for projects within the floodplain to ensure compliance with the NFIP and continued resiliency of our community.	Planning and Public Works—SWM	Pierce County Development Engineering Land Use Environmental Review Building Department
	A cost benefit analysis (CBA) should be conducted for existing roads and bridges with high associated flood and erosion protection costs to determine if other options, including but not limited to, relocation, vacating, or different bridge designs might be a more cost effective and suitable long-term solution. These options could be deemed impracticable due to engineering standards, right-of-way limitations, environmental impacts and/or level of service. If CBA is utilized, considerations should include, but not be limited to, right-of-way acquisition, construction costs, long-term maintenance costs, mitigation costs and habitat benefits, permitting, interruptions of service levels, flood events, planning and acquisition of travel corridors, and transportation needs.	Pierce County – Office of County Engineer	Pierce County SWM



5.6 Flood Insurance

5.6.1 Flood Insurance and the Community Rating System

Standard homeowners or business insurance does not cover flooding. High risk areas for flooding, mapped as the 100-year floodplain, have a one percent annual chance of flooding, equating to a

26 percent chance of flooding over the life of a 30-year mortgage. Other areas may flood more frequently, leading to an even higher risk.

The cost of federal flood insurance and the lack of knowledge about the NFIP may limit some homeowners from purchasing flood insurance. The NFIP's Community Rating System (CRS) program is a voluntary incentive program that recognizes and encourages community floodplain management activities that exceed the minimum NFIP requirements. As a result, flood insurance premium rates are discounted to reflect the reduced flood risk resulting from community actions and activities that are performed each year.

Flood Insurance Utilization

Flood insurance as a means to provide site-specific property protection for at-risk properties is underused within Pierce County. Less than 10 percent of the properties within a FEMA-designated floodplain have a flood insurance policy. This is well below the national average. The lack of public knowledge about flood hazards may result in a lack of understanding of the magnitude of flood risks that an individual property owner faces, thereby limiting participation in the flood insurance program. Greater promotion of the flood insurance program, education about flood risks, and awareness about the flood insurance discounts available in some communities should increase participation. Only three communities in Pierce County (unincorporated Pierce County, the City of Fife, and the City of Orting) participate in the CRS program, which leads to lower flood insurance rates in those communities.

In recent years, there has been an increase in the purchase of flood insurance in mapped 100-year floodplain areas. All homeowners in these areas with mortgages from federally regulated or insured lenders are now required to buy flood insurance. However, this only applies to approved and adopted FEMA maps, which are now over 20 years old (mostly dating to 1987). When the new FEMA maps are approved, substantially more residential and commercial structures will require flood insurance.

FEMA's New Flood Insurance Pricing Methodology

FEMA is updating the NFIP risk rating methodology through the implementation of a new pricing methodology called Risk Rating 2.0 (see https://www.fema.gov/flood-insurance/risk-rating). The methodology leverages industry best practices and cutting-edge technology to enable FEMA to deliver rates that are actuarially sound, equitable, easier to understand, and better reflect the overall flood risk. With Risk Rating 2.0, FEMA now has the capability and tools to address rating disparities by incorporating more flood risk variables. These include flood frequency, multiple flood types—river overflow, storm surge, coastal erosion, and heavy rainfall—and distance to a water source along with property characteristics such as elevation and the cost to rebuild. Currently, policyholders with lower-valued homes are paying more than their share of the risk, while policyholders with higher-valued homes are paying less than their share of the risk. Because Risk Rating 2.0 considers rebuilding costs, FEMA can equitably distribute premiums across all policyholders based on home value and a property's unique flood risk. With the new flood insurance pricing structure, every flood insurance policy gets the full CRS discount, whereas before only policies within the Special Flood Hazard Area received the discount. Pierce County currently is a Class 2 community that receives a 40 percent discount on flood insurance.

Programmatic recommendations related to flood insurance are provided in Table 5.16.

Table 5.16. Flood Insurance Programmatic Recommendations

Timeline	Action	Lead Department	Partners
	Pierce County should participate and maintain good standing in the NFIP to ensure the availability of subsidized flood insurance in their communities.	Planning and Public Works—SWM	N/A
	Pierce County residents and businesses located in the mapped 100-year floodplain should be encouraged to purchase flood insurance through the NFIP.	Planning and Public Works—SWM	N/A
	Pierce County will continue to participate in the NFIP's CRS Program and will strive to continue to be a Class 2 community.	Planning and Public Works—SWM	N/A

Notes:

N/A = not applicable

5.7 Home Buyouts and Property Acquisition

Property acquisition is typically required for capital improvement projects. It is also a risk reduction strategy in its own right. Pierce County's property acquisitions must follow WAC 468-100-101, RCW 8.26.010, and the federal Uniform Relocation Act. These regulations provide minimum standards for projects or assistance programs that require the acquisition of real property or the displacement of persons from their homes, business, or farms. This requires that persons that are displaced are relocated to a dwelling that is decent, safe, and sanitary. It also provides for moving expenses and up to 42 months of rent differential. Properties are acquired for several reasons, listed below:

- **Property acquisitions in support of an active project:** Properties located within a project area are identified and purchased on a willing seller basis first. Funding for these projects is provided through state and federal grants, local fund sources such as the flood control zone district, and county funds.

- **Property acquisitions for future projects:** SWM has a limited budget item for opportunity acquisitions, which allows for the acquisition of properties that are within a future project area. Properties are identified through sales listings or by homeowners reaching out to the county. Currently, the fund balance can only accommodate one to two acquisitions per year.
- **Property acquisitions for flood damaged structures:** Following a flood or other natural disaster, the federal government makes funding available to communities to apply for help to buy homes that have experienced repetitive damages and loss. These funds are provided through a competitive grant process and are on a willing seller basis only.

Pierce County has acquired many repetitive flood loss properties and other flood-prone homes using federal funds, state grants, and local funds as a risk reduction strategy to eliminate repetitive flood damages and to help preserve and restore floodplain areas. Pierce County maintains a list of interested property owners who have expressed interest in selling their property. The interested property owners list is scored, ranked, and prioritized for consideration of potential acquisitions as funding becomes available. Acquisition status of properties on the list of consideration often change, resulting in changes to the priority of any given property.

Acquisition of homes and properties are based on fair market value appraisals prepared by a qualified independent Members Appraisal Institute consulting appraiser. Following acquisition, structures, all utilities, and accessories on site are typically demolished to restore or improve the floodplain's storage/conveyance capacity. When possible, components of acquired structures can be salvaged to provide opportunities for re-use by non-profit community groups interested housing programs.

Especially when acquiring homes that are in the lower side of local housing costs, it can be challenging to find safe, affordable housing within the county where low-income residents can be relocated. Removal of existing affordable housing exacerbates the current affordable housing shortage. Pierce County should develop an affordable housing strategy that accounts for its role in decreasing the availability of affordable housing, even while reducing flood risks to ensure that relocated residents are moved to a safer location where they can afford to continue to live.

Acquisition of undeveloped land in flood hazard areas is another tool that may be used to prevent property development and preserve natural resource values. While floodplain regulations limit and restrict development in flood hazard areas, they often fall short of preventing development from occurring. Property owners seeking to build on their floodplain-encumbered property often consume a significant amount of staff time trying to determine how their building plans and objectives can be accommodated in or near the flood hazard areas. New development in flood hazard areas, while significantly regulated and restricted, may still have costly consequences in terms of public safety and property damage if flood conditions change or new mapping indicates the floodway or flood hazard areas have changed.

Programmatic recommendations for home buyout and property acquisition in Pierce County are presented in Table 5.17.

Table 5.17. Home Buyout and Property Acquisition Programmatic Recommendations

Timeline	Action	Lead Department	Partners
	Pierce County should identify properties that are potential candidates for home buyouts or property acquisition based on flood risk reduction measures and projects. Pierce County should continue to update this list of properties after significant flood or channel migration events occur.	Planning and Public Works—SWM	Office of the County Engineer; Pierce County Parks
	Pierce County and other local governments should continue to seek federal and state grants to assist property owners in flood-prone and repetitive loss areas and to enable buyouts or acquisitions.	Planning and Public Works—SWM	Local governments in Pierce County
	Pierce County should annually budget local funding for immediate floodplain acquisition where properties are put on the market and grants are not likely to be timely.	Planning and Public Works—SWM	Conservation Organizations
	Pierce County should conduct outreach to property owners to inform them about flood risks and potential for buyouts to assess possible interest.	Planning and Public Works—SWM	N/A
	Pierce County should develop an affordable housing strategy for displaced residents due to acquisitions of homes in the floodway	Planning and Public Works—SWM, Planning and Land Services, Human Services, Communications	Cities; Puget Sound Regional Council; Community Land Trusts and affordable housing organizations

Notes:

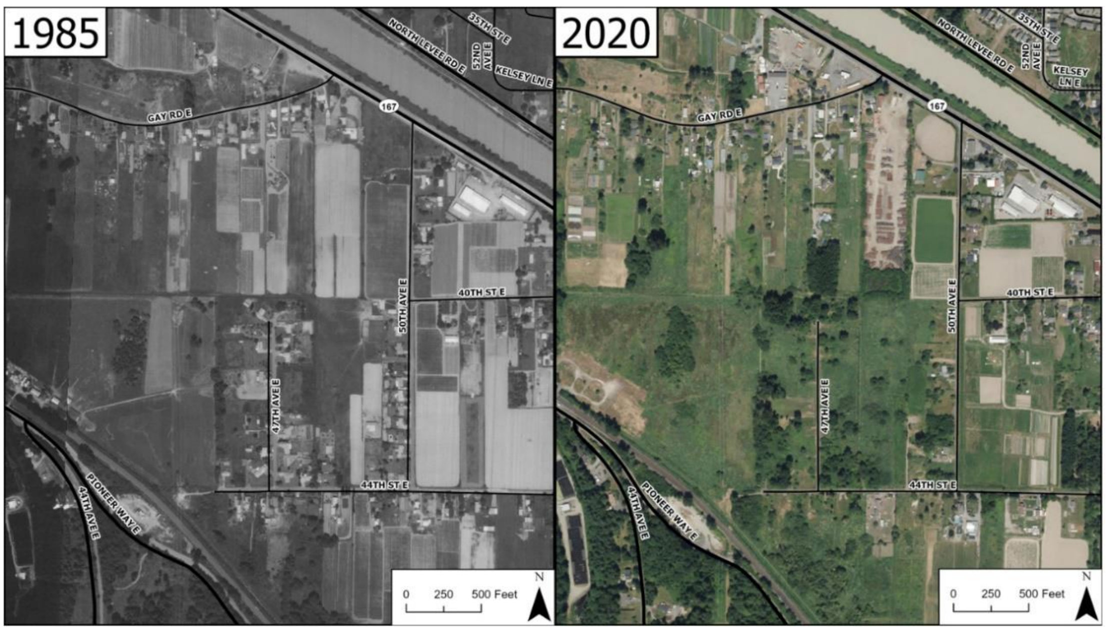
N/A = not applicable

5.7.1 Acquisitions for Capital Improvement Projects and Property Management

Another aspect of floodplain property acquisition is purchase of property to facilitate construction of flood risk reduction facilities such as setback levees. Such projects can increase flood storage and conveyance, reduce damaging high flow velocity, reconnect the river to the floodplain, and restore natural riverine processes. There are also benefits for open space, riparian and off-channel habitat, and sediment deposition. An example of acquisitions on the landscape in the Clear Creek basin is shown in Figure 5.4.

Acquisitions can be in the form of fee simple deed land purchases or flooding, drainage, or conservation easements. Pierce County primarily purchases identified and prioritized riverine and stream floodplain property on a voluntary basis. Property owner willingness, interest, and time frame for selling is taken into consideration and account for potential property acquisition prospects. In some cases, condemnation (acquisition through eminent domain authority) may need to be considered when a negotiated agreement cannot be reached, or a parcel is critical to acquire for a planned active capital project. The use of condemnation must be approved and granted by the Pierce County Executive and ultimately by the county council through a county ordinance process.

Figure 5.4. Property Acquisitions in the Clear Creek Project Area



5.7.2 Home/Structure Elevation and Flood Proofing

Acquisition of flood-prone homes in Pierce County is not always feasible due to high costs, available grants, and benefit/cost requirements that limit eligibility. For some homes, elevation or floodproofing of the structure may be another option to reduce the risks and costs of future flood damages, particularly in coastal flood hazard areas (see Figure 5.5). Because elevation of the structure does not address other risk factors, such as emergency access during a flood or the potential for damage by flood-borne debris, this option is not preferred by Pierce County in riverine flood hazard areas. Homeowners often need technical assistance to understand options and make decisions about home elevation and permitting.

Current PCC does not allow floodproofing of residential structures. Instead, Pierce County can apply for FEMA Hazard Mitigation Assistance grants to assist homeowners with the elevation of homes in flood-prone areas. The financial matches to these grants are often paid by the homeowners. If homeowners have an NFIP policy and experience a flooding event in their home, homeowners can access Increased Cost of Compliance (ICC) funds through their NFIP flood insurance policy. The maximum payout for ICC funds is $30,000, which could help offset some of the cost to elevate.

Figure 5.5. Example of a Home Elevation in Sumner, Before and After

Table 5.18 presents programmatic recommendations for home elevation and flood proofing actions.

Table 5.18. Home Elevation and Flood Proofing Programmatic Recommendations

Timeline	Action	Lead Department	Partners
	Develop a coastal structure elevation initiative.	Planning and Public Works—SWM	Willing property owners
	Pierce County should develop a financial assistance program that assists property owners with methods/strategies that would increase their resilience to changing environmental conditions.	Planning and Public Works—SWM	Pierce County Health Department; Community Development; U.S. Army Corps of Engineers

Home/Structure Elevation Considerations

Home elevation involves raising the structure at least 1 to 2 feet above the 100-year BFE, depending on foundation type, as shown in Figure 5.6. This can substantially reduce the threat of future damage and ensures compliance with state and county regulations when the project is not in a floodway. Elevation projects are appropriate when relocation to high ground is not feasible and the structures are subjected to ponding water in the floodplain with low-velocity floodwaters. Elevation projects do not completely remove the flood risk, and emergency response may still be required for evacuation. Elevating can reduce flood damage to the structure. Elevation projects are not a viable alternative in areas subject to high-velocity flows, bank erosion, or channel migration hazard areas.

Structure elevations are generally not recommended when existing structures are close to being classified as substantially damaged and are located in a mapped floodway (based on CMZ, DFF, and/or FEMA Floodway). This is because when a project incurs substantial damage, it is required to meet current code, and current code does not allow structures to be substantially improved in a floodway. In Pierce County, substantial damage occurs when a structure has suffered damages that equal or exceed 50 percent of its value. Damages are cumulative and tracked on a 5-year cycle. It should be noted that the costs to elevate an existing structure are not counted toward the substantial improvement if the structure is elevated to the county elevation standards. Any improvements not related to the elevation would still be counted.

Access to and/or from an elevated structure is another important issue to consider when deciding if home elevation is an appropriate strategy. Access issues include the day-to-day Americans with Disabilities Act concerns as well as emergency services, which may have limited access due to floodwater inundation over the roadway. A garage may not be able to be elevated due to fill concerns. In many instances, residents may not be able to drive to or from their homes during flood events, resulting in safety risk to residents if emergency response personnel cannot access flooding areas.

Figure 5.6. Home Elevation in the McKenna Vicinity of the Nisqually River

Floodproofing of Commercial Structures

The PCC and FEMA 44 CFR 60.3 does not allow floodproofing of residential structures. However, commercial structures can be floodproofed to prevent floodwaters from entering the structure during flood events. This might involve waterproof coatings, impermeable membranes, or a floodwall built of masonry or concrete (see Figure 5.6). Doors and other openings must be equipped with permanent or removable shields.

Floodproofing may reduce the risks to a structure and contents, and it may be less costly than other retrofitting options, but there are also disadvantages. These include the need for ongoing maintenance, leakage of floodproofing materials, and installation of removable shields that require human intervention just before the flood occurs.

The programmatic recommendation for floodproofing of commercial structures is presented in Table 5.19.

Table 5.19. Floodproofing of Commercial Structures Programmatic Recommendations

Timeline	Action	Lead Department	Partners
	Review all critical facilities in the floodplain to determine if they can be floodproofed. If they are unable to be floodproofed, consider relocation.	Planning and Public Works—SWM	Pierce County Fire Department, Pierce County Sheriff's Department, Schools, Pierce County Department of Emergency Management

5.8 Agricultural and Floodplains

Agricultural lands are traditionally located within the broad, flat floodplains and valleys of major rivers. Farms often include land in floodways that are not typically thought of as floodplain environments. Agricultural properties contain fewer structures at risk of flooding, and agriculture can help maintain the flood storage and flow conveyance capacity of floodplains. Partial flooding of agricultural property is common and can be accommodated as part of the seasonal pattern of farming activities. Conversely, excessive flooding can create topsoil erosion and sediment deposition across agricultural fields. This soil movement can reduce soil fertility, change topsoil textures, increase sediment loads in watercourses, and damage surface drainage infrastructure. These physical changes can reduce the viability of farm businesses.

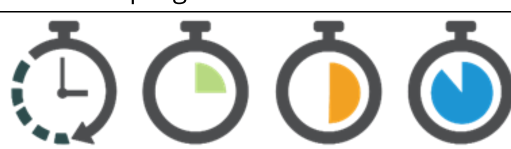
Crop production is common in the lower, middle, and upper Puyallup River and Carbon River valleys and South Prairie Creek valley. Livestock production and pasture lands are more common in the shallower rocky soils of central and south Pierce County that were originally prairie habitats. Mapped floodways associated with surface and groundwater flooding are commonly found on parcels used for agriculture in both crop and livestock areas. These areas may have high water tables that reduce the need for irrigation, or they have historically been recognized by famers and landowners as poorly suited to more intensive uses.

This plan strives to balance the needs of agricultural activities with flood hazard management principles and floodwater storage needs. Like other land uses, agricultural development involving filling, grading, or clearing in an unincorporated Pierce County floodplain requires consideration of the adverse effects on adjoining areas. A greater understanding is needed about the relationship between agricultural uses and the ecosystem services they provide to floodplains. Economic considerations of maintaining agriculture in floodplains also require further investigation to determine the unexpended costs of investment in infrastructure and potential property damage reductions that agricultural uses avoid compared to new development.

Table 5.20 addresses the review of and amendments to the PCC and other policies to enable agricultural practices in floodplains, including removal of sediment deposited by floods; increased support following emergency events; improved protocols for the leasing of publicly held floodplain lands suitable for agriculture; development of drainage management plans; investigation of opportunities to separate agricultural drainage from natural channels; and evaluations of economic benefits of maintaining agricultural activities in flood-prone environments.

Table 5.20. Agriculture in the Floodplains Programmatic Recommendations

Timeline	Action	Lead Department	Partners
	Pierce County should quantify the reduction of expenditures/benefit associated with agricultural uses as an alternative to other types of development in floodplains.	Pierce County Long Range Planning	Pierce County SWM; partner organizations
	Conduct an assessment of Pierce County-owned properties located within a flood hazard area for possible passive recreational use.	Pierce County Parks	Pierce County SWM; partner organizations
	Develop a drainage management program to improve drainage on agricultural lands located in floodplains and flood-prone areas. This could include programmatic permitting for maintenance, recovery after floods, and providing technical assistance to drainage districts and farmers. Recommendations made by the Agricultural Drainage Task Force to streamline permitting and collaboration with other regulatory agencies could also be reflected in any such program.	Pierce County Long Range Planning	Pierce County SWM, Washington State Department of Fish and Wildlife, U.S. Army Corps of Engineers, Washington State Department of Ecology, Pierce County Development Engineering, Pierce County Land Use and Environmental Review, drainage districts, Pierce Conservation District
	Pierce County should continue to identify publicly owned floodplain lands suitable for agricultural use and work with the agricultural community to improve and promote the current leasing program. If county properties are inventoried and parcels are assigned lease valuations for agricultural purposes, they should be promoted through partner organizations of the Floodplains for the future program.	Various departments in Pierce County Planning and Public Works	Various departments in Pierce County Planning and Public Works; partner organizations



5.8.1 Challenges of Agricultural in the Floodplains

Support Structures in Floodplain and Floodways

Pierce County's development regulations prohibit the construction of new structures in a floodway except for structures that do not require a building permit (PCC 18E.70.040.B, Replacement of an Existing Structure). Structures are defined in PCC 18.25 as "... anything that is constructed in or on the ground or over water, including any edifice, gas or liquid storage tank, and any piece of work artificially built up or composed of parts and joined together." Outside paving does not require a building permit, nor do accessory buildings used as greenhouses, pump houses, tool and storage sheds, and similar one-story buildings when the floor area does not exceed 200 square feet. Non-fixed structures like shade-cloth houses, high-tunnels, and hoop-houses constructed for nursery or agricultural purposes do not require a building permit. Retaining walls less than 4 feet in height do not require a permit. Fences used for agricultural purposes do not require a permit if they are less than 8 feet in height.

The county provides an agriculture building exemption for one-story, detached agriculture buildings up to 576 square feet (PCC 18E.70.040.B.8.c). The International Building Code defines an agriculture building as a "... structure designed and constructed to house farm implements, hay, grain, poultry, livestock or other horticulture products." Agriculture buildings are only exempt from review if they are located on parcels larger than five acres, comply with provisions of the PCC, and are not located within a floodway, wetland, or regulated fish and wildlife species area. Additional information can be found in PCC 17C.

Regulations for the flood fringe allow new structures when meeting certain requirements, such as having the first horizontal member above the BFE and having areas below the BFE constructed to allow the passage of floodwater, such as pier and pile construction. Piles are mechanically driven or jetted deep into the ground. Piers are vertical structural members that are supported entirely by concrete footings. Both must be embedded sufficiently below the expected depth of erosion to remain stable during floods. These standards can be applied to the lower Puyallup River floodway and allow non-residential agricultural buildings with low risk of creating adverse conditions for adjoining areas.

Livestock flood sanctuaries are permitted, in accordance with PCC 18E.70.040.C-8, where approved fill materials raise the ground above the BFE. During flood events, farm equipment, stored crops, and livestock can move to these elevated safety zones. In floodplain settings, these must create compensatory storage. No structures are permitted on sanctuaries, so any protection offered to stored crops or farm inputs like feed or fertilizer must be provided by temporary agriculture structures as defined above.

Agricultural Composting

Composting vegetable matter is important to sustainable crop farming. The WAC 173-350-220, Composting Facilities, governs agricultural composting. Several levels of agricultural composting are exempt from having to secure a solid waste handling permit, including the composting of vegetable matter when all compost is used on-site. "Agricultural composting" means composting of agricultural waste as an integral component of a system designed to improve soil health and recycle agricultural wastes. It is conducted on lands used for farming. Vegetable matter is referred to as a “Type 1 feedstock” and defined as source-separated yard and garden wastes; wood wastes; agricultural crop residues; wax-coated cardboard; pre-consumer vegetative food wastes; and other similar source-separated materials that the jurisdictional health department determines to have a comparable low level of risk in hazardous substances, human pathogens, and physical contaminants. However, whether exempt from a solid waste handling permit or not, agricultural composting must meet certain standards. Surface water and groundwater must be protected, nuisance odors and vector attraction controlled, and an annual report filed with the local health department.

The concern with composting in a floodway or floodplain stems from its association with fill. Compost is not fill when it is spread across a field, it is a soil conditioner that breaks down into dust. Compost when being produced is in a transitional state. Storage on a pad or container is temporary. Clarification in the PCC that compost is not considered fill will remove an obstacle to productive agriculture.

Agricultural Drainage Assessments, Ditch Maintenance, and Invasive Plants

Poor drainage is a limiting factor for agricultural properties within the floodplain or flood-prone areas, particularly in the Puyallup River watershed and in many agricultural areas in central and southern Pierce County. Draining excess water off agriculture lands primarily relies on a system of drainage ditches and nearby creeks and streams. Existing drainage systems are typically a mix of man-made ditches (including roadside ditches) and natural or modified streams that empty into larger streams and rivers. The ability of these streams and ditches to transmit runoff is impacted by the county’s transportation-centric ditch maintenance standards and inactive or ineffective drainage districts; excessive sediment or invasive plants, which clog the channels; and regulatory barriers, such as the presence of threatened and endangered species, which impact the timing and method of ditch or stream improvements.

Pierce County’s Agriculture Program is working with SWM and the Pierce Conservation District to provide additional services to agricultural and rural landowners in floodplain and flood-prone locations. Projects completed as part of the Agriculture Drainage Task Force, including an online drainage support tool and the outline of how to perform drainage network analyses, should help guide conversations about developing plans to better manage drainage systems. Regulations for in-channel clean-up and maintenance are complicated for individual landowners to navigate. The creation of multi-year drainage management plans should help county and state regulatory agencies collaborate with agricultural interests to reduce conflicts. There are also efforts to expand investments into agricultural drainage infrastructure through the Floodplains for the Future program, including culvert replacements and potential improvements to drain tile infrastructure.

As part of the Floodplains for the Future Program, a subgroup called Farming in the Floodplain Project (FFP) focused its efforts on the Clear Creek subbasin's agricultural drainage system, which is managed primarily by Drainage District 10. The FFP conducted a drainage inventory to understand the complexities of the system and what drainage ditches were a priority to enhance drainage efficiency. Through this experience, the FFP worked with stakeholders to identify multiple recommendations to improve drainage on agriculture lands in flood-prone and floodplain areas. Although the project was focused on a small subbasin of the Puyallup River watershed, many of the recommendations may apply to improving drainage on agriculture lands located in floodplain and flood-prone areas in other parts of the county.

As a first step to improving drainage in the Clear Creek area, the FFP conducted an invasive plant removal from drainage ditches. The project involved landowners; farmers; Drainage District 10; and multiple regulatory agencies such as Washington State Department of Fish and Wildlife, Pierce County Planning and Public Works, Tribes, and Washington State Department of Ecology. Following removal of the invasive plants, the FFP and Pierce Conservation District recruited local community volunteers to replant sections of the cleared ditches in an effort to shade out regrowth of the invasive plants. This work continues to be maintained and monitored for effectiveness, with areas adjacent to drainage ditches showing improved in-channel vegetation control. Additional information on the FFP can be found at https://farmingintheflood plain.org/.

5.8.2 Preserving Pierce County Agricultural in the Floodplains

Agriculture Resource Lands

Pierce County redefined Agriculture Resource Lands (ARL) in 2018, and the ARL zoning designation continues to restrict extensive development. Many agricultural parcels located in floodplain and floodway areas do not meet the requirements to be zoned as ARL, so this classification does not ensure permanent or broad restrictions on development. Agricultural conservation easements are one effective tool to ensure limited development in flood-prone areas.

Agriculture Conservation Easements

Since 2004, over 1,350 acres of farmland have been preserved through conservation easements. These have been funded through county programs such as Conservation Futures and Transfer of Development Rights, and by private farmland conservation entities like Washington Farmland Trust and Forterra. Pierce Conservation District works with the Washington State Conservation Commission to administer funds supporting agricultural easements. An important local funding source for agricultural easements is the Floodplains for the Future (FFTF) program operated by Pierce County SWM. The FFTF is funded primarily by the Washington State Department of Ecology’s Floodplains by Design grant program. Other funding sources used to establish these easements include U.S. Department of Agriculture-Natural Resource Conservation Service programs like the Agricultural Conservation Easements Program and the Regional Conservation Partnership Program.

Agricultural conservation easements have been difficult to execute in the last five years due to a lack of staff support and unclear regulatory guidance from federal agencies. The Strategic Conservation Partnership, a collective of organizations including Washington Farmland Trust, Forterra, Pierce Conservation District, and Pierce County (Transfer of Development Rights and FFTF), works to prioritize potential land areas that are either in danger of being converted away from agriculture or that have significant long-term value and importance to Pierce County's agricultural sector. Many of these farm properties are located in the floodplain or are marked by flood hazards. Establishing conservation easements on properties with flood risks eliminates the potential for future development, complementing flood risk reduction efforts pursued by Pierce County SWM.

Two farm properties have been conserved since 2018, totaling 54 acres. Since conservation easements began to be established in the mid-2000s, eight farm properties that contain land in regulated floodways have been conserved, protecting over 400 acres of farmland within and adjacent to high-risk flood hazard areas.

Leasing of Floodplain Land for Agricultural Use

Pierce County SWM has purchased significant floodplain land in the major river valleys and in other flood-prone areas over the past 25 years as a means to eliminate flood risk properties and promote compatible activities in floodplains. The county is expected to continue floodplain property acquisitions using state and federal grants and other fund sources over the next 20 years. Some of these lands are suitable for agriculture and have been leased for agricultural use.

The agricultural lease program can be promoted to increase the amount of land in agricultural production. Pierce County SWM, in partnership with Planning and Public Works' (PPW's) Strategic Business Division and Agriculture Program, can evaluate county-owned floodplain lands for soil type, inundation frequency, accessibility, available utilities, zoning allowances, and other features important to agricultural production. Results of the evaluation can be shared on the county's website and with Floodplains for the Future partners. The Strategic Business Division and Agriculture Program can work with the agricultural community and prospective lessees to improve the current leasing program.

5.9 Multiple Benefits

5.9.1 Water Resource Inventory Areas

Water Resource Inventory Area 10 Habitat

The Puyallup-White Watershed (Water Resources Inventory Area [WRIA] 10) is a glacially fed watershed that drains approximately 1,053 square miles between Mount Rainier and Commencement Bay. The upper basin is primarily forested and includes a mix of national park, national forest, and private commercial timber lands. Although undeveloped, many of these forest lands contain significant road networks and are subject to periodic disturbance from timber harvesting activities where late-seral (old growth) forest originally existed. Land use transitions to a mix of agriculture, commercial forestry, open space, and low-density residential in the middle basin. The lower basin is dominated by commercial, industrial, and high-density residential and urban uses. The watershed includes portions of the Puyallup Indian Reservation and also King County. There are three major rivers in the watershed. The Puyallup River is the largest, flowing approximately 46 miles from glacial headwaters on Mount Rainier before discharging to Commencement Bay. Commencement Bay is a 5,700-acre embayment with 25 miles of shoreline, 440 acres of intertidal and shallow subtidal habitat, and approximately 510 acres of open water habitat. The White River flows about 68 miles from glacial headwaters on Mount Rainier to its confluence with the Puyallup River near Sumner. The Carbon River flows 33 miles from its glacial headwaters before discharging to the Puyallup River near Orting. The lower Puyallup, White, and Carbon Rivers are channelized and confined within a system of levees and revetments. The watershed supports several species of native salmonids, including Chinook (FERC [ESA] listed), chum, coho, pink salmon, steelhead (ESA-listed), bull trout (ESA-listed), and coastal cutthroat trout. The watershed is home to the only existing spring Chinook salmon population in south Puget Sound and is considered a core bull trout recovery area. Salmonids in various life history stages use habitat throughout the watershed during every month of the year, including nearshore habitats of Commencement Bay and associated small stream mouths.

Several Puyallup River tributaries, including Kapowsin, Fennel, Clarks, and Clear creeks, supply important spawning habitat for chum and pink salmon. South Prairie Creek, a major Carbon River tributary, is considered one of the most productive reaches for Chinook and steelhead spawning in the watershed. Upper White River tributaries such as the Clearwater, Greenwater, and West Fork White Rivers, along with major creeks such as Huckleberry, Silver, and Boise, supply important spawning habitat for White River Spring Chinook.

The White River Hatchery, operated by the Muckleshoot Indian Tribe, has brought the White River Spring Chinook back from merely a dozen fish in the early 1980s to several thousand today and continues to be important to the recovery of this stock. The Tribe relies upon Spring Chinook culturally and has ceremonial fisheries when there are sufficient adult salmon returns. The Puyallup-White River Watershed is one of the most populated and farmed basins in the Puget Sound region, and development pressure continues to increase throughout the watershed as area population grows and farms and forests are converted to residential and commercial uses. Much of the watershed lacks sufficient riparian shade due to development, levees and their maintenance, and infrastructure. Levees and revetments in the lower watershed isolate salmon from important off-channel and floodplain habitats needed and used for rearing and refuge. Water quality is impaired in portions of the watershed due to high bacteria levels, high water temperatures, and low dissolved oxygen. Shoreline and nearshore habitats have been degraded by armoring, dredging, and overwater construction.

Three major dams—Electron Dam on Upper Puyallup River and the Mud Mountain and Buckley Diversion dams on White River—impact salmonid migration and instream flow. Mud Mountain

Dam also affects floodplain connectivity downstream. Overall priorities for restoration and protection are levee setback and floodplain reconnection projects; preservation of intact floodplain and riparian habitats; restoration of natural stream features such as large woody material (LWM), natural banks, and deep pools; restoration and protection of highly productive tributary and mainstem river reaches; removal or alteration of passage barriers; restoration of hydrologic regimes; and restoration of nearshore and riparian habitats.

Water Resource Inventory Area 11 Habitat

The Nisqually Watershed (WRIA 11) is a glacially fed watershed that drains approximately 761 square miles between Mount Rainier and the Nisqually Delta. Land use in the upper basin is primarily forested and includes a mix of national park, national and state forest, and private commercial timber lands. Land use in the lower basin is more varied and includes areas of public and private forest, prairie, agriculture, and some low- to moderate-density residential development. The watershed includes portions of Thurston and Lewis counties, Joint Base Lewis-McChord (JBLM), and the Nisqually Indian Reservation. There are over 300 streams in the Nisqually Watershed, for a total of 714 miles of stream channel, with only approximately 382 miles accessible to anadromous salmonids due to the presence of natural migration barriers and hydropower infrastructure. The Nisqually River is the largest drainage in the watershed, flowing approximately 78 miles from the Nisqually Glacier on Mount Rainier to a large delta in south Puget Sound. The lower 5.2 miles of the river mainstem is constrained by revetments and levees. At over 1,900 acres in size, the Nisqually Delta is one of the largest river deltas in Puget Sound and supplies diverse salmonid-rearing habitat, including mudflats, salt marsh, tidal channels, and eelgrass beds. Significant subbasins in Pierce County include Red Salmon Creek, Muck Creek, Ohop Creek, and Mashel River. Red Salmon Creek discharges to the Nisqually Delta from a small drainage at the northeast extent of the watershed. McAllister Creek is a spring-fed floodplain system in Thurston County that discharges to the southern part of the delta.

Muck Creek drains a 93-square-mile area and discharges to the Nisqually River north of Yelm. Ohop Creek flows 11.9 miles before discharging to the Nisqually River southwest of Eatonville. Mashel River flows over 32 miles from a small unnamed lake before discharging to the Nisqually River at Nisqually State Park. The watershed supports several species of native salmonids, including Chinook (ESA-listed), chum, coho, pink salmon, steelhead (ESA-listed), and coastal cutthroat trout. The majority of Chinook, steelhead, and pink salmon spawn within the mainstem lower Nisqually River and the Mashel River. Steelhead are present in watershed streams year-round.

The watershed is a major producer of wild chum in south Puget Sound and is home to a uniquely timed late season run. The Nisqually Delta supplies regionally significant rearing habitat for non-natal salmonids, including bull trout and Chinook from south, central, and north Puget Sound watersheds. The Nisqually Watershed is one of the least developed watersheds in the south Puget Sound region. Much of the area is protected from development due to location within Mount Rainier National Park, Gifford Pinchot National Forest, Nisqually State Park, JBLM, and the Billy

Frank Junior Nisqually River National Wildlife Refuge. The Nisqually River is also one of the least degraded major rivers in the Puget Sound region. However, stream water quality in portions of the watershed is impaired due to high bacteria levels and temperatures and low dissolved oxygen. Some lakes in the watershed are also affected by high phosphorous inputs and nearshore habitats have been degraded through placement of shoreline armoring and fill. Instream flow conditions and salmonid migration in the lower Nisqually River are affected by the LaGrande Dam, Alder Dam, and Centralia Diversion Dam.

Overall priorities for restoration and protection are preservation of intact floodplain and riparian habitats, restoration of hydrologic regime, projects that enhance instream habitat diversity and promote natural riverine processes, floodplain reconnection projects, and riparian restoration and enhancement projects.

Water Resource Inventory Area 12 Habitat

The Chambers Clover-Creek Watershed(WRIA 12) is a small spring and groundwater-fed basin covering 144 square miles between the Nisqually and Puyallup watersheds. Chambers Creek is the largest creek in the Chambers Watershed with widths of up to 25 feet and depths ranging from 6 inches to 2 feet. Major tributaries to Chambers Creek include Clover, North Fork Clover, Spanaway, Morey, Flett, and Leach creeks. Sequalitchew Creek is contained in a separate subbasin and discharges directly to Puget Sound.

Some areas of the watershed are natural with adequate instream and riparian habitat, forests, wetlands, and connected floodplains, especially on property owned by JBLM, but most of the watershed has been heavily urbanized and developed. Portions of the streams have been straightened, diverted, armored, and contained in pavement-lined channels and culverts. Nineteen miles of the shoreline are developed, and armored and natural processes are affected by railway infrastructure that disconnects nearshore areas and tidal flows from estuaries and salt marshes, as well as upland habitat.

The watershed once supported robust runs of coho, chum salmon, and steelhead trout Sockeye and Chinook salmon and coastal cutthroat trout were also found in the watershed. Today, the watershed primarily supports cutthroat trout and coho and chum salmon. Resident coastal cutthroat trout occur throughout Clover Creek and in all perennial reaches and have been documented spawning on the Naches Preserve. They also can be found in seasonal reaches, such as North Fork Clover Creek at Golden Given. However, these reaches go dry in the summer. Sea run coastal cutthroat is expected to forage in the nearshore areas, including the small estuaries. The nearshore areas also support foraging, rearing, and migrating wild and ESA-listed salmonids from other river systems throughout Puget Sound.

Along with development, threats to habitat include water quantity, particularly in summer months when instream flows are so low that large areas of the creeks go completely dry. Other water quality issues include increased siltation, low dissolved oxygen, fecal coliform, metals, and high-water temperatures. There is also the potential for contamination due to stormwater runoff past industrial discharges and tire dust due to the high-density road network. General restoration and protection strategies include protection and restoration of highly productive tributary and mainstem areas, especially the lower four miles of Chambers Creek; floodplain reconnection; removing fish barriers, especially Chambers Creek Dam; restoration of hydrologic regime; restoration of pocket estuaries and nearshore habitats; and water quality improvement.

Water Resource Inventory Area 15 Habitat

The Kitsap or Key Peninsula-Gig Harbor-Islands Watershed (KGI; WRIA 15 East Kitsap Peninsula) is a 158-square mile rain and groundwater fed watershed within the Kitsap Peninsula Watershed made up of two peninsulas and many islands between Case Inlet, the Tacoma Narrows, and Colvos Passage. The largest islands in the watershed include Fox Island, McNeil Island, and Anderson Island. Land use is primarily a mix of forest, pastureland, and moderate-density residential, with some high-density residential and commercial development associated with Gig Harbor. The watershed includes portions of Mason and King counties.

There are no major rivers within the watershed, but there are many small, low-gradient salmon-bearing streams that drain into Puget Sound. Significant subbasins include Rocky, Minter (Huge), Purdy, Burley, Wollochet, Artondale, North (Donkey), and Crescent creeks. These subbasins represent small drainages, and most of the streams are less than 2 miles in length, with a few exceptions. Rocky Creek flows five miles from Wye Lake to Rocky Bay in Case Inlet. Minter Creek flows approximately 6.3 miles from headwaters in Kitsap County to Minter Bay in Case Inlet. Purdy Creek flows approximately 3.5 miles from headwaters in Kitsap County to Burley Lagoon. North (Donkey) Creek and Crescent Creek both flow approximately three miles before discharging into Gig Harbor Bay. The Watershed also includes approximately 179 miles of marine shoreline with diverse nearshore habitats, including salt marshes, tidal embayments, bluff-backed beaches, and submerged aquatic vegetation beds.

The watershed supports several species of native salmonids, including Chinook (ESA-listed and non-listed), chum, coho, steelhead (ESA-listed), and coastal cutthroat trout. Many streams in the watershed support productive spawning runs of chum and coho. The remaining steelhead are no longer productive and are at risk of extirpation. Watershed streams also supply significant rearing and foraging habitat for other juvenile and adult salmon. Chinook using watershed streams appear to be primarily hatchery stock. However, threatened Chinook from north, south, and central Puget Sound watersheds can be found year-round using the extensive nearshore marine habitats in the watershed for refuge, foraging, and migration. Bull trout are also believed to forage in nearshore marine waters of the watershed. Development pressure has been rapidly increasing in the watershed in recent years, as forest and agricultural land is being converted to residential and commercial uses. Partial and full fish passage barriers have been identified on many streams throughout the watershed that limits access to important spawning and rearing habitat. Nearshore areas have been significantly altered by shoreline armoring, construction of overwater structures, and dredging. Water quality in several streams, embayments, and nearshore areas within the watershed is impaired by low dissolved oxygen and high bacteria. Some streams are also known to be impaired by high temperatures and low pH levels.

Overall priorities for restoration and protection are preservation of intact habitats, including forests, riparian areas, and estuaries; removal or modification of passage barriers to restore access to spawning and rearing habitats; removal or modification of overwater structures to reduce impacts to nearshore habitats; and removal or modification of shoreline armoring to restore natural coastal processes.

5.9.2 Salmon Habitat

Under natural conditions, a river and floodplain create ideal salmon habitat by acting as a single ecological unit that absorbs energy and stores sediment and flood water. In their undisturbed state, this relationship is expressed in meandering channels, pools with large wood, side channels, gravel bars, wetlands, and off-mainstem channel stream areas (e.g., oxbow cutoffs, wall base channels), which provide cool, clean water with an abundance of refuge and food. Over the past two million years, salmon have successfully evolved to use this ecosystem. Adult salmon use gravel bars for spawning and wood-enhanced pools for holding and cover. Juvenile salmon use the slower water off-channel areas for refuge and rearing, especially during flood events. Over the past 150+ years, the floodplain has been systematically separated from the river channel by dams, levees, estuary filling, and floodplain development.

Today, salmon populations throughout the Puget Sound are in decline, including in the Puyallup and Nisqually Rivers. For example, the Puyallup River Fall Chinook stock is estimated to have an historical run of 64,000 fish compared to about 2,000 today. Chinook that spawn naturally are expected to produce two to three returning adults, while historically they were expected to produce seven to 10 returning adults (ICF 2021). In the Puyallup River Watershed, this loss in productivity and abundance is tied directly to habitat loss (Mobrand 2001). Salmon habitat loss in the flood planning area is well documented in the Limiting Factor Reports for the Puyallup and Nisqually Watersheds (Kerwin 1999, 2000) and is attributed primarily to the filling of estuary and floodplain areas, levees, and dams. Each of these categories represents projects that isolate the floodplain from the river channel.

Large habitat restoration projects completed between 2001 and 2020, including flood protection projects, have resulted in increased floodplain reconnection, which has been identified as the main contributing factor to salmonid population improvements in the Puyallup River and Chambers-Clover Watersheds. (ICF 2021.)

Ideally, future flood management projects would result in the removal or setting back of levees to improve the long-term storage capacity of the floodplain for water and sediment. These types of floodplain reconnection projects supply flood, fish, and riparian habitat benefits and have limited maintenance requirements over time.

Programmatic recommendations related to salmon habitat are provided in Table 5.21.

Table 5.21. Salmon Habitat Programmatic Recommendations

Timeline	Action	Lead Department	Partners
	Partner with the Pierce County Shore Friendly program to identify additional grant sources and implement projects.	Pierce Conservation District	Planning and Public Works—SWM
	Complete/update Pierce County fish passage culvert inventory for fish passage and flood risk.	Planning and Public Works—SWM	Pierce County Maintenance and Operations, Pierce County Office of the County Engineer, Nisqually River Council, Puyallup Tribe of Indians, Muckleshoot Tribe, Squaxin Island Tribe Watershed Councils, Washington Department of Fish and Wildlife, select contractors
	Prioritize projects that restore hydrology to a more natural condition to reduce flood risk, reduce sediment transport, and improve water quality and fish habitat.	Planning and Public Works	Cities, Interested Landowners, South Puget Sound Salmon Enhancement, Puyallup Tribe of Indians, Muckleshoot Tribe, Squaxin Island Tribe, Nisqually Tribe
	In shared watersheds, work with the cities and counties on land use planning at the watershed scale to achieve flood risk reduction, fish passage, and ecological benefits.	Planning and Public Works—SWM	Cities in Pierce County, Kitsap County, Thurston County, Mason County, Kitsap County, and King County
	Consider incentives to encourage joint/co-located stream crossings to reduce future flooding, fish passage problems, and impacts to fish habitat.	Planning and Public Works—SWM, Land Use and Environmental Review, Long Range Planning	Puyallup Tribe of Indians, Muckleshoot Tribe, Squaxin Island Tribe, Watershed Councils, DNR
	Create incentive program to keep all class of wetlands, which all contribute to increased water quality, reduced flooding, and improved habitat for fish and wildlife.	Planning and Public Works—SWM, Land Use and Environmental Review, Long Range Planning	Puyallup Tribe of Indians, Muckleshoot Tribe, Squaxin Island Tribe, Nisqually Tribe, watershed councils

Timeline	Action	Lead Department	Partners
	Ongoing Near Term Mid Term Long Term		

5.9.3 Habitat and Riparian Area Mitigation

Flood management capital projects require permits from multiple local, state, and federal agencies. These agencies have policies that vary regarding allowable impacts to the resources they regulate. Agencies share a general strategy for conditioning permits for projects, focusing first on attempting to avoid the impact, if possible, then on minimizing and mitigating for any unavoidable habitat impacts or consequences. Mitigation may not be limited to new projects but also be applied to projects that maintain a condition that is detrimental to the resource being protected (e.g., fish, wetlands, or shorelines).

Many of the proposed projects within this 2023 Flood Plan will be unable to completely avoid impacts, and it will be important to proactively define mitigation opportunities that address anticipated impacts in support of improving the efficiency of permitting process. This requires an understanding of projects, river processes, and factors that currently limit or adversely impact river and floodplain systems. Anticipating and preparing for adequate mitigation will help to accelerate projects proposed by this 2023 Flood Plan and supply better protection for fish and riparian habitat. See Table 5.22 for the programmatic recommendations related to habitat and riparian area mitigation.

Table 5.22. Habitat and Riparian Area Mitigation Programmatic Recommendations

Timeline	Action	Lead Department	Partners
	Pierce County should engage resource agencies and Tribes in creating fish and riparian habitat area advance and/or off-site mitigation opportunities to mitigate for impacts of 2023 Flood Plan projects that cannot be mitigated on-site. Pierce County should work with agencies to establish policies for crediting advance mitigation and creating an account for property acquisition if considered possible.	Planning and Public Works—SWM	Pierce County Land Use and Environmental Review, U.S. Army Corps of Engineers, Washington Department of Fish and Wildlife, Washington State Department of Natural Resources, Muckleshoot Tribe, Nisqually Tribe, Puyallup Tribe
	Ongoing Near Term Mid Term Long Term		

5.9.4 Water Quality

Water quality in lakes, rivers, estuaries and the Puget Sound are negatively affected by surrounding land use. Regulatory agencies have identified many water bodies that experience impaired water quality. These impairments are most commonly due to excessive sediment, nutrients, bacteria, or chemical contaminants entering the waterway, or alteration of natural landscape features like vegetation and soil. Changes to surrounding land use can also alter flow regimes and increase pollution carried to surface water via runoff. These stressors result in changes that hinder legally protected, beneficial uses like aquatic habitat, aesthetics, recreation, or drinking water. Significant investments have gone into mitigating these stressors and restoring water quality. Improved stormwater and wastewater treatment technologies, critical area regulations, habitat restoration projects, and pollution prevention programs are all actively employed to help protect and improve water quality in Pierce County.

Flooding has the potential to mobilize contaminants at scales that can quickly overwhelm standard water quality infrastructure and protections, which could result in degraded conditions that may pose significant risks to human health and aquatic ecosystems. The range of potential contaminants is broad but includes the following categories:

- **Nutrients:** Flooding of agricultural lands, wastewater treatment plants, on-site septic systems, and maintained grass areas can mobilize nitrogen and phosphorus from human and animal wastes, fertilizers, and fine sediments. When present in excess, nutrients can cause harmful algal blooms, alter natural food webs, and result in low dissolved oxygen concentrations.
- **Sediment:** Tremendous amounts of sediment from watershed sources or erosion can mobilize during flooding. Excess sediment transport and subsequent deposition is damaging to habitat, aquatic life, and infrastructure. Sediment can also alter drainage patterns and increase future flood risks.
- **Pathogens:** Human and animal waste from sewage treatment plants, on-site septic systems, agricultural operations, and other sources has many potentially harmful bacteria, viruses, and parasites. During flood events, these may enter floodwaters untreated and pose significant risks to human health. Even as floodwaters recede, exposure via contaminated drinking water sources like groundwater wells remains significant.
- **Harmful chemicals:** Heavy metals, petroleum products, solvents, pesticides, surfactants, and a host of other potentially harmful or hazardous materials can enter waterways during flood inundation. These substances may pose immediate risk to human health and aquatic life. Depending on factors like pervasiveness, persistence, and interactions with other chemicals, the long-term effects of such pollutants on environmental health can be costly and difficult to reverse.

While the relative makeup of pollutant types may vary, the risk of water quality contamination during flood events is present across most land use categories in developed areas, for example:

- **Residential:** Flooding in these areas may result in the release of household hazardous wastes, lawn, and garden chemicals (fertilizers, pesticides, herbicides), automotive chemicals, petroleum products (fuel oil, gasoline), and untreated wastewater.
- **Commercial:** Flooding may result in release of a wide range of pollutants, including hazardous wastes, solvents and cleaning products, automotive chemicals, petroleum products, pharmaceuticals, untreated wastewater, stockpiled sediment, and a host of others.
- **Industrial:** Flooding may result in the release of industrial-strength chemicals used in manufacturing process, hazardous waste products, metals, solvents, petroleum products, and many others. Impacts from releases in these areas is much higher, although risk of release may be offset by redundant safety protocols and containment systems.
- **Agricultural:** The primary concerns from agricultural flooding are large or concentrated volumes of fertilizers, pesticides, herbicides, animal waste, and fine sediments. Fuel oil, untreated wastewater, and household hazardous wastes are also potential risks.

When pollutants are mobilized by floodwaters, the result can be damaging to human health, water quality, aquatic life, and habitat. The range in extent, magnitude, and types of pollutants released is highly variable, making the impacts difficult to predict. The proper storage, handling, and management of chemicals, waste, and other pollutants is essential to protect aquatic resources from the adverse impacts of flooding. Prevention strategies include regulation that keeps pollutants out of flooded areas, construction and maintenance of stormwater controls, and implementation of best management practices like proper storage and secondary containment. Regulatory and structural controls are supported by educating the public and businesses on pollution prevention, conducting source control inspections, and supplying technical assistance.

Programmatic recommendations for water quality are presented in Table 5.23.

Table 5.23. Water Quality Programmatic Recommendations

Timeline	Action	Lead Department	Partners
	Continue to maintain and enhance structural stormwater controls and implement sediment best management practices per NPDES permit requirements to reduce the impacts of urban flooding	Planning and Public Works—SWM	Pierce County Development Engineering, Pierce County Maintenance & Operations, private developers
	Continue to ensure low impact development strategies are the preferred and most commonly used approach to managing stormwater for new and redevelopment to reduce urban flooding.	Pierce County Development Engineering	Washington State Department of Ecology, Washington Stormwater Center

Timeline	Action	Lead Department	Partners
	Manage hazardous materials in flood-prone areas through the source control inspection and technical assistance program to ensure best management practices are in place.	Planning and Public Works—SWM	Cities in Pierce County that have a permit to discharge stormwater from their built drainage system, residents and business owners, Washington State Department of Ecology
	Encourage connection to sanitary sewer in lieu of new septic systems within the 100-year floodplain and areas of high seasonal groundwater or frequent groundwater flooding.	Tacoma-Pierce County Health Department; Pierce County Land Services	Pierce County Sewer, Pierce County SWM, Master Builders Associations, State Department of Health
	Retrofit private well casings to protect against floodwater inundation and encourage connections to public water systems where possible.	Tacoma-Pierce County Health Department, Pierce County Land Services	Pierce County Sewer, Pierce County SWM, Master Builders Associations
	Ensure public outreach and education about human health risks from poor surface and drinking water quality during and after flood events.	Planning and Public Works—SWM	Tacoma-Pierce County Health Department, Pierce County Land Service
	Supply technical assistance and education to residents and businesses within frequently flooded areas on source control and proper storage and isolation of hazardous materials, chemicals, wastes, and other pollutants to prevent contamination of flood waters.	Planning and Public Works—SWM	TBD
	Pierce County should educate residents and businesses with on-site sewage systems and drain fields in frequently flooded and high groundwater areas to not use them during rainy periods that inundate their septic or drain fields. This causes contamination of surface and interflow in the soil and risks backup of sewage into the home or business.	Planning and Public Works—SWM, Tacoma-Pierce County Health Department	TBD

Notes:

TBD = to be determined

5.9.5 Rights and Access to Rivers and Shorelines

Rivers and associated riparian corridors are desirable locations for passive or active recreational uses for Pierce County residents. These areas are also an important part of Tribal treaty rights established in the late 1800s. Activities include trail use, fishing, boating, and passive recreation. Within the planning area, there is extensive river mileage with minimal public access. Many fishermen and boaters access rivers at unauthorized locations, and many people are using the rivers with few appropriate supporting facilities (e.g., parking and restrooms). The Pierce County Park, Recreation, and Open Space Plan (Chapter 19D.160) (Pierce County 2020) identifies riverfront water access as a high priority and value.

Public lands in flood hazard areas are often not suitable for public use due to regulatory issues, liability concerns, easement issues, or compatible use. Many of Pierce County's levees and revetments have limited public access due to the easements that were granted exclusively to Pierce County for flood management purposes. Where public access is possible, Pierce County has made these areas available for passive use. Users can find this information on the Pierce County website.

As new levees are constructed, public access opportunities should be considered. Issues to consider include costs to make improvements for public access, available net-useable land, ongoing operation and maintenance costs, and concerns about potential environmental degradation, such as effects on habitat and water quality due to human traffic and incompatible uses.

Concerns about environmental degradation along rivers are mostly related to habitat and water quality impacts. This includes impacts to fish habitat (such as salmon spawning or rearing habitat) and wildlife habitat (such as vegetation and riparian corridor habitat). Water quality impacts can occur from bank erosion, pedestrian use of riverbeds and gravel bars, excessive or damaging use, littering (during general use or during fishing season), and improper disposal of garbage and human waste.

The programmatic recommendations related to rights and access to rivers and shorelines are presented in Table 5.24.

Table 5.24. Rights and Access to Rivers and Shorelines Programmatic Recommendations

Timeline	Action	Lead Department	Partners
	Pierce County should consider opportunities to improve public access to rivers, making use of publicly owned land along rivers with considerations for operational needs.	Planning and Public Works—SWM, Parks and Recreation	Cities and special interest groups
	Pierce County should seek to purchase land for future flood risk reduction facilities (e.g., setback levees) on a fee-simple basis and make limited use of easements on private land and incorporate provisions for public access where possible.	Planning and Public Works—SWM	TBD

Notes:

TBD = to be determined

5.10 Streams and Channel Management

5.10.1 Sediment Management in Small Streams

Sediment is a natural part of small stream systems and plays an important role in maintaining their form and function. However, changes in land use within a watershed often result in increased sediment delivery to small streams that can cause unwanted changes in these systems, such as decreased conveyance capacity during high flows and declines in habitat and water quality. Excess sediments can enter streams through external sources, such as stormwater runoff, or from instream erosion of the stream bed (known as incision) and banks.

Conversion of forest and other open space to more intensive uses, such as commercial and residential development, is typically associated with reductions in wetland area and infiltration capacity and an increase in impervious surface coverage within a watershed. Development can also result in altered upland drainage patterns through changes to natural topography and construction of artificial drainage networks. These changes can significantly increase the volume and velocity of runoff entering streams associated with storm events, which in turn increases fine sediment delivery and the erosive power of storm flows. This can worsen channel incision and streambank erosion; cause filling of low gradient stream reaches; smother aquatic organisms and their habitats; increase delivery of excess nutrients, bacteria, and other pollutants to the stream; and increase nuisance vegetation growth in areas of deposition. Suspended sediments also decrease water clarity, which is an aesthetic as well as environmental concern, and can lead to increased water temperature and decreased dissolved oxygen levels.

Sediment management currently poses a challenge in streams throughout Pierce County, with the Clarks Creek, Swan Creek, and Clear Creek basins of particular concern. The primary source of excess sediments in these watersheds appears to be increased runoff from residential and commercial development. Stormwater runoff carries sediments from impervious surfaces and erodes drainage ditches and other overland flow pathways, delivering high loads of fine sediments to streams. In addition, increased stormwater runoff volume from impervious surfaces and drainage pipes and ditches has resulted in channel incision and streambank erosion in some locations. Channel incision is known to affect Clear, Clarks, Diru, Rody, Silver, and Woodland creeks. It is noted that some incision in Clarks and Clear creeks is the result of historical channelization of the Puyallup River. Instream erosion has resulted in unstable or failing streambanks at many locations, which threatens the integrity of important infrastructure like roadways and utilities.

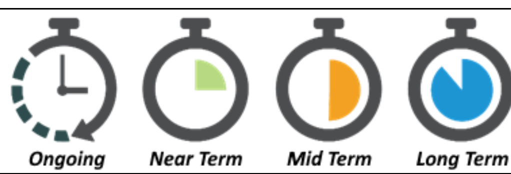
In Clarks Creek, excess sediment contributes to water quality impairment by promoting excessive aquatic vegetation growth that leads to low dissolved oxygen concentrations. Nuisance vegetation also increases deposition of fine sediments in the creek, which further reduces channel capacity in low-gradient reaches. Declining water quality observed in Swan Creek has been attributed to increased concentrations of sediment, nutrients, and bacteria.

Small stream sediment management is being approached through a combination of actions designed to control point sources, reduce instream erosion, and restore floodplain sediment and water retention functions. Specific measures in the suite of management actions being pursued include retrofitting existing stormwater detention facilities, enhanced maintenance of existing stormwater facilities, targeted construction of new stormwater detention facilities, tributary streambank channel stabilization, and wetland and floodplain protection or restoration.

Table 5.25 presents the programmatic recommendations for sediment management in small streams.

Table 5.25. Sediment Management in Small Streams Programmatic Recommendations

Timeline	Action	Lead Department	Partners
	Gather information on culverts with high sedimentation issues that cause water quality and flood issues.	Planning and Public Works—SWM, Maintenance and Operations	N/A
	Develop best management practices to address sediment management and vegetation management in flood-prone areas.	Long Range Planning and Land Use Environmental review	Pierce Conservation District



5.10.2 Local Monitoring

To supplement the river monitoring system maintained by the USGS and others, Pierce County and local partners maintain a network of stream, groundwater, and water quality monitoring sites. These gauges, which supply critical flow information during flood events, model flood risk and are used for planning purposes for overall water resource management. Pierce County recommends that an additional gauge be added on the Carbon River in Orting near Bridge Street to supply flow and stage information nearer to urban areas. The only existing gauge on the Carbon River is at Fairfax at RM 16.1, which is more than 12 miles upstream of Orting.

Local monitoring programmatic recommendations are provided in Table 5.26.

Table 5.26. Local Monitoring Programmatic Recommendations

Timeline	Action	Lead Department	Partners
	Identify partners who maintain their own gauges and define a method of obtaining approval and access to data.	Planning and Public Works—SWM	Cities in Pierce County
	Incorporate new stream monitoring sites for future flood modeling.	Planning and Public Works—SWM	Orting, other Cities in Pierce County

Notes:

TBD = to be determined

5.11 Flood Risk Reduction Facility Repair and Maintenance

5.11.1 Recommended Design and Management Strategies

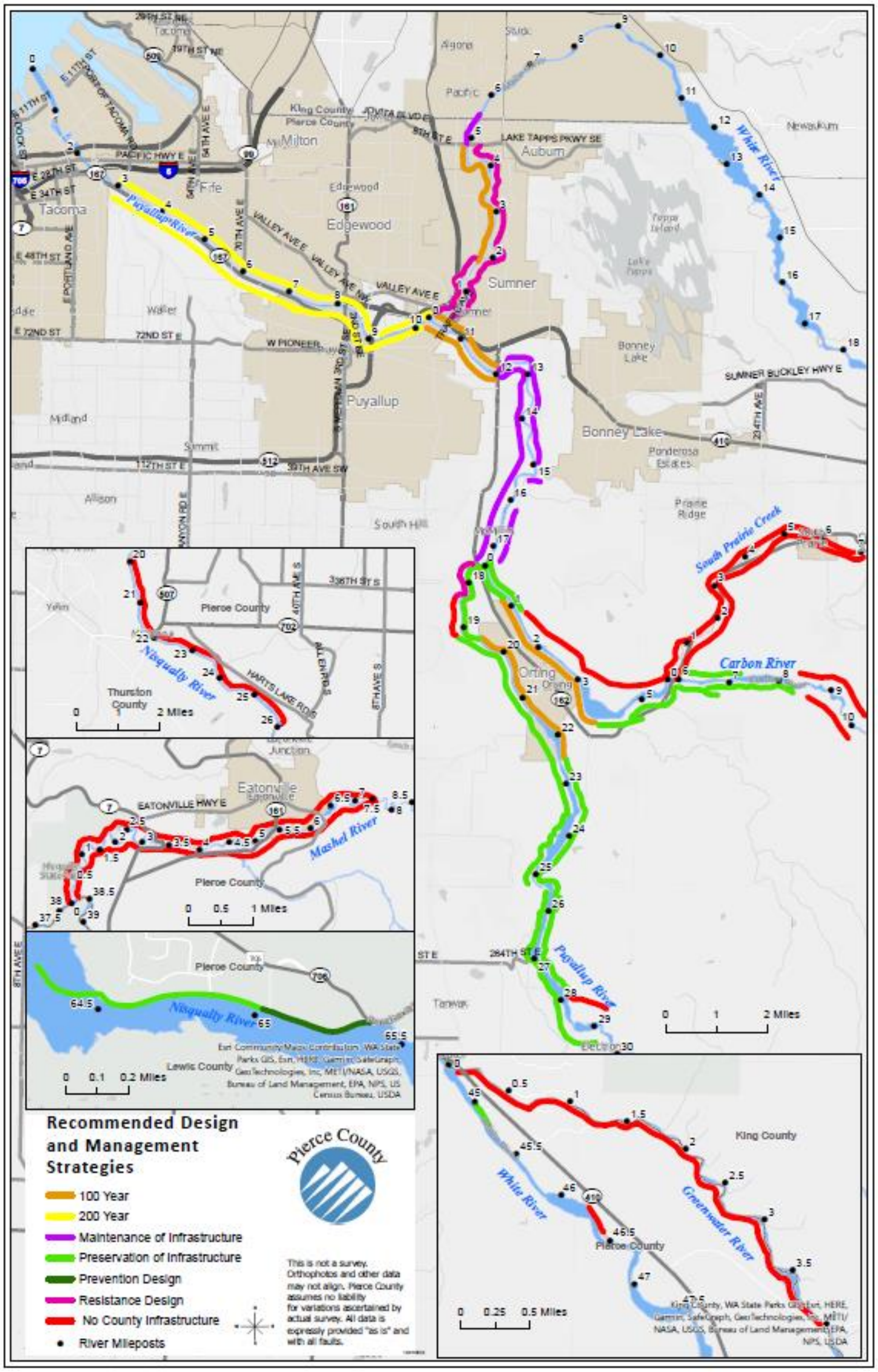
This 2023 Flood Plan applies a dynamic, customized level of design to flood-risk reduction facilities and maintenance using different management strategies for each sub-planning area or river reach. This includes structural approaches for levee and revetment reaches. Four levee levels of design and two different revetment designs are available for application by reach or sub-reach. Interim risk reduction measures are described in the County's System Wide Infrastructure Framework Plan (Pierce County 2017). Additionally, non-structural approaches, such as floodplain development regulations and acquisition/buyout of property or structures, are applicable to all river reaches and other areas where flooding occurs.

This 2023 Flood Plan moves away from the level of service concept that was described in the 2013 Rivers Flood Hazard Management Plan in favor of a more holistic approach to infrastructure use and design. This approach reflects the unique physical, economic, and cultural characteristics on various reaches of Pierce County's rivers and other surface water management infrastructure.

Pierce County's recommended design and management strategies are tailored to flooding, land use, channel migration risks, and river reach priorities. Management strategies for reaches containing flood risk reduction facilities identify levels of protection goals for levees and revetments, as described in the recommended management strategies map (Figure 5.7).

Pierce County set the strategic direction for applying river reach management strategies in March 2022. The strategies are applied on a river reach basis, specifying the applicable river miles. Left or right bank land use types, risk, and resource expenditures were factors considered in applying alternative strategies to 11 river reaches. This 2023 Flood Plan relies on structural approaches for levee and revetments for all reaches, regardless of ownership of the existing flood risk reduction infrastructure. In some cases, a combination of approaches may be appropriate.

Figure 5.7. Recommended Design and Management Strategies for Pierce County's Flood Risk Reduction Infrastructure



The following are design and management strategies for Pierce County's Flood Risk Reduction Infrastructure and where they can be applied.

- **100-Year Event:** Levees are designed to be structurally sound and maintained to the 100-year of event (water surface plus 3 feet of freeboard).

  Application – Most new levees, including setback levees (e.g., Soldiers Home, Calistoga setback levees) and in urban areas (e.g., city centers, high density residential) such as Puyallup, Sumner, Pacific, and Orting, not including the Lower Puyallup River.

- **200-Year Event:** Levees are designed to be structurally sound and maintained to the 200-year event (water surface plus 3 feet of freeboard).

  Application – Lower Puyallup River from the river mouth at Commencement Bay to its confluence with the White River (RM 0–10.4), including the cities of Tacoma, Fife, and Puyallup, and parts of unincorporated Pierce County. This could include an extensive setback levee along North Levee Road or some other approach.

- **Maintenance of Infrastructure:** This can be achieved through actions performed to maintain the structural characteristics as they existed prior to damage.

  Application – Rural (low density residential) and open space areas, agricultural areas, areas of salmon spawning and rearing (particularly for listed species, including Chinook, steelhead, and bull trout). This is proposed for all levee reaches not in the Lower and Middle Puyallup, Lower White River, or Orting area.

- **Preservation of Infrastructure:** Maintain the existing alignment and infrastructure, and may include improvements to the structure to increase its resistance to future damages and reduce flood risk. Changes may include upsizing toe or face armoring or reducing the slope of the riverside face to add stability. Preservation actions do not include changing the location of the alignment or raising the elevation of the levee profile.

  Application – Existing levees in the Middle Puyallup River reach between RM 12.0 and 17.4; this is an urban/rural transition area, with higher value agricultural areas and some Chinook and steelhead spawning.

- **Prevention Design:** Revetment design and river channel management is carried out to prevent channel migration and significant riverbank erosion. This is typically where there is no room for retreat and there is a life-line roadway that must remain open. There is a commitment (if practical) to put the river back in its pre-damaged alignment if the revetment fails. Designs might include large toe/facing rock, large woody material, bio-revetments, and engineered log jams.

  Application – Revetment at the entrance to Mount Rainier National Park, the only year-round access road (SR 706) to Mount Rainier.

- **Resistance Design:** This strategy maintains current revetment conditions. Revetment design and river channel management is carried out to resist channel migration and riverbank erosion. There is no commitment to "put the river back" if the revetment fails; a revetment repair might be constructed along the new location of the riverbank, depending on river conditions and channel migration zone mapping. However, the reconstructed revetment may use larger armoring rock or other design features to minimize the risk of future failure as well as reduce future maintenance and repair needs.

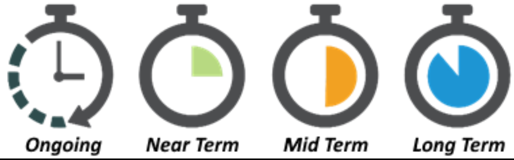
  Application – Applies to all revetments along the Puyallup, Carbon, and White Rivers not designated as prevention design or proposed for conversion to a levee for flood risk reduction.

Design and Management Strategies programmatic recommendations are provided in Table 5.27.

Table 5.27. Design and Management River Strategies Programmatic Recommendations

Timeline	Action	Lead Department	Partners
	Conduct a system-wide conditions assessment for each reach in Pierce County. This assessment would help determine the condition of the flood control infrastructure owned by Pierce County. This assessment would include factors such as channel capacity, type of infrastructure, and structural integrity.	Planning and Public Works—SWM	City of Fife, City of Puyallup, City of Orting, City of Tacoma, City of Sumner, U.S. Army of Corps of Engineers, Puyallup Tribe of Indians, Muckleshoot Tribe, Washington State Department of Transportation, Pierce County Maintenance and Operations
	Develop design standards for flood risk reduction infrastructure that would describe how infrastructure should be constructed or reconstructed if altered.	Planning and Public Works—SWM	City of Fife, City of Puyallup, City of Orting, City of Tacoma, City of Sumner, U.S. Army of Corps of Engineers, Puyallup Tribe of Indians, Muckleshoot Tribe, Washington State Department of Transportation, Pierce County Maintenance and Operations, Port of Tacoma, and the various railway companies in Pierce County
	Build a culvert and discharge pipe inventory	Planning and Public Works – Maintenance and Operations	City of Fife, City of Puyallup, City of Orting, City of Tacoma, City of Sumner, U.S. Army of Corps of Engineers, Puyallup Tribe of Indians, Muckleshoot Tribe, Washington State Department of Transportation, Pierce County Planning and Public Works—SWM, Port of Tacoma, various drainage districts in Pierce County

Timeline	Action	Lead Department	Partners



5.11.2 Levee Asset Management

Pierce County has developed a Rivers Asset Management Program (RAMP) to ensure that all levees, revetments, and related appurtenances are properly maintained. The program includes annual condition assessments, a coordinated plan for inspecting and repairing the facilities during high flow events (Rapid Damage Assessments), and standard operating procedures for maintenance and preservation activities. Currently 27 levees are enrolled in the PL 84-99 program overseen by the U.S. Army Corps of Engineers (Corps). The program is voluntary where, if Pierce County maintains their enrolled levees to the standards defined for the program, the Corps will assist the county with flood damage rehabilitation, provide emergency assistance and assist with emergency preparation activities. To obtain help from the Corps, Pierce County must maintain eligibility through a verification process conducted on a semi-annual basis known as a Continuing Eligibility Inspection. For a facility to be eligible in the PL 84-99 program, an inspection rating of "acceptable" or better must be reached. Overall management of the physical aspects of the flood risk reduction system are maintained with a unified approach following similar maintenance practices for levees and revetments.

Asset management specialists conduct condition assessment inspections each year between December and March, when there is typically less vegetation coverage from deciduous trees, shrubs, and grasses, as well as low water conditions which allow for better visual inspection on the structure face and toe. Drone inspections like the one shown in Figure 5.8 are conducted in areas that are difficult to access, or permissions are not granted by the underlying parcel owner. In addition, culverts/discharge pipes are visually inspected annually, and video inspected once every five years.

Figure 5.8. Carbon River Right Bank, Milepost 1.0

Deficiencies are identified and collected with geospatially referenced points, lines, or polygons, representing the type/size/location as well as the assessment rating criteria. Pierce County rates deficiencies on a 0 to 9 condition-rating scale. A score of zero means there is no deficiency. A score of one to three means a deficiency is present but it does not affect the performance of the asset at the time of inspection. A score of four to six means a deficiency is present and requires work to be completed. The work to fix the deficiency is of lower importance but should be completed prior to the next assessment. A score of seven to nine means a deficiency is present and requires work to be completed as soon as possible. In addition to inspecting for the deficiencies, mitigation items are also assessed during the annual condition assessments: gravel bar planting opportunity, revegetation needs, mitigation/enhancement plant failure, and identifying locations for mitigation opportunities to add large woody material (LWM) associated with summer repair work.

All non-structural deficiencies are automatically placed on a work order map, which is a spatial representation of all work requests in Pierce County. They are organized into work orders such as mowing, culvert/discharge pipe cleaning, or access road grading. After the work is prioritized by the Maintenance Program Manager based on deficiency type, severity of the deficiency, size of the deficiency, and if access or encroachments are affected, it is placed on the maintenance schedule and assigned to the maintenance crews.

Structural deficiencies are analyzed by the Engineering team and evaluated for inclusion in the annual structural repair program as seen in Figure 5.9. Engineers prioritize the work based on severity, extent, and risk. Collecting the data geospatially allows for our county's maintenance department to supply a higher-level risk analysis of the system. This data is also coordinated with flood risk maps, public infrastructure, development patterns, demographic data and current or evolving river conditions. The resulting repairs are designed with guidance from engineers, biologists, regulatory agencies, operations staff, and Integrated Streambank Protection Guidelines (WDFW 2003) to help include consideration of habitat mitigation, risk, and constructability.

Figure 5.9. Carbon River, Alward Road at Fish Ladder

As shown in Figure 5.10, 220 linear feet of bank erosion was repaired due to bank erosion that was threatening 177th Street East.

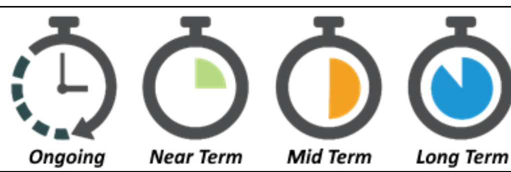
Figure 5.10. Carbon River Left Bank, Milepost 0.4, Before and After 2020 Repair

Deficiencies that are found to be below the threshold requiring maintenance activity will be reevaluated the following year or will be placed on an On-Going monitoring schedule. Deficiencies not addressed by the general standards will be corrected through specific structural solutions, some of which may require additional research and analysis. When the time needed for these efforts' delays implementation of a corrective action, applicable Interim Risk Reduction Measures will be identified, developed, and deployed. Interim Risk Reduction Measures include engineering investigations, comprehensive floodplain management, or flood warning and emergency evacuation protocols. The intent is to prevent further deterioration of the system while specific solutions are developed and implemented. Pierce County engineering staff will monitor these locations and perform regularly scheduled condition assessments and track changes to decide whether the segment deficiency merits a higher priority for correction. If condition assessment trends over time show deteriorating conditions and the need for extensive and costly repairs, a recommendation is made to the Capital Improvement Program for further investigation.

Levee asset management programmatic recommendations are provided in Table 5.28.

Table 5.28. Levee Asset Management Programmatic Recommendations

Timeline	Action	Lead Department	Partners
	Develop annual report of deficiencies in a shareable and consumable format.	Pierce County Maintenance and Operations	
	Develop a workgroup to update drainage/ riverine infrastructure data. This workgroup would also create a data portal.	Pierce County Maintenance and Operations, SWM	Cities, other Pierce County Departments
	Develop a levee vacation plan.	Pierce County SWM	Pierce County Maintenance and Operations
	Develop a risk assessment map based on inundation area of the damaged segment of levee.	Pierce County Maintenance and Operations, SWM, and IT Spatial Services	
	Conduct a geotechnical analysis of the levee prism to include the structural integrity of the concrete panels, and profile analysis for capacity.	Pierce County Maintenance and Operations, SWM, and U.S. Army Corps of Engineers	Puyallup Tribe



5.11.3 Flood Risk Reduction Infrastructure Assessment

Pierce County owns, operates, and maintains over 70 miles of flood risk reduction facilities (levees and revetments) made up of 84 segments on four major rivers systems (Puyallup, White, Carbon, and Nisqually). Managing these facilities at their lowest life cycle cost requires a systematic approach. Pierce County has a comprehensive asset management program, which provides a mechanism to make informed decisions based on data collection and analysis. Staff conduct annual condition assessments to determine the appropriate level of action necessary to maintain the infrastructure. The primary focus has been on the maintenance of the existing infrastructure to maintain a specified “level of design,” with the aim of restoring a structure back to a defined “level of protection.” In other words, maintenance is typically taken as a restorative action. On the other end of the spectrum are improvements, most of which are undertaken to improve the overall performance and reliability of a structure. Improvements are designed in the form of setback levees or revetments. This approach not only replaces a deficient structure but also improves flood protection and supplies additional multiple benefits.

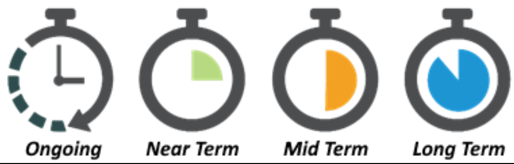
For situations where the costs outweigh the benefits of setting a structure back from the active river channel, a different asset management approach is necessary—preservation. If there is still a need for flood risk reduction structures, but options are limited, the best approach is to preserve the existing alignment and perform improvement actions to the existing infrastructure or rebuild it in its entirety. However, on a case-by-case basis, some variation is necessary to address the method to reduce flood risk. Most of the time a replacement structure can be designed and constructed using modern techniques to build a better structure than existed before, as well as supplying improvements for aquatic habitat. The result is reduced flood risk, improved confidence that the structure will withstand flooding, and a more reliable facility.

Pierce County does not have an official policy for the preservation of flood risk reduction structures. County staff have completed several preservation projects and attempted to develop a rationale for such actions in the 2017 Pierce County System Wide Improvement Framework plan. However, the intent of this discussion is to develop a recommendation for creating a procedure to include in the future management and upkeep of the County’s flood risk reduction facilities. Developing this procedure would inform the current asset management program. This 2023 Flood Plan recommends that Pierce County SWM and Maintenance and Operations formally develop a preservation program as well as a flood risk reduction facility safety program. Having a system-wide analysis would provide Pierce County with the additional information needed to assess the useful life of the flood risk reduction structures.

Table 5.29 presents the programmatic recommendations for flood risk reduction infrastructure assessment in Pierce County.

Table 5.29. Flood Risk Reduction Infrastructure Assessment Programmatic Recommendations

Timeline	Action	Lead Department	Partners
	Develop a design standards manual for county flood risk reduction facilities. Create standards and cross sections for specific river reaches.	Planning and Public Works—SWM	Pierce County Maintenance and Operations, Department of Emergency Management, cities in Pierce County, Planning and Land Services
	Develop rock-sizing methodology that applies to Pierce County rivers.	Planning and Public Works—SWM, Maintenance and Operations	U.S. Army Corps of Engineers Silver Jackets
	Create a map of what the level of design should be (in the future) for our infrastructure projects.	Planning and Public Works—SWM, Maintenance and Operations	TBD



Notes:

TBD = to be determined

5.11.4 Levee Accreditation and Levee Certification

Pierce County owns and maintains many levees along the lower 10.4 miles of the Puyallup River, the lower White River within the Sumner city limits, and the left bank of the Carbon River and the right bank of the Puyallup River surrounding Orting. However, there are no levees that are certified or accredited in the county. The terms “Levee Accreditation” and “Levee Certification” are often used interchangeably and are often confused. Levee Certification is the process that specifically addresses the physical aspects of the structure. It looks at how the structure was constructed and designed, and if the structure meets the requirements of 44 CFR Section 65.10 (mapping of areas protected by levee systems). If a levee owner wants to have their structure certified, they must supply documentation that the design of the levee meets the construction standards for a one percent annual chance flood. Levee Certification does not guarantee performance, and it is still up to the levee owner to ensure that the levee is working properly.

To have a levee become an accredited levee, it must first go through the levee certification process and there must be an adopted operation and maintenance plan for the levee. Levee accreditation also only applies to levees with a level of service 100 years or more. Having an accredited levee supplies risk reduction to at least the one percent annual chance flood and shows the area behind the levee at a moderate risk. This is reflected on FIRMs, and policy owners will notice a change in their flood insurance premiums.

Levee accreditation is based on a snapshot in time when the levee is constructed. A levee could meet the criteria of being "accredited" on the day it is certified but within a short time span could be quickly out of compliance due to a storm event or aggrading river. The obligation is then on the community to continue to monitor and modify the structures in the system to ensure they supply the level of risk reduction that is inferred by the accreditation process. Levees work as a system—any modification to one part of the system has an impact across the channel as well as upstream and downstream. Currently, Pierce County currently has no levees that are accredited.

In 2011, the USGS completed a study of sediment delivery by river to Puget Sound using existing data (USGS 2011). This study concluded that river systems that start on glaciated volcanos, like Mount Rainier, deliver 13 times the sediment load of other rivers. Sediment data available for Puyallup and Nisqually Rivers was collected between 1964 and 1966. Significant flood events and other mass wasting events have occurred since then, and the estimated sediment discharge for the rivers today is exponentially larger than the estimated annual 1.1 million tons in the 1960s.

The amount of bedload, or the sediment that settles to the bottom of the riverbed, is what affects the carrying ability of the river, and it continues to increase. The USGS collected data between 1984 and 2009 documenting aggradation in the Puyallup, White, and Carbon Rivers. Totals, as measured by changes in average channel elevation, were as much as 7.5, 6.5, and 2 feet on the Puyallup, White, and Carbon Rivers, respectively. In the Orting area, there has been significant aggradation of the riverbed between 2006 and 2016, which resulted in the loss of freeboard for the newly constructed Soldiers Home Levee and the Jones Levee.

Improvements in technology make it easier and less expensive to monitor riverbed elevations. Starting in 2020, Pierce County began collecting low level LiDAR imaging of its river systems. This information is collected and analyzed on a 3-year cycle, which allows the county to make decisions about the size of new levees or necessary maintenance activities to keep up with aggradation.

Pierce County will not pursue levee accreditation with FEMA for the levee system along the Nisqually River for the foreseeable future based on development patterns. The county will decide at the time of construction if it should proceed with levee accreditation for levees along the Puyallup, White, and Carbon Rivers.

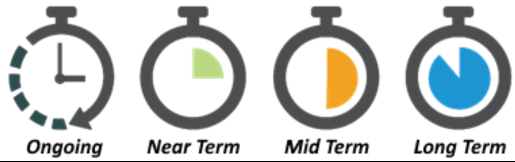
More information on levee certification and accreditation can be found online:

- Levee Certification versus Accreditation: https://www.mvk.usace.army.mil/Portals/58/docs/LSAC/LeveeCertification.pdf
- Statewide Levee Inventory and Flood Protection Study: Report on Certification and Accreditation: Sediment Load from Major Rivers into Puget Sound and its Adjacent Waters: https://pubs.usgs.gov/fs/2011/3083/pdf/fs20113083.pdf
- Channel-Conveyance Capacity, Channel Change, and Sediment Transport in the Lower Puyallup, White, and Carbon Rivers, Western Washington: https://pubs.usgs.gov/sir/2010/5240/pdf/sir20105240.pdf

Table 5.30 presents the programmatic recommendations related to levee certification and accreditation.

Table 5.30. Levee Certification and Accreditation Programmatic Recommendations

Timeline	Action	Lead Department	Partners
	All levees will be built to meet or exceed Corps certifications standards.	Planning and Public Works—SWM	USACE, TBD
	The decision to seek accreditation of a new levee should be made at the time of construction.	Planning and Public Works—SWM, Pierce County Executive	TBD



Notes:
TBD = to be determined

5.12 Flood Education, Flood Warning, and Emergency Response

5.12.1 Flood Education and Outreach Program

Flood hazard education and outreach is an important and low-cost tool that can increase awareness and motivate actions that improve public safety, reduce flood and channel migration risks, and protect natural floodplain functions.

With a coordinated and comprehensive education and outreach program, residents are more aware of the resources available to (1) make informed decisions about property purchases and land use, (2) be prepared for flood events, and (3) know what to do during and after a flood. Pierce County's flood education and outreach program web page provides information on flood preparedness trainings, the flood warning system, technical assistance to flood-related inquires from the public, and information on local fairs and outreach events for Pierce County residents living in and around floodplains. To further meet this 2023 Flood Plan goals, a more comprehensive education and outreach program should be developed and implemented.

Community Rating System Outreach Criteria

The CRS provides credits for education and outreach activities. The CRS credits messages that clearly state what the audience should do (e.g., "Turn around, don't drown" or "Get a floodplain permit from . . . ") or that provide some basic information with a note on where to get more information (e.g., "You may live in a floodplain. Find out by calling 555-1234" or "Information on ways to protect your property from flooding can be found at http://piercecountywa.org.3495/Flooding)."

There are six priority topics that the CRS wants to see delivered:

- Know your hazards
- Insure your property for your flood hazard
- Protect people from the hazards
- Protect your property from the hazards
- Build responsibility
- Protect natural floodplain functions

The number of homeowners and individuals purchasing and maintaining flood insurance is low in Pierce County. The CRS program has an activity to improve flood insurance coverage in communities. Credit is given for performing a comprehensive assessment of insurance coverage, developing a program to make improvements, and monitoring the results of the program. Pierce County should continue to conduct education and outreach to residential and commercial property owners impacted by revised flood insurance coverage requirements.

5.12.2 Flood Warning

Flood forecasting is not an exact science, and the forecast of peak river flows and stages often change throughout a flood event. The National Weather Service (NWS) identifies frontal storm systems out in the Pacific Ocean that could result in flooding days in advance of reaching the Pacific Northwest coast. The NWS also provides river peak flow forecasts early on in the development of a storm system. As the storm system moves landward into western Washington, the NWS issues updated river forecasts that typically refine the original forecasts when more data is available. Updated forecasts continue to be released throughout the storm and flood event, in which forecasted peaks continue to change. This complicates the planning and response efforts of emergency managers because decisions regarding public safety need to be made ahead of time, prior to the onset of flooding.

When the NWS issues river peak flow forecasts, they do not provide much indication on the confidence or probability of the forecasted peak. Further research and development of the technology to provide probabilistic river forecasts would be quite beneficial to emergency managers and responders. This would provide more confidence in the NWS forecast data. Otherwise, emergency personnel are left speculating and deriving their own conclusion as to the confidence and accuracy of the forecast flow data.

Making decisions on when to evacuate an area due to flood risk is extremely challenging given the uncertainty of forecast information. Pierce County SWM serves as the subject matter expert when it comes to flooding in the county. SWM provides information to Pierce County Department of Emergency Management and first responders to allow them to make an informed and timely decisions. With this being said, there is a need for better tools and information in order to provide credible evacuation notices and gain the public's trust.

Flood Warning System

Pierce County has flood threats from river flooding, urban flooding, coastal flooding, and groundwater flooding. Significant flooding that threatens life is principally in the river corridors. Pierce County rivers are short and steep and reach tidal Puget Sound about 50 miles away from their source. Major flooding is associated with "atmospheric river" weather events that create flash flood events and usually see rivers crest within 24 to 48 hours from the initial tropical moisture coming ashore. The NWS Seattle office sends out notices and weather briefings up to seven days in advance of an approaching atmospheric river. By three days out, the approximate west coast target becomes clearer as does the forecasted rain intensity. Dam operators are notified and, when available, lower reservoir pools in advance. Websites get updated with daily briefings, River Forecast Office and Advanced Hydrologic Prediction Service river crest forecasts are analyzed for expected impacts; maintenance crews will be notified to start shifting their hours to have a 24-hour crew available; and material is prepositioned.

One day out, the focus of the band of intense rainfall takes shape (note an atmospheric river can deliver a Mississippi River's worth of rainfall in a band 20 miles to 100 miles wide), and low-lying area hot spots are directly contacted to be ready for a flood. When the rain begins, USGS telemetry gauges are continuously checked and NWS Observation data and Snow Telemetry Network (SnoTel) snow pack data are checked hourly for cumulative precipitation and any additional runoff from the warm tropical moisture unravelling the mountain snow pack. Automatic text message alerts are sent when the river gauges get to preset thresholds. County staff and emergency partners are connected and informed through the Pierce County Warning, Alert, and Response (PCWARN) network and by logging into the WebEOC portal. When overtopping is expected, reverse 911 calls and Pierce County (PC) Alert calls (PC Alert messages go out to people who preregistered to receive direct notification, which is especially necessary if they do not have a land line) are sent out and emergency services are coordinated to go to the neighborhood(s) to encourage any called evacuation. Sandbagging and flood fighting is coordinated between the Emergency Operations Center and the County Maintenance Operation Center. When local forces are not enough, the Corps and state assistance will be requested.

Pierce County collaborates with the NWS to create threat assessments for each forecasted flood threshold on the multiple Advanced Hydrologic Prediction Service forecast sites. These are further customized to be seen in flow (cfs) or stage (FT), depending on the unique threat that the channel morphology has for the area (i.e., sometimes stage is a better indicator of risk, and sometimes it is volume).

> **FT**
>
> **FT refers to the gauge height (in feet) of the river reach in which the gauges is located.**

Coastal flooding events are associated with king tide events combined with atmospheric low-pressure systems. Each year a cycle of King Tides will occur in each winter month for a 1-week period. Public notices are sent out for each in advance of the forecasted king tide, with special attention given in the days ahead of each event for the forecasted weather systems and wind direction. Puget Sound shoreline has waterfront facing each cardinal point of the compass. Typically, only wind-driven waves coming from the quadrant facing a structure will cause damage.

Real time information on river flows and stage (water levels), SnoTel data, and observed rainfall sites during flood events are critical to inform the public, emergency personnel, and agencies in making evacuation and emergency response decisions. Flood forecast information provided to Pierce County focuses on a prediction of flood flows. This information then must be further interpreted to determine the potential impacts on Pierce County residents. Higher flood flows result in higher water elevations, depending on the characteristics of the river, which can be highly variable. Flood elevations can then be used to forecast which portions of the floodplain will be inundated.

Pierce County has a four-phase flood warning system, see Table 5.31 below.

- **Phase 1:** Action Flow: no flooding is occurring; however, river flows may be at an elevated flow stage.
- **Phase 2:** Minor Flooding: minor flooding is likely to occur. Low-lying areas and pasture may flood due to rivers or streams overtopping their banks.
- **Phase 3:** Moderate Flooding: moderate flooding is likely to occur. Adjacent property may be flooding and have more dangerous high-velocity flow and debris.
- **Phase 4:** Severe Flooding: severe widespread flooding is likely to occur. Dangerous high-velocity flow, debris, and deep water may be associated with severe flooding.

For additional information on the four phases of flooding, please see Appendix F.

Table 5.31. Four Phase Flood Warning Systems for River Systems in Pierce County

River System (location)	Phase 1	Phase 2	Phase 3	Phase 4
Lower Puyallup River (Puyallup gauge)	Less than 35,500 cfs	35,500–45,000 cfs	45,000–50,000 cfs	Greater than 50,000 cfs
Middle Puyallup River (Alderton gauge)	Less than 20,000 cfs	20,000-30,000 cfs	30,000-45,000 cfs	Greater than 45,000 cfs
Upper Puyallup (Orting gauge)	Less than 10,000 cfs	10,000–13,500 cfs	13,500–16,000 cfs	Greater than 16,000 cfs
Carbon River (Fairfax gauge)	5,000–7,500 cfs	7,500–9,500 cfs	9,500–12,500 cfs	Greater than 12,500 cfs
Upper Carbon (Fairfax gauge to MRNP)	5,000-7500 cfs	7,500-9,500 cfs	9,500-12,500 cfs	Greater than 12,500 cfs
Lower White River (Auburn gauge)	5,000 cfs	5,000–7,500 cfs	7,500–12,000 cfs	Greater than 12,000 cfs

River System (location)	Phase 1	Phase 2	Phase 3	Phase 4
Upper White River (above Buckley gauge)	Less than 10,000 cfs	10,000–15,000 cfs	15,000–20,000 cfs	Greater than 20,000 cfs
Middle Nisqually River (McKenna gauge)	10,000–14,700 cfs	14,700–23,200 cfs	23,200–26,500 cfs	Greater than 26,500 cfs
Upper Nisqually River (National gauge)	Less than 10,000 cfs	10,000–15,000 cfs	15,000–20,000 cfs	Greater than 20,000 cfs
South Prairie Creek (South Prairie)	Less than 4,000 cfs	4,000-5,500 cfs	5,500-8,000 cfs	Greater than 8,000 cfs

Notes:

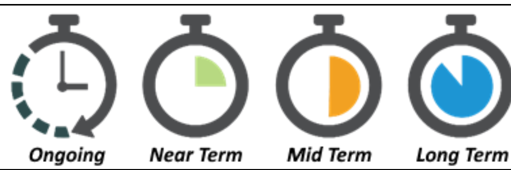
cfs = cubic feet per second

Table 5.32 presents the programmatic recommendations for flood warnings.

Table 5.32. Flood Warning Programmatic Recommendations

Timeline	Action	Lead Department	Partners
	During flood events, Pierce County will continue to use all information sources to evaluate the risks. These sources could include NWS flood information bulletins, advisories, watches, and warnings as well as coordinating with dam operators of Alder Dam and LaGrande Dam.	Pierce County	National Weather Service, Pierce County River Watch, Tacoma Public Utilities, Corps Dam Operations center, NRCS, Cascade Water Alliance
	Pierce County should coordinate with and disseminate information to local Public Safety Answering Points concerning flood advisories, watches and warnings, and conditions as they become available. When required, Pierce County should work with the NWS to alert the public of imminent flooding through various methods, including National Weather Radio, Pierce County Alert, and when necessary, door-to-door notification. In portions of the Puyallup Valley, Pierce County should use the audible voice feature of the lahar warning All Hazards Alert Broadcast sirens and the AM 1580 emergency radio station.	Pierce County Department of Emergency Management	South Sound 911

Timeline	Action	Lead Department	Partners
	Work with the cities and adjacent counties to coordinate the definitions of the four phases of activation, flooding, and emergency response.	Pierce County Emergency Management	Pierce County SWM; Pierce County Maintenance and Operations; cities of Pierce County, King County, Mason County, Lewis County, Kitsap County and Thurston County; WSDOT; other emergency response partners
	Pierce County should maintain mapping for selected nominal flows with the most up to date information on inundation mapping for each river system. Pierce County should work with local partners to develop protocols or criteria to guide when evacuation procedures should be implemented.	Planning and Public Works—SWM	TBD
	Outreach effort to educate the public on the four phases of flooding.	Planning and Public Works—SWM	Pierce County Emergency Management, Pierce County Maintenance and Operations



Notes:

TBD = to be determined

Monitoring Gauges

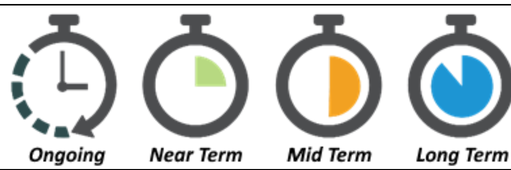
Pierce County uses a broad range of gauges to predict and monitor flow levels, including river and stream gauges, rainfall gauges, SnoTel (snowpack) gauges, groundwater wells, and National Oceanic and Atmospheric Administration tide gauges. An analysis of the current network of gauges should be performed to get a better understanding of the gaps in the system and where new gauges could be placed. This analysis would allow Pierce County SWM and other departments within the county to better understand and respond to potential flooding locations. This system should be resilient with built-in redundancy, so if a gauge fails, there are still reliable data available to make decisions.

The USGS monitors 33 gauges in the planning area on the Puyallup and Nisqually river systems for river flow and/or stage that are used for flow tracking and response. There are eight gauges located in the Nisqually watershed and 25 are located in the Puyallup watershed. Altogether, there are a total of 26 gauges, supported by Pierce County, King County, Puget Sound Energy, Tacoma Power, Cascade Water Alliance, and the City of Puyallup.

Programmatic recommendations for monitoring gauges are presented in Table 5.33.

Table 5.33. Monitoring Gauges Programmatic Recommendations

Timeline	Action	Lead Department	Partners
	Pierce County SWM should continue its joint agreements with the USGS to monitor river stage and flow at USGS gauges on major rivers in Pierce County. A new gauge should be added on the Carbon River in the Orting vicinity.	Planning and Public Works—SWM	USGS, U.S. Army Corps of Engineers, National Park Service, adjacent counties, local cities and towns
	Collaborate with the NWS to assist with climatic gauge station installations so that the NWS can develop and implement new technology for more accurate river flooding forecasts.	National Weather Service	Pierce County SWM
	An analysis should be conducted of new technologies that may open up new opportunities to install gauges that have been traditionally difficult to sustain.	Planning and Public Works—SWM	USGS, U.S. Army Corps of Engineers, National Park Service, adjacent counties, local cities and towns



5.12.3 Flood Evacuations

As rivers approach flood stage and threaten to overtop infrastructure (as shown in Figure 5.11), it may become necessary to send out warning and evacuation notices to residents informing them of the risk. The decision to evacuate is a voluntary and individual decision. Pierce County strives to provide timely information for the public and first responders to make informed decisions on evacuation plans. The county will deliver up-to-date incident information, to inform the public of the necessity to evacuate. The more individuals understand the flooding problems and risks in advance, the better informed they will be in making life safety decisions.

Figure 5.11. Former Del Rio Mobile Home Park 1996 Viewed from 96th Street East Bridge

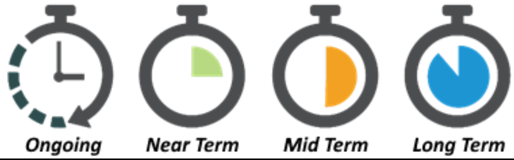
This should be based on various river stages and flows at different gauge locations. Some flood-prone areas are impacted by lower stages of river flow, while others are more impacted at higher flow stages. This will likely require a more detailed investigation and hydraulic analysis to determine these relationships. Ultimately, a Stage-Flow versus Evacuation rating or chart could be developed. Depending upon actual conditions, this could be a useful tool for evacuation planning and decision-making purposes. The flood inundation mapping that was completed in 2022 (see Appendix F) will add additional information that will help Pierce County Department of Emergency Management and first responders on when and where to issue community warnings and evacuations.

Pierce County has 10 high hazard dams that could directly affect communities (Washington State Department of Ecology, Dam Safety Office 2020). Pierce County's 2020 Hazard Identification and Risk Assessment (HIRA) plan (Pierce County 2020) describes these hazards and expected impacts along with maps and figures that show the inundation area, timing, and depth of potential flood due to a dam failure. Pierce County's Department of Emergency Management duty officer standard operating guidance gives direction for actions to be taken.

Table 5.34 presents the programmatic recommendation for high hazard dams.

Table 5.34. High Hazard Dams Programmatic Recommendations

Timeline	Action	Lead Department	Partners
	Develop a public outreach program that addresses dam safety in Pierce County.	Pierce County Emergency Management	Pierce County SWM, Pierce County Maintenance and Operations, dam operators



5.12.4 Emergency Response

Central coordination, communication, and well-established protocols are necessary components of an effective and timely emergency response to flooding. Local governments, agencies, emergency personnel, and the public all benefit from an approach with defined roles and responsibilities and clear expectations. In the absence of these features, roles may overlap, gaps in coordination and communication may occur, and emergency response and flood fighting become less effective.

Some flooding can be minor and localized, while other flooding can be more severe and widespread. The need to protect both public and private infrastructure becomes necessary during many flood events. During response to flooding, Pierce County uses a variety of methods to prevent the advance of floodwaters toward structures or infrastructure. The county encourages the public to be situationally aware of flood risk and to take appropriate measures to ensure their safety and protect their property.

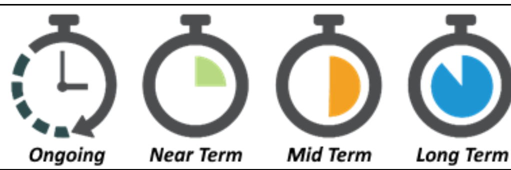
Following a flood, a timely and predictable process should be developed and made available to flood-impacted individuals to guide them through the recovery process. Such a process allows the public to recover more quickly from flood events and supports broader economic recovery.

Programmatic recommendations for emergency response to flooding are provided in Table 5.35.

Table 5.35. Emergency Response Programmatic Recommendations

Timeline	Action	Lead Department	Partners
	Pierce County should continue to coordinate flood response and recovery activities by supporting the maintenance and operations of the Pierce County Emergency Operations Center (EOC) and ensuring that individual departments support its flood-related activities by assigning staff to the EOC. The county should operate under the guidelines of its Comprehensive Emergency Management Plan, develop or modify existing standard operating procedures for flood operations within the various departments, and ensure that flood response activities are carried out within the parameters of the Incident Command System and the National Incident Management System.	Planning and Public Works—SWM, Maintenance and Operations, and Pierce County Department of Emergency Management	TBD
	State and federal reimbursement of disaster response expenses require very specific documentation. All municipalities that desire reimbursement of these costs should implement standard accounting methods to expedite this process.	Pierce County Emergency Management	County departments and cities in Pierce County
	Pierce County should periodically review and update its standard guidance and protocols for emergency flood hazard response to address internal and external coordination before, during, and after conducting emergency response activities.	Planning and Public Works—SWM, Maintenance and Operations	TBD
	Protocols should be developed to implement evacuation procedures and routes in all floodplains.	Pierce County Emergency Management	Pierce County Maintenance and Operations, Pierce County SWM
	As the threat of potential flooding develops, Pierce County should continue to monitor the rivers on scene through the use of the Pierce County River Watch program and SWM staff at both historical flood sites and other areas with at-risk structures in order to provide advance warning of emerging flood risks.	Pierce County Emergency Management	TBD

Timeline	Action	Lead Department	Partners
	Pierce County will coordinate the distribution of sandbags when they are available and may provide sandbags and sand when available to county fire districts and city and town public works departments. Individuals may request sandbags from the individual fire district or city/town public works departments. Property owners are responsible for placing sandbags and cleaning up sandbags after a flood event and meeting any regulations relating to sandbagging activity.	Pierce County Emergency Management	TBD
	Pierce County should continue to support the River Watch Program in support of county flood response activities.	Pierce County Emergency Management	Pierce County SWM
	Work with King County to develop a flood warning system for the Greenwater River.	Planning and Public Works—SWM	King County



Notes:
TBD = to be determined

Since 1962, there have been 15 presidential disaster declarations that included flooding in Pierce County (see Table 5.36). These declarations do not include the many flood responses that Pierce County has responded to that do not qualify as a federal disaster.

Table 5.36. Federal Flood Disaster Declarations, 1964- 2021

Federal Flood Disaster Declarations	Notes
DR-185-WA--12/1964	Wide-ranging flooding affected 19 counties in both eastern and western Washington.
DR-328-WA--2/1972	King, Pierce, and Thurston counties flooding.
DR-492-WA--12/1975	13 counties flooded.
DR-545-WA--12/1977	16 counties were declared. Very heavy rain in the upper Nisqually watershed caused significant damage.
DR-784-WA--11/1986	Two deaths. $11 million in private property damage and $6 million in public damage.
DR-852-WA--1/1990	Flooding from a severe storm throughout seven Washington counties. Stafford Act assistance provided $17.8 million.
DR-883-WA--11/1990	Flooding from severe storm throughout much of Washington 19 counties declared. Stafford Act assistance provided $57 million.

Federal Flood Disaster Declarations	Notes
DR-896-WA--12/1990	Flooding from severe storm and high tides. 10 counties declared. Stafford Act assistance provided $5.1 million.
DR-1079-WA--11-12/1995	100-year flood at Alderton on the Puyallup River and 50-year flood at La Grande.
DR-1100-WA--1-2/1996	Three deaths in Washington. Stafford Act disaster assistance provided – $113 million. SBA disaster loans approved - $61.2 million.
DR-1159-WA--12/96-2/1997	Ice storm, snow, and flood. Stafford Act assistance – $83 million, Small Business Administration $31.7 million.
DR-1499-WA--10/2003	Severe storms and flooding throughout much of Washington. 15 counties declared.
DR-1671-WA--11/5-6/2006	Major flooding on the Puyallup, Carbon, White, and Nisqually Rivers.
DR-1817-WA—01/06-16/2009	Flooding from a severe storm throughout much of Washington. 23 counties declared.
DR-4056-WA-1/14-23/2012	Severe winter storm, flooding, landslides, and mudslides. 11 counties declared.

When heavy rains and flooding are forecasted, Pierce County departments and divisions coordinate response efforts to address developing needs to protect critical infrastructure and the public before, during, and after events. For additional information on Pierce County's flood preparedness program, visit the county's flood preparedness web page.

Flood Emergency Drills or Exercises

While every flood that impacts Pierce County has some features in common, changes in staffing and coordination processes happen continuously; regularly scheduled training ensures that organizations remain ready to respond effectively. Exercises or drills identify problems, improve coordination, and make actual response go much smoother. The more a skill is practiced, the easier it becomes to implement in an actual situation. Repetition is an effective means to executing and responding to the real event according to plan. Different jurisdictions, agencies, or organizations are not always familiar with the capabilities, methods, or response orientation of neighboring jurisdictions or the other agencies involved in a flood response. Being able to work together, initially in an exercise format prior to an actual emergency, enhances their ability to respond and work together during an actual flood event.

Pierce County has a long history of flood-related activities by various county departments, much of which is coordinated with cities, towns, Tribes, and other agencies in the county. Flood response coordination is typically handled through Pierce County's Emergency Operations Center (EOC) and the Central Maintenance Facility. These two divisions work cooperatively with other departments in Pierce County as well as with other local, state, and federal officials. Visit the Pierce County Emergency Management web page for additional information on Pierce County's EOC and the Department of Emergency Management.

Exercises test the effectiveness of emergency response plans so that gaps and deficiencies can be identified and addressed. These exercises serve to build an environment of mutual support by building relationships (within other county departments and with our community partners) and establish points of contact before an emergency. Floods are the leading cause of damages from a natural disaster annually nationwide. Exercises set a baseline of knowledge and capabilities against which future exercises and actual events can be compared. Exercises show both strengths and gaps in the portion of the plan being tested. An after-action review (or debriefing) points out those areas of the plan and exercises that may need attention. Programmatic recommendations for emergency drills are provided in Table 5.37.

Table 5.37. Emergency Drill Programmatic Recommendations

Timeline	Action	Lead Department	Partners
	Pierce County should continue to carry out a flood emergency exercise involving the various departments active in flood response on an annual basis. The exercise should be in compliance with the Homeland Security Exercise and Evaluation Program.	Planning and Public Works—SWM	Pierce County departments
	Pierce County should coordinate flood exercises with the various jurisdictions, agencies, and organizations typically impacted by floods.	Planning and Public Works—SWM, Emergency Management	Cities in Pierce County; Pierce County departments
	Pierce County should conduct exercises that practice permit review following a flood event.	Pierce County Annex divisions	Pierce County SWM, Pierce County Emergency Management

5.13 Streams/River Channel Management

5.13.1 River Channel Monitoring

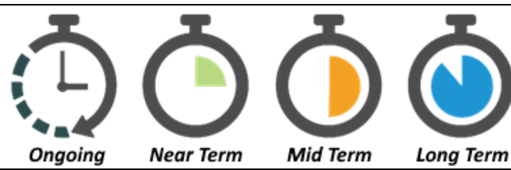
Real-time information on river flows and stage during flood conditions are critical to inform the public, emergency personnel, and agencies in making evacuation and emergency response decisions. Flow and stage data also support future modeling efforts and updating of flood mapping. River channel conditions along the rivers included in this plan are dynamic and require monitoring to track the aggradation and degradation of the riverbed channels. Tracking conditions of the riverbeds allows the county to differentiate between long-rising bed elevations and pulses of sediment that move through the river system.

Pierce County

Past capital projects, which include levee/revetment construction and repairs, levee setback projects, and gravel removal projects, have had little or no quantitative monitoring, with the exception of annual condition assessments. Better information is necessary to track project outcomes with respect to levee performance, habitat improvements, and river channel characteristic changes. The programmatic recommendations for river channel monitoring are shown in Table 5.38.

Table 5.38. River Channel Monitoring Programmatic Recommendations

Timeline	Action	Lead Department	Partners
	Pierce County should update LiDAR or other equivalent mapping of the entire river planning area on a 3-year cycle.	Planning and Public Works—SWM	Puget Sound LiDAR consortium
	Document (using photos) the extent of flooding and high-water marks along mainstem river corridors (Puyallup, Carbon, White, South Prairie, and upper Nisqually Rivers) during major flood events.	Planning and Public Works—SWM, Maintenance and Operations	Pierce County Emergency Management
	Monitor long-term changes in river channel conditions on a 7-year recurring basis, including river channel cross-sections, flood conveyance capacity, and sediment transport and deposition on the Puyallup, Carbon, lower White, and upper Nisqually Rivers.	Planning and Public Works—SWM	USGS, University of Washington, U.S. Army Corps of Engineers, adjacent counties



5.13.2 Management of Large Woody Material

In addition to flood waters and a large sediment load, Pierce County rivers carry an abundance of LWM during high flow events. These typically originate from landslides or stream bank erosion upstream or from previously deposited wood in the stream channel or floodplain. Along river reaches passing through moderately to heavily developed uplands and floodplains, wood accumulations can cause problems during flood events when logjams form or increase in size, or if woody material lodges on or adjacent to obstructions such as bridge piers or levees. This can contribute to lost capacity in the river channel, thus raising water surface elevations and worsening flooding, or it can result in greater risk of channel migration and river avulsion. Specific flood-related risks that can result from woody material accumulations include damage to bridge footings, erosion of stream banks, backwater flooding, and channel migration.

Wood also plays a major role in habitat and channel-forming processes, by stabilizing stream channels, accumulating sediment, and forming physical habitat that benefits salmon and other species. During the last century, logging, wood salvage, forest conversion, and flood control efforts all contributed to a great reduction of large wood in Pierce County rivers. The extent of wood removal and the methods used to remove wood from river channels contributed to the degradation of fish and wildlife habitat, including habitat for species listed as threatened under the ESA.

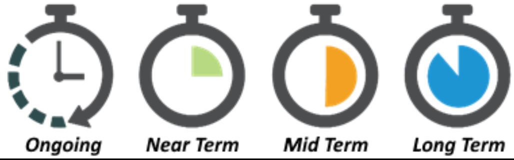
From the early 1900s to the 1960s, wood material was trapped in cable nets and removed from rivers either by hauling and/or burning. Private harvest of wood for use as firewood was also common. Up to the 1980s, removal of wood from Pierce County rivers was still common as a flood control and maintenance measure. Wood was routinely removed and or cut-up from above the water line and within the rivers, where it lodged on critical man-made structures or improvements (Pierce County 1991).

Since the listing of Puget Sound Chinook salmon as a threatened species and revision of Pierce County LWM management practices in the mid-1990s, in-channel wood accumulations have increased significantly. In-channel LWM is known to promote the formation of quality fish habitat, thus requiring a balance between flood risk reduction and LWM management.

Programmatic recommendations for LWM are presented in Table 5.39.

Table 5.39. Large Woody Material Programmatic Recommendations

Timeline	Action	Lead Department	Partners
	Repositioning of LWM from mid-channel bridge piers by Pierce County, Washington State Department of Transportation, cities, and private railways should be done in a manner that does not create new flood or channel migration risks and can be accomplished using techniques that result in the least disturbance to the river channel and aquatic habitat. Whenever possible, wood removed from these facilities should be used for habitat restoration or enhancement projects.	Jurisdiction with impacted bridge	Pierce County Department of Emergency Management, Pierce County SWM
	Work with resource agencies and Tribes to identify river segments that largely function naturally and where LWM poses little or no threat to public safety or public infrastructure. LWM in these areas should not be repositioned or removed, provided it does not pose an imminent threat to public facilities.	Planning and Public Works—SWM	Resource agencies, Tribes
	Carry out project-specific monitoring to evaluate the effectiveness of in-river projects. Monitoring will vary by project type but should include consideration of water surface elevations, sediment erosion and deposition, hyporheic flow, and habitat elements.	Project Sponsor	Resource agencies and Tribes



5.13.3 Mainstem Rivers Sediment Management

Since the initiation of the Pilot Gravel Removal Project in 2009, Pierce County has continued to study the feasibility of sediment removal to reduce flood risk. In 2014, the Sediment as a Risk Reduction Tool Project began, building on previous work but focused more on public safety and the reduction of flooding during moderate events. It was conceived to be one in a suite of flood management strategies, in addition to other flood risk reduction strategies as presented in the 2013 Flood Plan; however, a significant need for shorter-term flood risk reduction tools, such as sediment removal to aid in reducing flood damages during moderate events that are protective of valuable habitat and natural resources, were still needed. This is especially the case where alternative flood risk reduction strategies such as setback levees are not effective or feasible or could not be implemented for many years.

It was important to choose a suitable site where impacts to resources were minimized and benefits to existing infrastructure were maximized. Project team members engaged in a nearly year-long process throughout 2016 to select a site that best met the criteria set early in the process. The team analyzed 41 miles of Pierce County-managed river systems to look at where rivers were depositing and storing sediment. The reach that scored the highest in the final analysis was an approximately half-mile stretch of the Puyallup River between Puyallup and Sumner, known as Old Cannery Reach. More information on the site selection process can be viewed in the Habitat and Flood Capacity Creation Project Background and Overview document available at http://www.ciercecountywa.gov/4487/Habitat-and-Flood-Capacity-Creation-Proj.

Following the site selection, Pierce County met with federal and state agencies to seek feedback on the feasibility of the concept of sediment removal specifically at the confluence of the Puyallup and White Rivers. Because of the feedback received during that outreach, Pierce County reevaluated the purpose of the project, placing more focus on creating new habitat in addition to mitigating flood risks with sediment removal. The project was renamed the Habitat and Flood Capacity Creation Project to reflect the multiple benefits resulting from the project. Various efforts in Pierce County have sought to study whether sediment management could be incorporated as a flood risk reduction tool. The Habitat and Flood Capacity Creation Project was set apart from these previous efforts because it incorporated habitat creation in a reach of the Puyallup River where none currently exists or was degraded with the added benefit of flood reduction.

Technical work for this project location continued into 2018, including design plans and environmental documentation and permitting packages. However, feedback from the Corps indicated that the project, as designed, would require additional analysis, design and mitigation measures before a permit would be issued. Pierce County evaluated the anticipated level of effort and the costs associated with permitting the project under this new guidance from the Corps. Due to the enhanced timeline and costs, the county made the decision to place the project on the inactive list. Visit Pierce County's Habitat and Flood Capacity Creation website for an overview and lessons learned summary report.

After the conclusion of the Habitat and Flood Capacity Creation Project, spanning almost 10 years with a cost of approximately $2 million, Pierce County has determined that it will no longer study sediment removal as a standalone solution for flood reduction. Future setback levee and habitat restoration projects could include a sediment removal component, but it will not be the sole purpose of these projects. With the lessons learned from the project, the county is also willing to assist other jurisdictions and organizations that wish to pursue sediment removal.

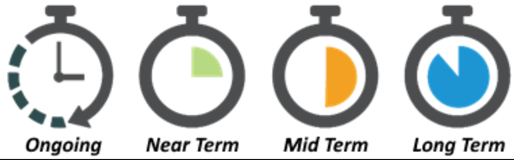
The 2013 Flood Plan included recommendations for sediment management and gravel removal. Two sites were specifically mentioned for gravel removal pilot projects (116th Street East point bar gravel removal and Ford levee setback reach gravel removal). More emphasis was given to the Pierce County Pilot Gravel Removal Project, and the two project locations were not selected. There are no gravel removal projects proposed in this 2023 Flood Plan.

The mainstem rivers sediment management programmatic recommendations from the 2013 Flood Plan have been revised for this 2023 Flood Plan, as shown in Table 5.40. These revised recommendations focus on the continued study of sediment transport through the watershed as well as levee setback projects as the most appropriate way to address excess sediment in riverine environments.

Table 5.40. Mainstem Rivers Sediment Management Programmatic Recommendations

Timeline	Action	Lead Department	Partners
	Pierce County should pursue levee setback projects as the preferred means to manage downstream sediment transport. Levee setbacks promote sediment deposition by allowing channel migration, thus increasing channel length, decreasing gradient, and promoting braiding of the river.	Planning and Public Works—SWM	U.S. Army Corps of Engineers, Puyallup Tribe, Squaxin Island Tribe, Nisqually Tribe, Muckleshoot Tribe, USGS
	The Puyallup, White, Carbon, and Nisqually river systems will have low level LiDAR flown every three years to monitor the conditions of the riverbeds.	Planning and Public Works—SWM	TBD
	Pierce County will conduct sediment transport study to examine aggradation rates in the mid and lower Puyallup River and the lower White River.	Planning and Public Works—SWM, USGS	TBD

Timeline	Action	Lead Department	Partners
	Site-specific sediment management in Pierce County shall be guided by technical sediment transport and biological studies and analysis of resource and habitat impacts, and shall consider the dynamic nature of sediment transport.	Planning and Public Works—SWM	U.S. Army Corps of Engineers, Puyallup Tribe, Squaxin Island Tribe, Nisqually Tribe, Muckleshoot Tribe, USGS



Notes:

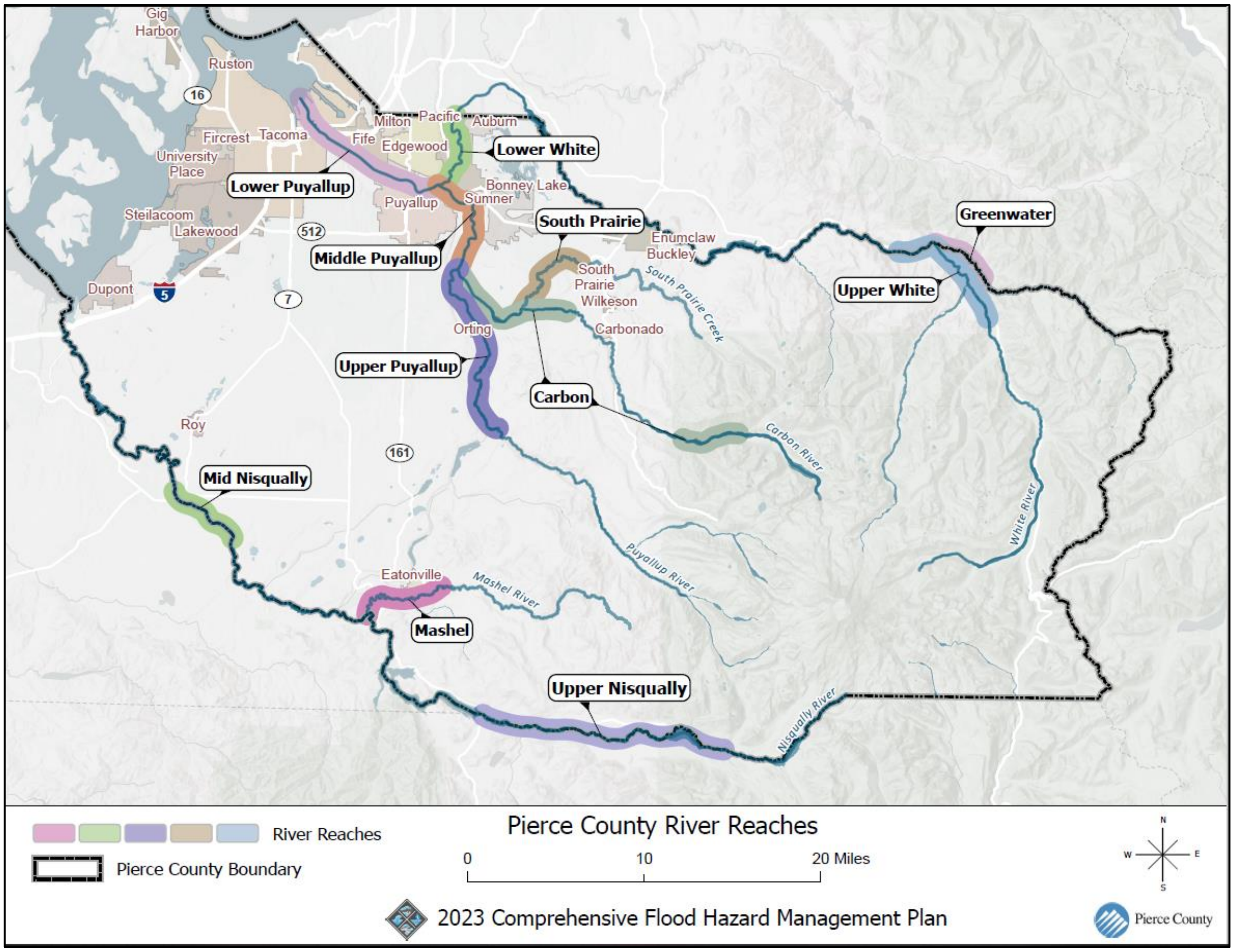
TBD = to be determined

6 Management Strategies and Recommended Capital Projects for Flood Hazards in Pierce County

This chapter describes riverine characteristics and management strategies for each of the 11 Pierce County flood hazard sub-planning areas shown on Figure 6.1. For each of these sub-planning areas, river reach management strategies and capital projects are recommended to address flood and channel migration risks. The remaining sections of this chapter, which cover each sub-planning area on Figure 6.1 and urban, coastal, and groundwater flooding, are organized into the following sections:

- Overview
- Geology and Geomorphology
- Hydrology and Hydraulics
- Ecological Context and Salmonid Use
- River Management Facilities, Flooding, and Flood Damage
- Flow Warning Matrix
- Key Accomplishments since the 2018 Flood Plan Update
- Land Acquisitions
- Flood and Channel Migration Hazard Mapping
- Problem Identification
- River Reach Management Strategies
- Recommended Capital Projects (if applicable)

Figure 6.1. Pierce County River Sub-Planning Areas



6.1 Flooding and Channel Migration Problems

Pierce County has identified flooding and channel migration problems for each sub-planning area. Problems include, but are not limited to, the following:

1. Levee/revetment overtopping or breaching
2. Tributary backwater flooding
3. Public safety/emergency evacuation
4. Channel migration problem areas
5. Flooding of structures and infrastructure
6. Sediment/gravel bar accumulation
7. Facility maintenance and repair needs
8. Floodplain development regulations

9. Fish habitat problem areas
10. Public access issues

The list of problems for items 1 through 6 above were evaluated and scored using four criteria listed below to help prioritize the level of effort to expend on developing alternative solutions. The maximum points that can be scored for each criteria listed below is 10.

1. **Existing land use of affected area** (Consequences) – This criterion gives different weights to different types of land uses affected by flooding including: (1) critical facilities, (2) critical infrastructure, (3) environmental assets, (4) public infrastructure, (5) commercial or industrial uses, (6) residential (urban or rural), (7) resource lands, and (8) developed recreational.
2. **Severity of potential flood or channel migration impact** (Consequences and Severity) – This criterion is intended to evaluate the type and magnitude of the impacts irrespective of the scale at which the impact occurred. This includes (1) public safety problems; (2) severe, moderate, or minor infrastructure or property damage; and (3) inconvenience flooding or channel migration.
3. **Area of impact** (Consequences and Severity) – This criterion describes the scale of the problem. Is the problem impacting a large area or affecting a large number of people, or is it largely localized? Categories include (1) regional (large scale impacts); (2) major center, large neighborhoods; (3) moderate (numerous structures or roads impacted); and (4) localized (affects a few homes or businesses).
4. **Frequency of flood or channel migration occurrence** – This criterion is used to describe how often economic and/or structural damage has occurred from flood or channel migration events. Frequency considers the number of occurrences within the last 30 years. Channel migration is defined as any significant landward bank erosion. Categories include (1) three or more occurrences, (2) two occurrences, and (3) one occurrence.

6.2 River Reach Management Strategies

The river systems in Pierce County are highly variable, both from river to river and between reaches within any given river. Major sources of variability include (1) development and land use in the adjacent floodplain; (2) presence of "river management facilities"; (3) river channel gradient and width; (4) presence of salmon spawning and rearing habitat; and (5) sediment transport, accumulation, or erosion. The combination of these factors has shaped historical river management by Pierce County.

This 2023 Flood Plan proposes a more dynamic, customized recommended design and management strategy for each sub-planning area or reach, based on the characteristics noted above. This includes structural approaches for levee and revetment reaches. Four levee levels of design and two different revetment designs are available for application by reach or sub-reach. Additionally, non-structural approaches, such as floodplain development regulations and acquisition/buyout of property or structures, are also proposed for each reach. More detail on the river management strategies is presented for each of the 11 sub-planning areas below and in Section 5.11.1, Recommended Design and Management Strategies, in Chapter 5, Programmatic Recommendations.

6.2.1 Property Acquisitions

Across Pierce County, the Pierce County Planning and Public Works Department, Surface Water Management Division (SWM) has removed 41 homes, totaling an estimated 120 acres, since 2018. It is the intent of Pierce County to keep homes, businesses, and infrastructure out of dangerous floodplain areas and to restore the floodplain to a more natural state to increase the ability of communities to recover following a flood. For additional information on Pierce County's Home Buyout and Property Acquisition program, please see Section 5.7, Home Buyouts and Property Acquisition, in Chapter 5.

6.2.2 Severe Repetitive Loss

SWM has been very active in the last several years purchasing properties in the repetitive loss areas and removing the structures from the sites. Of the 41 structures demolished since 2018, 8 of these structures were located on six repetitive loss properties.

In 2014, unincorporated Pierce County had 58 repetitive loss properties listed by FEMA. Of these, 31 were unmitigated, two were in different communities within city limits, and 25 had been mitigated. In 2018, unincorporated Pierce County had 63 repetitive loss properties listed by FEMA. Of the five additional properties that were added between 2014 and 2018—two were from the 2014 coastal winter storms and three were from the 2015 riverine flooding in the Clear Creek area. This brings the totals to 45 unmitigated, while the same two properties in other communities continue to be listed. Due to public disclosure issues, FEMA has been limited in updating Pierce County with a current repetitive loss list. Pierce County has five primary repetitive loss areas where many properties have experienced flood losses in the last 20 years: Clover Creek near Parkland, coastal Dash Point, mid Puyallup River south of Sumner, South Prairie Creek, and Clear Creek behind the River Road levee. While FEMA has a list of over 60 homes where property owners had purchased flood insurance to mitigate the cleanup and repair cost, homes will continue to be added to the repetitive loss list until these areas can be fully mitigated.

6.2.3 Capital Projects

The capital improvement projects recommended within this 2023 Flood Plan are intended to address flood risk to people and infrastructure by reducing flood impacts and building more resilient communities. This is a part of SWM's mission to reduce flood damage as well as to protect and improve water quality and natural resources for the benefit of our communities.

Since the 2018 Rivers Flood Hazard Management Plan, Pierce County staff analyzed ongoing flood problems in the previous plans and worked with stakeholders during the development of this plan to create a revised capital project list for the next 10 years.

This list includes ongoing projects to address flooding issues identified in the 2018 Flood Plan Update. Below is a table that illustrates Pierce County's capital projects that have been carried forward from the 2018 Rivers Flood Hazard Management Plan along with additional capital projects that have been incorporated into this plan.

Capital Projects for the 2018 Rivers Flood Hazard Management Plan	Additional Capital Projects incorporated into the 2023 Comprehensive Flood Hazard Management Plan
Clear Creek Floodplain Reconnection	White and Puyallup Rivers Confluence Property Acquisition
Rainier Manor/Riverwalk/ Rivergrove and SR-410 Flood Wall and Setback Levee	Ford Setback Levee
128th Street Corridor River Improvements	Jones Setback Levee
Neadham Road Floodplain Reconnection Orville Road Revetment at Kapowsin Creek	Carbon River Left Bank Voights Creek to SR-162 to Bridge- Feasibility Study
Butte Pit Setback Levee	
Carbon River Setback Leve, left bank near Bridge Street to upstream of Voight Creek	
Carbon River Right Bank Floodplain Connection	
Upper Carbon/Fairfax Road Bank Stabilization	

For many of the projects, a multitude of options were considered. However, only those that provide the best array of anticipated benefits were recommended for inclusion into this 2023 Flood Plan. The cost estimates developed for capital expenditures are preliminary, based on 2023 costs at a conceptual planning level design (approximately 10 percent design level) and the information available at the time. Projects selected from this 2023 Flood Plan will be included into the Capital Facilities Plan to advance from the conceptual design planning phase to the preliminary engineering design phase. Each recommended capital project will be accompanied by descriptions and graphics to provide a general overview of each project.

Preliminary prioritization of capital projects was carried out by scoring the projects based on nine criteria—problem criteria 1 through 4 listed above in Section 6.1 and the five project criteria listed below, which also shows the maximum points per criterion:

5. **Project Effectiveness** (maximum 12 points) – This criterion was used to assess the effectiveness of the proposed project at addressing and solving the problem. Project effectiveness was categorized as (1) complete solution to identified problem (e.g., acquisition/buyout that removes all structures in impacted area); (2) project addresses majority of identified problem, but some residual risk remains; and (3) project provides partial or temporary (defined as generally less than five years) solution to the identified problem (e.g., temporary super sack sandbags).

6. **Phasing and Sequencing of Projects** (maximum 5 points) – This criterion was used to assess the project actions that are phased over the lifetime of the plan. (This 2023 Flood Plan is a 10-year plan).

7. **Multiple Project Benefits** (maximum 25 points) – This criterion was used to assess the additional project benefits that would result from project implementation (beyond flood and channel migration risk reduction).

8. **Partnerships and Opportunity** (maximum 13 points) – This criterion is used to assess the partnerships, funding and leveraging issues, land ownership, and project readiness affecting project implementation.

9. **Best Management Practices (BMPs)** (maximum 5 points) – This criterion is used to assess BMPs within the county.

The maximum possible score is 100 points. A maximum of 40 points can be earned in the problem ranking criteria and a maximum of 60 points can be earned in the project ranking criteria, for a total of 100 points. Within this chapter, 15 projects were ranked, with scores ranging from a low of 33 up to a high of 69. For each project score, please see the Proposed Capital Project sub-sections within each major section in this chapter, along with Appendix D.

Included in the capital projects description are icons for each project's primary benefits. Surface Water Management designs capital projects to meet as many primary benefits as possible. The icons for each project benefit are shown below.


Agriculture


Fish Passage


Flood Risk


Riverine Flooding


Urban Flooding


Coastal Flooding

Habitat

Groundwater Flooding

Water Quality

Habitat Conservation Plan

This chapter also includes an overview of urban, coastal, and groundwater flooding (Sections 6.14, 6.15, and 6.16, respectively). Those sections describe the hazards in more detail and provide a summary from meetings that were conducted for each of these three hazards.

6.2.4 Partnerships

Partnerships have become more integral in the work that SWM does, based on the size, scope, and costs of projects. Developing projects with a multi-benefit approach is imperative to creating a resilient Pierce County and restoring our floodplains to a more natural and beneficial function. Table 6.1 demonstrates areas where SWM has partnerships throughout the region.

Table 6.1. Pierce County Surface Water Management Partnerships 2018-2022

River Reach	Federal Agencies	Floodplains For the Future	Lead Entities	Local Tribe(s)	Other Non-government Organizations	Pierce County Conservation District	Other Jurisdictions	Pierce County Flood Control Zone District	South Puget Sound Salmon Enhancement Group	State Agencies	USACE
Lower Puyallup	X (USGS gauging)	X	X	X	X	X	X	X	X	X	X (MMD)
Middle Puyallup	X	X		X				X		X	
Upper Puyallup	X	X						X			X (Jones)
Lower White	X	X					X	X			X (MMD)
Upper White		X							X		
Green-water		X							X		
Carbon		X						X			
South Prairie Creek		X	X	X	X	X			X		
Middle Nisqually	X										
Upper Nisqually	X							X			
Mashel River											

6.3 Lower Puyallup River

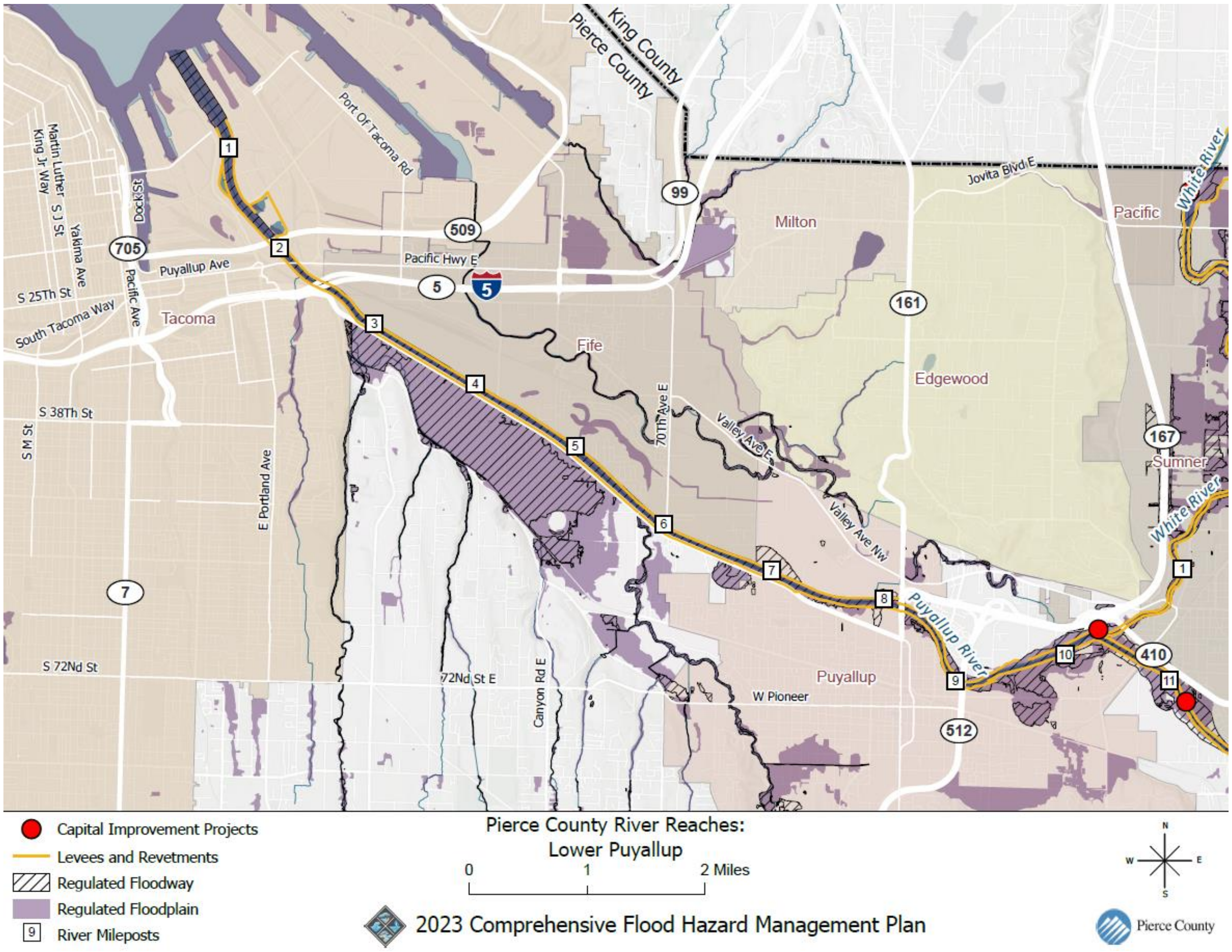
6.3.1 Overview

The lower Puyallup River begins at its mouth in Commencement Bay at river mile (RM) 0.00 and continues upstream to its confluence with the White River at RM 10.3, as shown in Figure 6.2. This river reach covers 59 square miles of planning area. It flows through the cities of Puyallup, Fife, and Tacoma and portions of unincorporated Pierce County. The bed of the river within the 1873 survey area below the mean high-water mark from approximately RM 1.55 to RM 7.35 is held in trust by the United States for the benefit of the Puyallup Tribe of Indians (Puyallup Tribe). The lower Puyallup River was straightened and narrowed with levees and revetments in the early 1900s along both banks to provide flood risk reduction for the lower Puyallup valley.

Five tributaries enter the lower Puyallup River, including Clear Creek and Clarks Creek and smaller streams such as First Creek (Roosevelt Ditch), Wapato Creek, and Deer Creek. Most of these tributaries have steep gradients and high-velocity flows in their canyon reaches until they meet the flat Puyallup River valley floor. Land uses along the lower Puyallup River vary greatly, from industrial uses near the outlet to Commencement Bay to heavily urbanized within the cities. This reach also has a wide mixture of agricultural, rural, and commercial uses.

The lower Puyallup River corridor includes extensive areas identified at risk from the one percent annual chance flood. The lower Puyallup River levees below the Meridian Street Bridge have been shown to not meet the FEMA standards (44 CFR 65.10) for accrediting them for flood protection. The initial drafts of the FEMA Digital Flood Insurance Rate Map (DFIRM) (2007 and 2009) show the extensive flood risk, based on 1998 topography. FEMA had a directive not to update the DFIRM in areas with non-accredited levees in the 2017 DFIRM and Flood Insurance Study, so the increased flood risk was “secluded” from the update, which left the area with the old 1980s mapping. There has been extensive development in the area since 1998 and several substantial flood events, all of which decrease the understanding of actual flood risk in the area.

Figure 6.2. Planning Area for the Lower Puyallup River Reach



6.3.2 Geology and Geomorphology

The lower Puyallup River valley is a broad, low-gradient alluvial plain. Historically, the river was a complex area of river channels, wetlands, and thick riparian forests (Entrix 2008). Between 1914 and 1930, the river was altered to its present condition by channelization and levee construction projects, as shown in Figure 6.3. Since construction of the levees, there has been little change in the river's position, and the threat of lateral channel migration is considered low, as shown in Figure 6.4. One hundred years ago, the river delta encompassed 5,000 acres of intertidal marsh; today less than 110 acres remain. Streambed elevation in relation to mean sea level in this segment varies from minus 8 feet at the mouth to +30 feet at RM 10.3. The average channel gradient varies from 0.035 percent to 0.06 percent between RM 3.75 and RM 10.3.

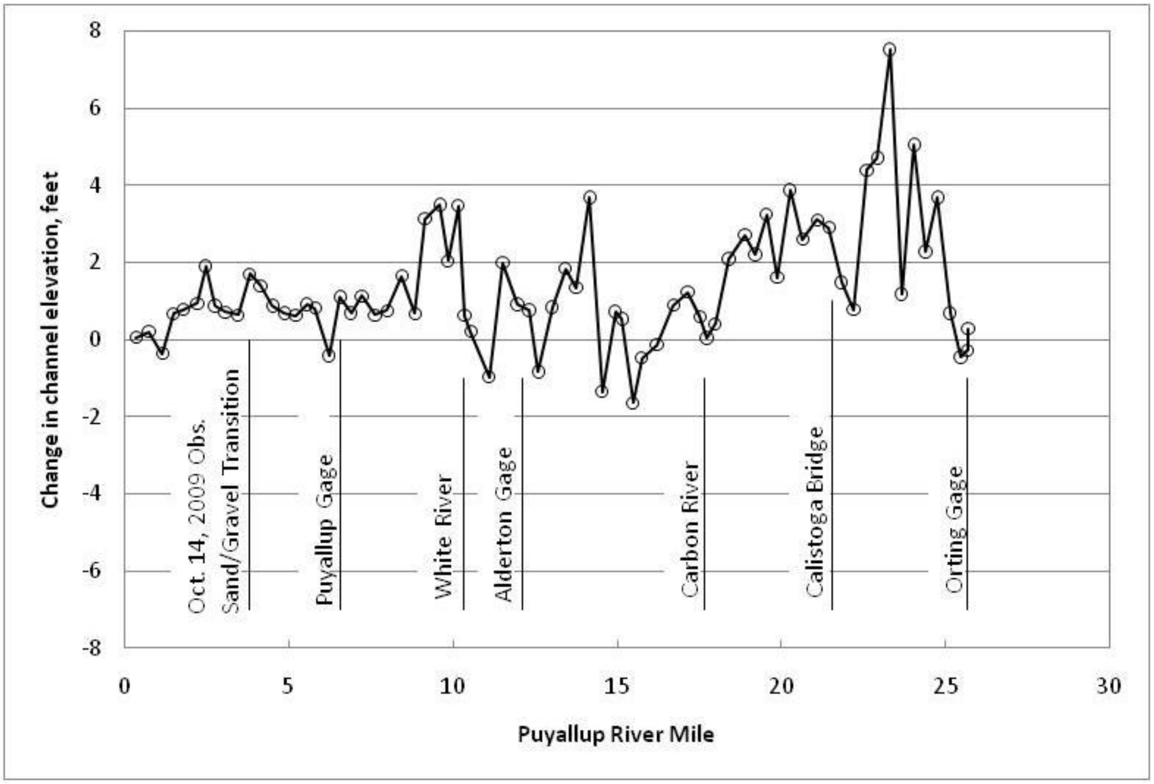
Figure 6.3. Puyallup River Delta, looking Upstream, Puyallup in the Far Background, 1916

Figure 6.4. Present-day Puyallup River Delta

The river's thalweg (the line of lowest elevation within a river or stream channel) meanders across the river bottom between the levees throughout this segment, which has resulted in a series of transient and alternating gravel bars that form and erode over time. Bed materials are primarily medium and fine sands with minor amounts of gravel. More than 95 percent of the sediment is less than one millimeter in diameter. The median particle diameter is 0.35 millimeter (medium sand) (Tetra Tech 2009).

Analysis by the USGS as part of a sediment transport study funded by Pierce County (USGS 2010) indicates an average riverbed elevation change of -0.5 feet to nearly +2.0 feet between 1984 and 2009, from the mouth at RM 0.0 to approximately RM 8.5 (see Figure 6.5). Upstream of RM 8.5 to the confluence with the White River at RM 10.3, sediment deposits increased the bed elevation between +0.5 feet to +3.5 feet.

Figure 6.5. Changes in River Bed Elevation, Puyallup River



6.3.3 Hydrology and Hydraulics

The lower Puyallup River watershed contains 106 square miles of tributary area, which is approximately 10 percent of the 948 square miles of the entire river watershed. The primary period of runoff and major floods typically extends from October through March. Since 1948, Mud Mountain Dam on the White River has provided a mechanism for flood control on the lower Puyallup River. The dam is operated by the U.S. Army Corps of Engineers (USACE) and provides storage of up to 106,000 acre-feet of water. The USACE is currently operating the dam under a revised water control plan in consideration of the loss in channel capacity and resulting elevated flooding concerns for the Sumner/Pacific reach along the lower White River.

The lower Puyallup River is a highly modified and managed reach of the river, so it does not fit standard statistical methods of estimating discharge. Flow data are available for 1906 and 1915-1947 for natural flows, and flow estimates are calculated for selected events since the dam was built. These data fit a mathematical curve, suitable for adjustment based on the Mud Mountain Dam Water Control Plan and extrapolating to rare events, such as a 500-year recurrence. The 2017 FEMA flood insurance study does not include flow data from several significant floods in the last 20 years. Table 6.2 summarizes the flood frequency flows for the lower Puyallup River.

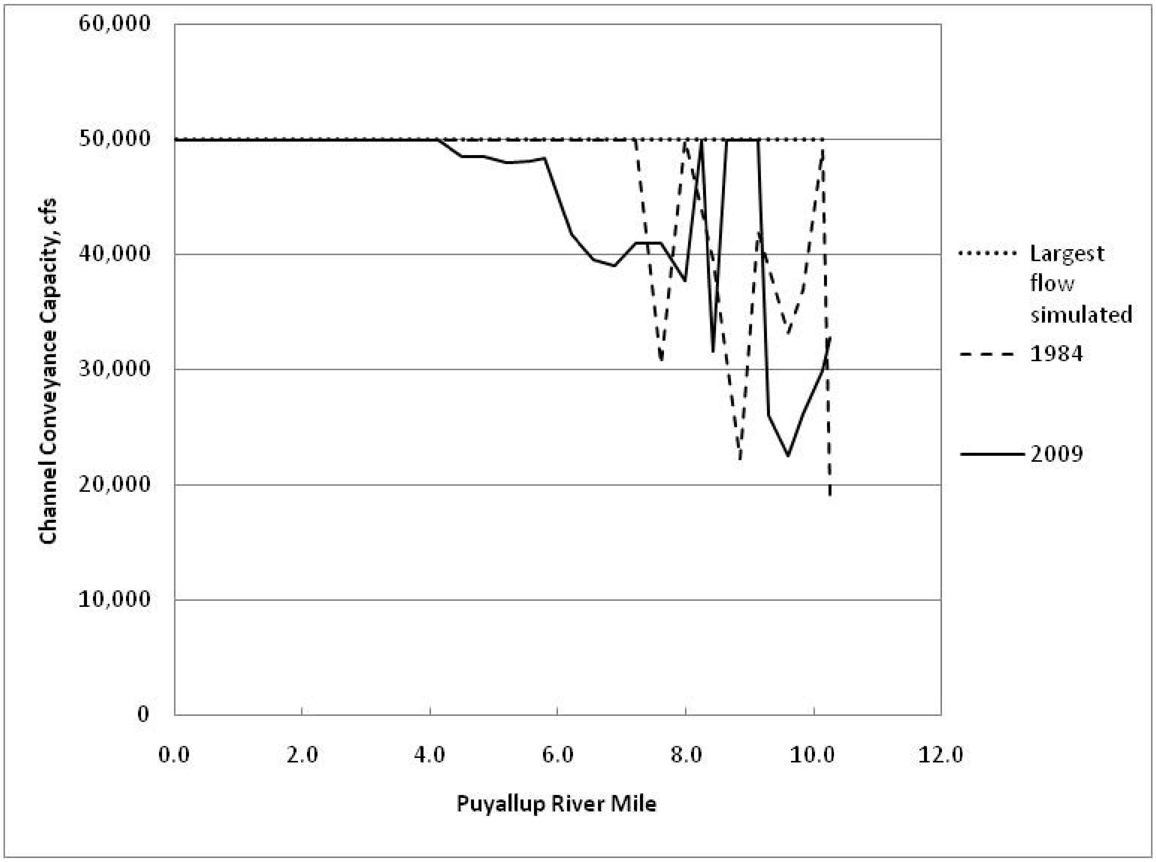
Table 6.2. Lower Puyallup River Flood Frequency Flows

	Discharge (cfs)				
WPLocation	10-year Event	50-year Event	100-year Event	500-year Event	Method
Lower Puyallup River at White River confluence	36,000	45,000	45,000	49,000	1987 FEMA Flood Insurance Study
Lower Puyallup River at Puyallup Gauge (#12101500)	41,000	46,000	48,000	63,000	2017 FEMA Flood Insurance Study for Pierce County (Northwest Hydraulics, Inc. 2006)

The USGS study of conveyance capacity (USGS 2010) indicates that the lower Puyallup River channel can convey between 48,000 and 50,000 cfs in the lower six miles of the river. However, between RM 6.0 and RM 10.3, the conveyance capacity of the main channel varies to between 23,000 and 50,000 cfs (see Figure 6.6). Channel form changes annually due to variations in sediment build up and loss over time and will continue to alter the capacity of these sections into the future.

The location, duration, and magnitude of potential levee overtopping sites were identified using a modeling simulation carried out by Tetra Tech and partners (Tetra Tech et al. 2009). The simulation indicated that a 100-year event would overtop the levee on the right bank at RM 3.3 and last nine hours. For the 500-year event, the simulation showed prolonged overtopping (greater than 24 hours) would occur on the right bank at RM 3.3 and on the left bank at RM 3.1. Shorter periods of overtopping would occur on the right bank at RM 3.7 and RM 4.1 and on the left bank at RM 4.5, RM 5.55, and RM 7.2.

Figure 6.6. Channel Conveyance Capacity for Lower Puyallup River



6.3.4 Ecological Context and Salmonid Use

The lower Puyallup River was historically the most ecologically diverse segment in the study area, but currently it continues to suffer from the effects of being heavily modified by dredging, levees construction, and urbanization. Several ecotones (a transition area between two biological communities, where two communities meet and integrate), all with specific physical and biological properties that impart unique habitats, still exist and are encountered in this reach as it transitions from marine to estuarine to freshwater. Each habitat is characterized by a collection of specific plants and animals. Pink, chum, fall and spring Chinook, steelhead, coho, sockeye, bull trout, and cutthroat trout all use this area. Because this is the lowest part of the river, all species of local fish are found here at adult and juvenile stages. For additional information on the habitat in this reach, please refer to the Water Resources Inventory Area (WRIA) 10 Habitat Section 5.9.1 in this plan.

Estuary

The Puyallup River estuary is the area where freshwater from the river interacts and mixes with the saltwater of Commencement Bay. Estuaries and the lands surrounding them are places of transition from land to sea and from freshwater to saltwater. Although influenced by the tides, estuaries like the Puyallup River estuary are areas protected from the full force of waves, winds, and storms by the fingers of land, mud, or sand that surround them. Tidal conditions in the Puget Sound directly affect the Puyallup River estuary and habitat formation. As the Puyallup River discharges into Puget Sound, freshwater flows over the top of the denser marine waters. At the same time, with the incoming tide, a deep saltwater wedge surges upriver to about RM 2.5. The height of the tide and the flow in the river influence the upstream extent of tidal surge. Higher river flows reduce the length of the surge, so the saltwater wedge moves farthest up the river during low river flows and high tides. Although the wedge may move up the river only a few miles, the tide elevates the river water level further. During low flow/high tide events, the Puyallup River will elevate due to tide action up to about RM 6.0 (Marks et al. 2009). This area of tidal influence defines the upstream extent of the estuary.

The saltwater wedge and freshwater river do not have a clean separation in salinity. As the wedge meets the river, stratification occurs and a range of salinities form as the waters mix. This mixing or “transition zone” is very important for salmon. The salinity gradient allows salmon to gradually adjust to differing biochemical conditions. A shallow embayment with large mudflats and salt marshes frequently characterizes the transition zone under natural conditions. The transition zone provides juvenile fish with abundant food sources and safety from predators due to the shallow water and the salinity gradient.

The Puyallup River estuary has been greatly diminished from its natural state. Ninety-one percent of the mudflats and 98.7 percent (Kerwin 1999, Shared Strategy 2007) of the emergent marsh have been excavated and filled since the late nineteenth century.

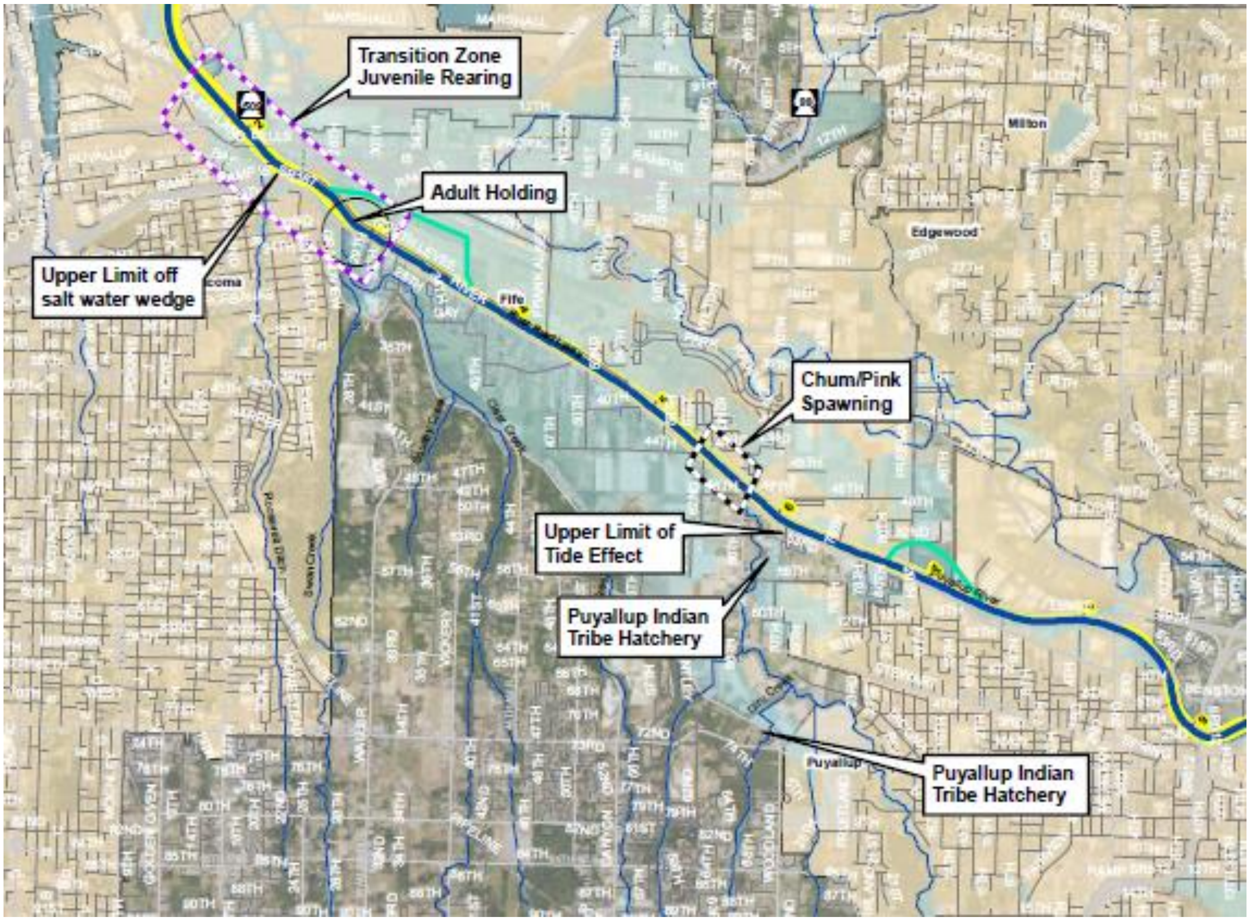
Lower Fresh Water River

Prior to levee construction, the lower Puyallup River was an area prone to flooding, where tributaries such as Hylebos Creek, Wapato Creek, Clear Creek, and Clarks Creek meandered through the Puyallup River floodplain. The tributaries would backwater during floods and high tides, which helped support and create wetlands. The merging of tributaries and wetlands provided over-winter habitat where juvenile salmon could avoid the higher velocities of the main river channel. During other times of the year, these wetland and stream complexes provided areas to feed and grow. Most of these areas no longer provide these functions due to floodplain development, filling of tidal wetlands and migration barriers such as flap gates and culverts.

A continuous bench of silt extends 10 to 50 feet riverward from the levee face between approximately RM 2.8 and RM 10.3. The top of the silt bench occurs at approximately the elevation of the 2-year flood event. Silt is deposited during floods and stabilized by well-rooted vegetation. River flows routinely erode silt and undercut the vegetation to form small, scalloped areas of trees that slump into the river. Trees and their roots reduce flow velocity and provide cover for fish habitat. In these areas, juvenile salmon can avoid being swept prematurely to Puget Sound, and adults can find areas to rest and acclimate to fresh water before continuing upstream. From about RM 5.0 to RM 10.3, sand and gravel bars begin to form. Chum and pink salmon begin to find some marginal spawning areas in this area where sport and tribal fishing is popular.

Figure 6.7 shows some of the key habitat features or salmonids in the lower Puyallup River, including the transition zone and rearing, holding, and spawning habitat for various species.

Figure 6.7. Salmonid Habitat in the Lower Puyallup River



6.3.5 River Management Facilities, Flooding, and Flood Damage

The lower Puyallup River is confined by nearly continuous levees and revetments from the river mouth at Commencement Bay to the river's confluence with the White River at RM 10.3. By restraining floodwaters from inundating the adjacent floodplain area, which includes residential, commercial, and industrial facilities within the Port of Tacoma and the cities of Tacoma, Fife, and Puyallup, these flood risk reduction facilities collectively protect the highest land and improvement values in Pierce County. Substantial damage to these flood risk reduction facilities has the highest consequence and risk on the Puyallup River system.

The lower 2.25 mile of levee from RM 0.74 to RM 2.98 are owned and maintained by the USACE. They were constructed in the late 1940s and completed in 1950 to protect the Port of Tacoma and other industrial areas (USACE 2009), as shown in Figure 6.8. Below RM 0.74, revetments extend to the mouth of the river at Commencement Bay; this section is the responsibility of the Port of Tacoma (see Figure 6.9).

Figure 6.8. Left Bank Levee at Tacoma Wastewater Treatment Plant (looking upstream)

Figure 6.9. Right Bank Revetment at Port of Tacoma Downstream of East 11th Street (looking downstream)

The channel conveyance included straightening of the channel, building levees, and making necessary bridge changes to convey 50,000 cfs between the East 11th Street Bridge and RM 2.9.

From RM 2.98 to 10.28, Pierce County currently owns and maintains approximately 15.05 miles of flood risk reduction facilities along the river in a combination of levees and revetments, as shown in Table 6.3.

Table 6.3. Levees and Revetments in the Lower Puyallup River

Name	Location[a]	Ownership
Right Bank		
Port of Tacoma Revetment	RM 0.0 – RM 0.74	Port of Tacoma
USACE Port of Tacoma Levee	RM 0.74 – RM 2.98	USACE
North Levee Road Levee	RM 2.98 – RM 8.12	Pierce County
Murphy Levee	RM 8.12 – RM 8.60	Pierce County
Benston/Boatman	RM 8.61 – RM 9.60	Pierce County
Old Cannery Levee	RM 9.68 – RM 10.28	Pierce County
Left Bank		
Simpson Revetment	RM 0.00 – RM 0.74	ROCKTENN CP LLC
USACE Portland Ave Levee	RM 0.74 – RM 2.96	USACE
River Road Levee	RM 2.96 – RM 7.50	Pierce County
Tiffany's Revetment	RM 7.50 – RM 9.37	Pierce County
Linden/Flashcube Revetment	RM 9.30 – RM 10.73	Pierce County

Source: USACE and Pierce County SWM records

Note: The Lower Puyallup is made up of 68 percent levees and 32 percent revetments.

[a] PL 84-99 USACE Flood Control and Coastal Emergency Act

RM = river mile; USACE = U.S. Army Corps of Engineers

Initial flood control work in Pierce County began on the Puyallup River prior to turn of the twentieth century. Early work was done by early settlers to protect agricultural lands and homesteads for a rapidly growing area. In 1907, the Washington state legislature gave county governments the authority to do flood-protection work on rivers. The same year, Pierce County formed Pierce County River Improvement (PCRI) and initiated flood control work on the lower Puyallup River reach between the mouth of the river to Puyallup.

As a result of the White River being diverted to flow into the Puyallup River in 1906, the Inter-County River Improvement (ICRI) was formed in 1914 to manage the additional burden placed on the lower Puyallup River. The ICRI was composed of Pierce County and King County to work jointly on the lower White and Puyallup rivers for flood control efforts. Following the formation of ICRI, the work started by PCRI resumed. The initial levees built from RM 2.8 to 10.3 were mostly constructed between 1914 and 1916. Significant levee construction and improvements followed in the 1920s and continued following the devastating 1933 flood. In wake of the major flood impacts on the Puyallup River valley, ICRI pursued the USACE to design and build a flood control dam to protect the lower Puyallup River valley and burgeoning Port of Tacoma. Congress authorized Mud Mountain Dam in the 1936 Flood Control Act. Construction began in 1939 and was completed in 1948.

Prior to 1983, ICRI and Pierce County performed periodic channel deepening and dredging to maintain flood conveyance capacity, particularly in the upper portions of the lower Puyallup River. Levees were mowed to maintain access and large trees were removed to prevent damage to the levee caused by invasive roots and tree overthrow. Since 1983, legal limitations have modified vegetation management practices and gravel and silt removal. In response to a federal court order in 1985, Pierce County and the Puyallup Tribe adopted an inter-governmental agreement for the Puyallup River Vegetation Management Program.

The estimated costs for substantial levee damage vary for right bank and left bank structures and contents, as shown in Table 6.4. Total costs of damages are estimated at $60 million for a 10-year event, $78.7 million for a 100-year event, and $93 million for a 500-year event (Tetra Tech 2009). More than 70 percent of estimated damage costs apply to commercial and industrial structures and activities.

Historical aerial photos show little evidence of instability or erosion, with the exception of two areas of potential instability in photos from 1996 (Tetra Tech 2009): (1) on the right bank at RM 5.0 and (2) the left bank at approximately RM 7.2. A reconnaissance performed for this study found little evidence of significant erosion of the silt benches. FEMA accreditation standards for levees were added to 44 CFR 65.10 in 1986 long after the construction of the lower Puyallup River levees.

The levees, while constructed to a high standard in their time, do not have the necessary freeboard to be accredited. In remapping the Puyallup River in early 2000s FEMA, their contractor and the Puyallup River communities understood that the previous 1970s risk mapping overstated the protection provided by the levees.

Table 6.4. Damage Costs by Flood Event (based on October 2023 costs)

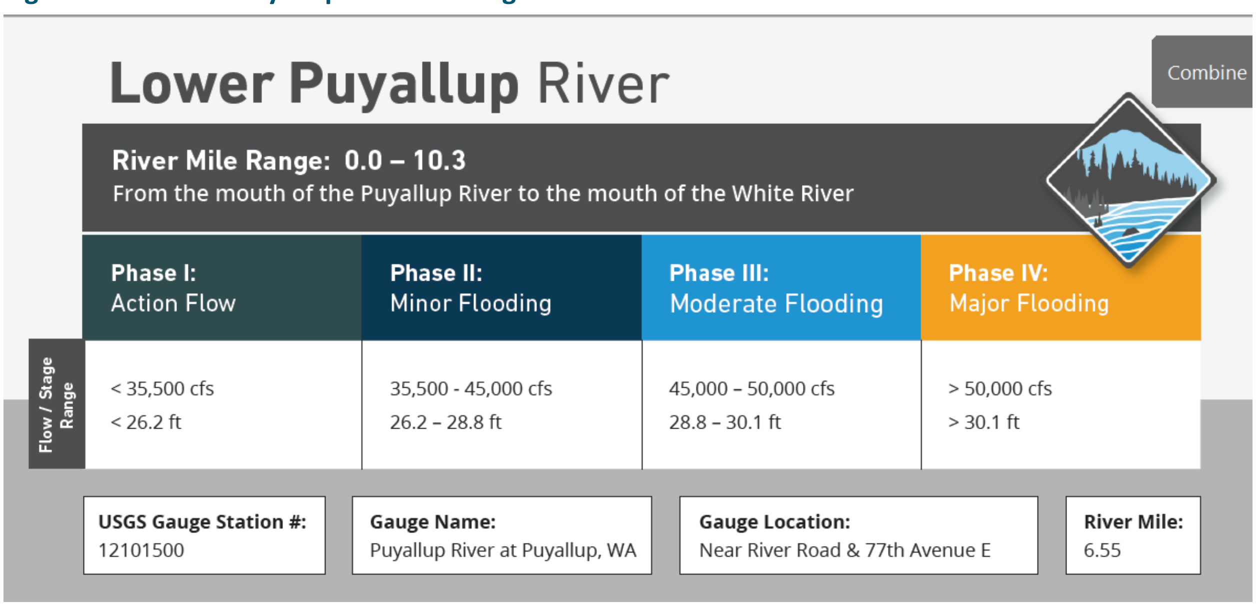
Event	Right Bank Residential	Right Bank Commercial	Right Bank Industrial	Right Bank Total	Left Bank Total	Total Damage Costs
10-year	$8.1M	$24.8M	$52.0M	$85.6M	$2.0M	$87.6M
100-year	$9.5M	$40.4M	$55.5M	$105.6M	$9.3M	$115.0M
500-year	$9.7M	$54.5M	$55.8M	$120.4M	$15.4M	$135.9M

Source: Lower Puyallup River Flood Protection Investigation – Without Project Analysis (Tetra Tech 2009). Costs have been updated to reflect current values.

6.3.6 Lower Puyallup Flow Warning Matrix

The Lower Puyallup River has four flow categories: Phase I, Action Flow; Phase II, Minor flooding; Phase III, Moderate flooding; and Phase IV, Severe flooding. These categories describe the observed or expected severity of the flood impacts in that area. However, the severity of flooding at a given stage is not necessarily the same at all river locations. Most river reaches in Pierce County have a defined flow warning matrix that is used during flood events. Figure 6.10 shows the flow warning matrix table for the Lower Puyallup River.

Figure 6.10. Lower Puyallup Flow Warning Matrix



Historical Flooding

Significant flooding occurred in the lower Puyallup River in 1917, 1933, 1934, 1965, 1977, 1986, 1990, 1996, 2006, and 2009 (see Table 6.5). The largest flood on record since construction of Mud Mountain Dam occurred in January 2009, with a flow of 48,200 cfs, which was an approximately 100-year event in the lower Puyallup River based on flood frequency flow estimates (FEMA 2009). Flows in excess of 45,000 cfs are considered severe with significant flooding expected. Moderate flooding occurred in the lower Puyallup in November 2014, again in October, November, and December 2015, and also in February 2020.

Table 6.5. Historical Flooding in Lower Puyallup River

Date	Puyallup River Flows at Puyallup Gauge (cfs)
December 1917	40,500[a]
December 1933	57,000[a]
October 1934	39,500[a]
January 1965	41,500
December 1977	40,600
November 1986	43,800
January 1990	44,800
November 1990	41,900
February 1996	46,700
November 2006	39,700
January 2009	48,200
November 2014	34,200
December 2015	39,800
February 2020	39,500

[a] Mud Mountain Dam (constructed on the White River in 1948) not in place.
Source of data: USGS Puyallup Gauge flow records

Flood Damage to Facilities

Flood damage to the levees along the lower Puyallup River has been infrequent in recent decades. In 2002, loss of riparian vegetation and bank erosion began on the right bank of the levee at RM 5.3. Bank erosion continued between 2002 and 2009, until it was repaired by Pierce County in 2009.

The levee and revetment in the vicinity of 12th Street SE (approximately RM 9.3, left bank) has been overtopped on several occasions in the last 20 years, including 1996, 2006, and 2009, resulting in flooding and sediment deposition along the top of levee and adjacent areas. No significant damages were identified.

Flood damages to the lower Puyallup River flood risk reduction facilities generally have been pretty mild in the past three decades. However, two substantial repairs have been made to repair damages due to erosion and one repair to fix fractured concrete panels. Damages from major floods and high-water events between 1990 and 2021 have resulted in approximately 26 identified damage locations comprising 0.6 mile of levees and revetments. Table 6.6 summarizes recorded levee and revetment damages. There are isolated locations along the reach where repairs have occurred. The system is approximately 100 years old and showing signs of its age. Pierce County maintenance crews annually inspect and monitor the reach and implement repairs when necessary.

Table 6.6. Summary of Damages to Lower Puyallup River Facilities (1990–2021)

Storm Season/ Segment Name	Bank	River Mile	Damage Lineal Feet	Damage
1996				
Tiffany's	Left	9.2	100	Toe and slope failure.
2005				
River road	Left	7.2	540	Concrete panel repair.
2009				
North levee road	Right	5.3	190	Silt bench repair.
2010				
Benston/boatman	Right	9.35	100	Moderate slumping.
Benston/boatman	Right	9.35	200	Moderate slumping, Major erosion; concrete panels collapsed.
2011				
Benston/boatman	Right	9.35	200	4-foot deep slump. Exposed concrete at toe.
Murphy	Right	8.47 – 8.54	390	Scour and minor cracking in silt bench. Scour 5 feet in areas.
North levee road	Right	4.27	105	4-foot slump.
North levee road	Right	4.45	106	Sha Dadx Seepage Control Buttress and drainage.
Old cannery	Right	10.3	60	Toe rock failure.
River road	Left	6.4	30	6-foot deep scour.
2012				
Murphy	Right	8.5	200	Toe and rock failure, some slump and erosion.
Murphy	Right	8.55	30	Scour pocket out of face, downed tree.
North levee road	Right	4.3	30	4-foot slump.
North levee road	Right	4.45	180	Sha Dadx: soil buttress - sand boils.
North levee road	Right	5.8	100	Melroy Bridge partial scour/slumping.

Storm Season/ Segment Name	Bank	River Mile	Damage Lineal Feet	Damage
River road	Left	3.05	40	Cave dug into silt on left bank, 5-foot scour depth.
River road	Left	6.4	30	6-foot-deep scour in silt bench due to culvert outfall.
2014				
River road	Left	7.45	45	Toe and face rock failure.
2015				
Benston/boatman	Right	9.35	150	Slump in revetment. Concrete panel missing.
2017				
Benston/boatman	Right	9.35	200	Storm drainage outlet onto revetment face has caused severe scour to occur and end segments of the outlet pipe have failed.
Benston/boatman	Right	9.3	140	Potential scour.
Murphy	Right	8.4	120	Silt bench scour.
Murphy	Right	8.41	25	Scour.
2020				
North Levee Road	Right	4.2	25	Silt bench repair.
Benston/Boatman	Right	9.3	300	Extensive scour beyond historic piling location.

6.3.7 Key Accomplishments since the 2018 Flood Plan Update

Major Projects

Since the 2018 Flood Plan Update was completed, there have been no major maintenance repairs in the lower Puyallup River reach. However, four projects took place along this reach since 2018.

Clear Creek Habitat Restoration Project

This project improved access to salmon habitat and increased flood storage capacity by removing sections of an existing access road separating Clear Creek from an adjacent wetland owned by the Port of Tacoma. The road removal resulted in approximately 5,000 cubic yards of floodplain excavation and greatly improved access to critical salmon rearing habitat. The project is located near the mouth of Clear Creek. Construction was completed the summer of 2022. Learn more about this project online at the Clear Creek Habitat Restoration web page.

Clear Creek Flood Gate Restoration

This project will replace an existing wooden flap gate on one of the two culverts that drain Clear Creek to the Puyallup River. The new gate will be mechanized and designed to work in conjunction with the other mechanized flood gate and be optimized to better allow fish passage and reduce impacts from flooding along Clear Creek. Construction is planned for the summer of 2023. Learn more about this project online at Clear Creek Flood Gate web page.

Clear Creek Strategy Plan

In 2020, Pierce County completed the first of its kind strategy plan for the Clear Creek/Riverside area. The purpose of the Clear Creek Strategy Plan (Strategy Plan) is to improve conditions related to flooding and drainage, agriculture and land use, social challenges, and fish habitat ecosystem functions. Pierce County conducted a facilitated process in which the community worked together to create solutions that achieved results desired by the people who live and work there. This process included stakeholder interviews and workshops as well as an open house with comment period. The resulting Strategy Plan is a flexible, comprehensive plan intended to set the broader framework for projects and studies within the watershed. The Strategy Plan guides decision-making, is a tool for education and communication, and provides a long-range perspective for the Clear Creek/Riverside area. More information about the Strategy Plan can be found at the Clear Creek Strategy Plan web page.

Clarks Creek Property Acquisition 'House of Tomorrow'

Pierce County was awarded a FEMA Flood Mitigation Assistance grant to acquire the property and house located at 4907 66th Avenue East in unincorporated Pierce County (see Figure 6.11). This project is a voluntary property acquisition by the property owner. The property and house experience frequent repetitive flooding (as shown in Figure 6.12) and damages due to its location along the Clarks Creek banks and shoreline. The purpose of this project is to mitigate the repetitive flood losses. Upon acquisition of the property, the house will be removed from the property and flood hazard area, thereby mitigating the flood losses. The House of Tomorrow is determined to be historically significant; however, it is not on the Pierce County Historical list or the National Historical Register of Historic Places list. Prior to acquisition of the property and removal of the house, much work will be performed to document the historical significance of the house and property in detail. This includes documenting the original owner and architect who designed the house, which was built in 1938. Pierce County is one of eight stakeholder signatories to an executed Memorandum of Agreement (MOA), which stipulates mitigation measures to resolve the project's adverse effects to the house and property historical significance. The other signatories to the MOA include:

- FEMA
- Washington Emergency Management Division
- Washington State Department of Archaeology and Historic Preservation
- Pierce County Landmarks and Historic Preservation Commission
- Washington Trust of Historic Preservation
- Documentation and Conservation of Building, Sites, and Neighborhoods of the Modern Movement in Western Washington

- Puyallup Historical Society

Figure 6.11. The House of Tomorrow on Clarks Creek in Unincorporated Pierce County

Figure 6.12. Flooding along Clarks Creek December 2015

This project is currently in the historical significance documentation stage, and Pierce County has retained a consultant to help with this type of project. Pierce County plans to have this project completed by September 2024. More information on this project can be found at the Clarks Creek Property Acquisition Project web page.

6.3.8 Land Acquisitions

A total of 65 acres of property was acquired between 2018 and 2021 in the Lower Puyallup reach. These property acquisitions supported capital projects located in Clear Creek, Rhody Creek, and the Port of Tacoma.

6.3.9 Flood and Channel Migration Hazard Mapping

Flood Hazard Mapping

Hazard mapping in the lower Puyallup River includes detailed flood studies (FEMA, NHC 2006) that show significant flood hazards in the lower Puyallup valley. The flood hazards were identified because the existing levees are not built high enough to meet current FEMA standards. In order to publish the countywide DFIRMs, the areas behind the non-accredited levees were secluded from map updates. This means that most of the lower Puyallup valley is showing the old flood risk as it was understood in the 1970s.

The FEMA/NHC study flood risk areas along the lower Puyallup River include extensive industrial, commercial, residential, and agricultural land uses along the right bank at the Port of Tacoma and the cities of Tacoma, Fife and Puyallup. Along the left bank, there are fewer commercial and industrial uses, but extensive residential and agricultural uses, and public infrastructure.

In unincorporated Pierce County, flood risk areas behind the levees are being regulated based on the risk of a levee failure or overtopping, even though this risk is not shown on the DFIRM. The Tacoma wastewater treatment plant, on the left bank between State Route 509 and Lincoln Avenue, is an example of a critical facility along the lower Puyallup River potentially subject to flooding.

The DFIRM maps for the lower Puyallup show 4,494 acres within the special flood hazard area (SFHA) or 100-year floodplain, and unincorporated Pierce County regulates an additional 942 acres as flood fringe. The mapped deep and fast flowing (DFF) area is 1,087 acres.

Channel Migration Hazard Mapping

Channel migration mapping methods require measuring changes over the period of record. No channel migration zones (CMZs) have been mapped for the lower river due to the river channel being confined between the levees for the last 100 years. The regulated FEMA floodway within existing levees is the default CMZ for the lower Puyallup River according to Pierce County Code (PCC) 18E.70.020.

Channel Migration Zone (CMZ)

The CMZ refers to the geographic area where a stream or river has been and is susceptible to channel erosion and/or channel occupation (Washington State Department of Ecology 2003).

6.3.10 Problem Identification

Table 6.7 sets out the flooding and channel migration problems identified in the lower Puyallup River floodplain.

Table 6.7. Priority Problems Identified in Lower Puyallup River

Location	Problem Description	Source
Levee and Revetment Overtopping and Breaching		
RM 2.9 – RM 3.1 LB	Levee overtopping potential upstream threatens Tacoma Wastewater Treatment Plant.	City of Tacoma
RM 2.98 – RM 8.12 RB	De-accredited North Levee Road levee results in increased flood risk for infrastructure and property.	City of Fife, Tacoma, Pierce County, Port of Tacoma
RM 4.8 RB	Flood levels in 2006 and 2009 nearly overtopped levee at 54th Avenue East.	City of Fife
RM 6.8 – RM 6.9 RB	Flood levels in 1996 and 2009 nearly overtopped levee at Freeman Road.	City of Fife
RM 8.5 RB	Golden Rose mobile home park silt bench erosion	Unincorporated Pierce County
RM 8.2 – RM 8.6 LB	Levee overtopping floods Tiffany’s skating rink, Riverwalk Apartments, and road underpass.	City of Puyallup, Pierce County
RM 8.1 – RM 8.2 RB	Levee overtopping floods North Meridian-north shore underpass.	City of Puyallup

Location	Problem Description	Source
RM 9.1 – RM 9.25 LB	Levee overtopping floods East Main Street "flash cube" building.	City of Puyallup
RM 9.3 – 9.5 LB	Levee overtopping floods RiteAid shopping center parking lot and loading docks.	Pierce County
RM 9.8 – RM 10.3 LB	Levee overtopping floods Linden golf course.	City of Puyallup
RM 9.4 – RM 10.6 LB	Levee overtopping and sedimentation impacts levee access road and public trail.	Pierce County
Tributary Backwater Flooding		
RM 2.1 LB	Backwater flooding at Cleveland Way pump station caused extensive flooding in 1996.	City of Tacoma
RM 2.9 LB	Clear Creek backwater flooding caused extensive flooding in 1996 and 2009; some flooding in 2006.	Pierce County, City of Tacoma
RM 5.0 RB	Oxbow Lake backwater flooding of pump station.	City of Fife
RM 5.8 LB	Clarks Creek backwater flooding of homes, multiple occurrences.	Pierce County, City of Tacoma
RM 6.9 LB	City storm drain flooding (NW 13th Avenue).	City of Puyallup
RM 7.9 LB	City storm drain flooding (4th Street NW).	City of Puyallup
RM 9.4 LB	Deer Creek backwater flooding (Shoppe concrete).	City of Puyallup
Public Safety/Emergency Rescues		
RM 2.9 – RM 4.8 LB	Clear Creek (>10 emergency rescues in 2009).	Pierce County Sheriff
RM 4.2 – RM 8.2 LB	Emergency evacuation in Fife in 2009.	City of Fife
Flooding of Structures and Infrastructure (Roads/Bridges) [not already noted above]		
RM 0.7 – RM 2.2 RN/LB	Three bridges of concern (11th Avenue, Lincoln Avenue, and Puyallup Avenue) – wood on piers and capacity.	City of Tacoma
RM 2.9 – RM 6.9 RB	Critical facilities (schools, police station) at risk of flooding due to overtopping/breaching of levee.	City of Fife
RM 3.1 LB	Localized road flooding north of I-5.	City of Tacoma
RM 4.0 – RM 5.5 RB	Potential flooding of Tacoma Power's Fife substation.	City of Tacoma
RM 5.75 RB/LB	Milroy bridge fails to meet minimum standard for bridge clearance.	Pierce County Transportation, City of Fife
RM 6.8 – RM 6.9 LB	Puyallup Wastewater Treatment Plant flooding.	City of Puyallup
RM 9.1	SR 512 bridge at Pioneer – wood accumulation and bed scour at piers.	WSDOT

Location	Problem Description	Source
Sediment and Gravel Bar Accumulation		
RM 2.9 – RM 6.9	Bed elevation increases between I-5 and Freeman Road a concern due to reduced conveyance capacity.	City of Fife, Pierce County
RM 5.8 – RM 10.3	Bed elevation increases from Clarks Creek to White River a concern due to reduced conveyance capacity.	City of Puyallup, Pierce County
Facility Maintenance and Repair Needs		
RM 2.8 – RM 8.6 RB/LB	Concrete panel repair as needed due to vegetation/roots. General condition of concrete panels is unknown due to presence of established silt benches.	Pierce County
Fish Habitat Problem Areas		
RM 2.6 – RM 3.7 RB	Levee separates river from historical estuary on Union Pacific property and adjacent farmland.	Pierce County, Puyallup Tribe
RM 5.0 RB	Oxbow Lake is former river meander that has been cut off from river by levee.	City of Fife
RM 6.7 – RM 7.4 RB	Freeman Road Oxbow cut-off from river by levee.	Puyallup Tribe, Pierce County
RM 8.2 RB	72-inch-diameter Wapato Creek outflow to Puyallup River prevents headwater flow to Wapato Creek.	Puyallup Tribe
RM 9.4 – RM 10.3 RB	Levee cuts off confluence wetlands river channel.	Puyallup Tribe
RM 9.6 – RM 10.5 LB	Levee cuts off-channel habitat and floodplain from river channel.	Puyallup Tribe
Public Access		
RM 0.6 – RM 2.9 RB/LB	USACE limits access to levee.	City of Tacoma
RM 2.0 – RM 6.5 RB/LB	Lack of connecting trail along river from RM 6.5 to City of Tacoma (on left or right bank).	City of Tacoma, Pierce County Parks
RM 6.8 – RM 10.7	Repeated flood damage to trail limits access; no trespassing sign at RM 6.8 discourages access.	City of Puyallup

Source: Pierce County SWM

LB = left bank; RB = right bank; RM = river mile; USACE = U.S. Army Corps of Engineers; WSDOT = Washington State Department of Transportation

6.3.11 River Reach Management Strategies

6.3.11.1 Conditions and Constraints of the Lower Puyallup River

Recommended river reach management strategies for the lower Puyallup River take into account numerous conditions and constraints, as follows:

- Development and land use in adjacent floodplain – The lower Puyallup River floodplain is suburban and rural and encompass parts of Puyallup and South Hill. The total assessed value of property in the 100-year floodplain is $272.6 million (EcoNorthwest 2022).
- River management facilities – Both the left and right banks of the Puyallup River are constrained by levees and revetments along the entire Lower Puyallup reach.
- River channel gradient and width – Channel gradient varies from 0.035 to 0.06 percent. Width varies from 350 feet to 500 feet in the lowest part of the river and narrows to 250 feet in the upper portion of the lower Puyallup River.
- Presence of salmon spawning and rearing habitat – All species of salmon are found in the lower Puyallup River, including Chinook, pink, chum, coho, and sockeye, as well as steelhead, bull trout, and cutthroat trout. Both spawning and rearing habitats are present.
- Riverbed ownership and tribal agreements with the Puyallup Tribe of Indians.
- Sediment transport accumulation and incision – Mostly sand and silt accumulate below RM 8, with mixed sand and silt and some gravel above RM 8. The mean riverbed elevation between RM 0.0 to approximately RM 8.5 changed in elevation from -0.5 feet to +2.0 feet between 1984 and 2009. Upstream of RM 8.5 to the confluence of the White River at RM 10.3, sediment deposits ranged from 0.5 feet to 3.5 feet (see Figure 6.7).

The primary objective for the lower Puyallup River is to maintain the structural integrity of the levee and revetment system so it continues to reduce risks to public health and safety and reduce property damages. Another objective is to make improvements to the levees so they can be accredited to FEMA standards.

The final management strategy objective is to identify capital projects that provide multiple benefits in addition to flood risk reduction. Additional benefits may include the enhancement and creation of aquatic habitat, riparian re-vegetation, and strategic placement of large woody material.

6.3.11.2 Lower Puyallup River Reach Management Strategies

Given the significant amount of development, major interstate transportation infrastructure, and commercial industry centers in the lower Puyallup River, this 2023 Flood Plan recommended design and management strategies are described below.

Structural Management Strategies:

- RM 0.0 – RM 10.3 left and right bank – The goal for levees should be 200-year event design plus three feet of freeboard.

Non-structural Management Strategies:

Floodplain development regulations

Property acquisition or purchase of development rights

6.3.11.3 Interim Risk Reduction Measures:

- No interim risk reduction measures (IRRMS) are recommended for this reach of the Puyallup River.

6.3.12 Recommended Capital Projects

The following capital improvement projects are recommended to address the priority problem areas identified in Table 6.7. Pierce County capital projects are defined as construction projects over $75,000. They are projects that may be elevated in priority and included within the 6-year Capital Improvement Plan element of Pierce County Comprehensive Plan. Projects less than $75,000 in unincorporated Pierce County are included within the Maintenance Program.

Riverine Flood Project **Project Score: 69**

Project Name: Clear Creek Floodplain Reconnection Project

Project web page location: www.piercecountywa.gov/3321/Clear-Creek-Flooding

Project location: RM 2.9, left bank, confluence of Clear Creek and Puyallup River (see Figure 6.13)

Estimated project cost over a 10-year period: $20 million

Total project cost: $58.1million

What is at risk?

The Clear Creek community sits between Clear Creek and the Puyallup River and varies in elevation between +10 feet to +20 feet (see Figure 6.14). The base flood elevation for the area is between 19 to 23 feet. During high flows on the Puyallup River, two gates close to keep the area safe from flooding from the Puyallup River, but this results in Clear Creek backing up and flooding up to 400 acres of farmland, commercial, and residential properties (see Figure 6.15). There was extensive emergency evacuation of this area by boat during the January 2009 flood event. Properties that are impacted by the backwater flooding of Clear Creek are estimated to be in excess of $42 million.

What is the recommended solution?

The Clear Creek area is in a designated DFF floodway due to the uncertainty that River Road levee would protect the area for flooding attributed to the Puyallup River. The area is also susceptible to frequent backwater flooding from the Clear Creek system that drains the plateau. Currently, there are no viable solutions to completely prevent the Clear Creek area from flooding. Ongoing proactive efforts to purchase property from willing sellers and relocate residents will have the largest influence on flood risk reduction.

A capital project concept was proposed in the 2013 Flood Plan that provided a non-mechanical interface between the Puyallup River and Clear Creek, with a ring-levee on the landscape at the 14- or 16-foot contour to contain the volume of the 100-year event. Community and local organization feedback demonstrated that a project on the landscape in this area would require a more integrated approach. The Clear Creek Strategy Plan, initiated by Pierce County in 2018 and completed in 2020, identified core values of the area that would need to be incorporated within a project design. This plan can be found online at the Clear Creek Strategy Plan web page. The Strategy Plan is a framework to support continued collaboration as actions develop on the landscape.

Figure 6.13. Location of the Clear Creek Acquisition and Floodplain Reconnection Project on the Lower Puyallup River

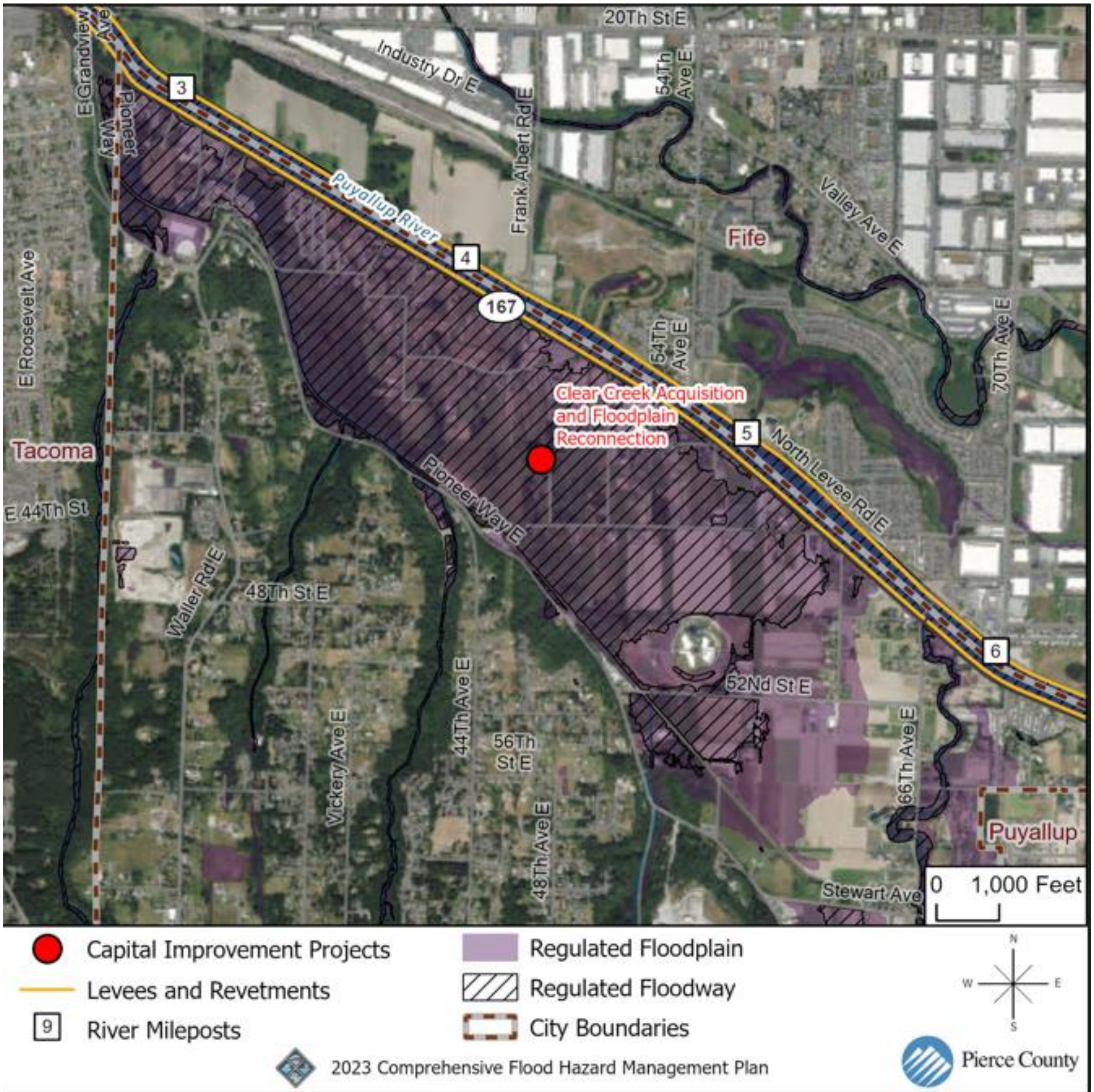


Figure 6.14. Image of the Clear Creek Area

Figure 6.15. January 2009 Flood Event in the Clear Creek Area
Photograph source: WSDOT

Because of the diversity of interests in the Clear Creek area and the high level of investment from multiple organizations, a landscape-scale project requires intensive collaboration. Project planning is now occurring with the established Floodplains for the Future partnership, a Pierce County led and facilitated effort of integrated floodplain management capital projects. The Clear Creek Integrated Design will identify and advance design on near-term actions and identify a conceptual long-term vision for habitat, agricultural land, and flood efforts in the floodplain bench and surrounding hydrologic inputs. Implementation of near-term actions will occur as funding allows, and Floodplain for The Future partners will continue to work towards refining and reaching the long-term concepts.

A few near-term actions being considered include agricultural drainage system improvements, re-meandering of Clear Creek, continued acquisition of flood-risk properties, and removal/replacement of Gay Road culverts and other agricultural culverts. Mid- to long-term actions consider a separation of the agricultural system from the habitat system, more extensive habitat improvements, and necessary infrastructure for an unconstrained confluence of Clear Creek and the Puyallup.

Who will Pierce County coordinate with on this project?

Pierce County is coordinating on the Clear Creek Floodplain Reconnection project with Floodplains for the Future, Puyallup Tribe, Pierce County OCE, Pierce County Agricultural Program, Pierce Conservation District, South Puget Sound Salmon Enhancement Group, Drainage District 10, residents and agricultural community, Port of Tacoma, Washington State Department of Transportation (WSDOT), BNSF Railway, U.S. Fish and Wildlife Service (USFWS), National Marine Fisheries Services (NMFS), Washington Department of Fish and Wildlife (WDFW), and USACE.

What are the environmental considerations?

Ultimately, this project will improve habitat complexity of Clear Creek, with the intention to improve connectivity of Clear Creek to the Puyallup River. The project will also improve agricultural drainage, with the intention to separate the drainage system, and will not increase the already-existing flood risk. Threatened species present in the project area include Chinook salmon, steelhead, and bull trout.

Additional Relevant Project Information

The Clear Creek Dialogue Group consists of representatives from affected Tribes, local government, non-profit organizations, the local drainage district, the Port of Tacoma, and other interested parties that are working collaboratively to develop a suite of projects that benefit farming, habitat, and reduce the flood risk while maintaining the character of community. The projects will work in concert with representative partners, thereby solving issues without diminishing the needs of other partners. The dialogue group and the design consultants are committed to have several actions available at the 30 percent design level by 2024.

What is the current status of the project?

The project is currently in the property acquisition and conceptual design phases.

What will take place with this project from 2023–2033?

Continued purchases of properties within the project area and coordination with the Clear Creek Dialogue Group will take place in the next 10 years.

What are the Project Benefits/Drivers?

Flood Risk

Riverine Flood Project **Project Score: 34**

Project Name: White And Puyallup River Confluence Property Acquisition

Project web page location: [Projects in Planning | Pierce County, WA - Official Website (piercecountywa.gov)]

Estimated project cost over a 10-year period: $3 million

Total project cost: $3 million

Project location:

Right bank of the Puyallup River between RM 9.4 and 10.3, immediately downstream of its confluence with the White River (see Figure 6.16).

What is at risk?

Houston Road (arterial) and one rural outbuilding. No residential, commercial, or industrial structures identified. Figure 6.17 shows January 2009 flooding over Houston Road East.

Figure 6.16. Location of the White and Puyallup Rivers Confluence Property Acquisition Project on the Lower Puyallup River.

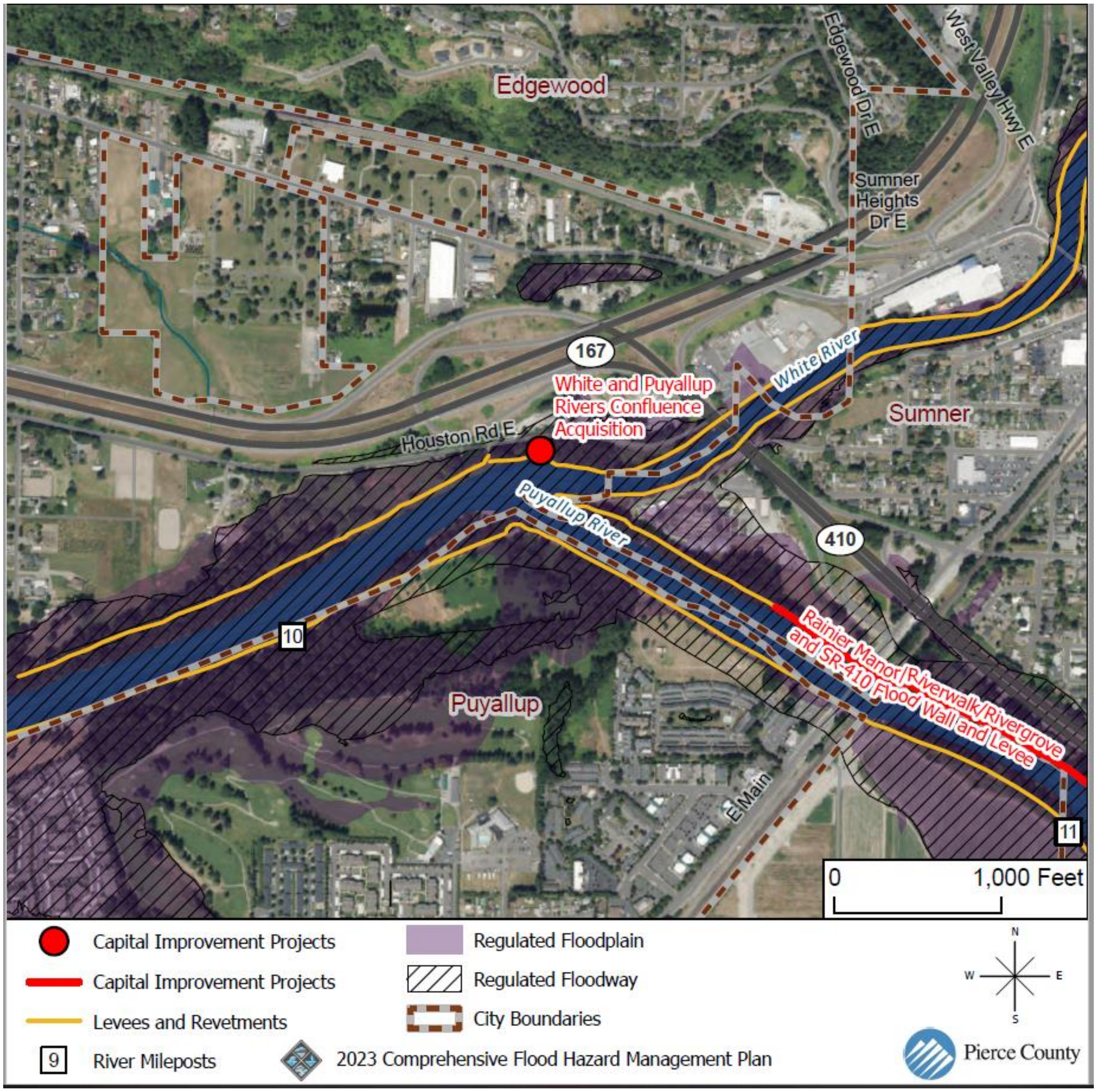


Figure 6.17. Flooding January 8, 2009, Houston Road East

What is the recommended solution?

Property acquisition is recommended at this location as part of a mitigation package for ongoing flood risk reduction structure maintenance and operations, as included in the draft Habitat Conservation Plan (HCP) as mitigation. Although Pierce County cannot commit to carrying out a floodplain restoration project during the proposed 30-year HCP permit term, the county will ensure funding for property acquisition during the HCP permit term, thus ensuring the floodplain will not be subject to any form of development or incompatible land use. Property acquisition does not offset the effects of the of taking of species under ESA, but acquisition does set the stage for future restoration that will benefit White River Chinook salmon as well as other species addressed in the HCP. Placing these parcels in county ownership would facilitate restoration by the county or through other partnerships.

What is the current status of the project?

No acquisitions have occurred to date.

What will take place with this project from 2023–2033?

Acquisitions could begin to take place from willing sellers during the 2023–2033 timeframe. Acquisitions would likely be implemented following receipt of Incidental Take permits from United States Fish and Wildlife Service and the National Marine Fisheries Service.

What are the Project Benefits/Drivers?

Habitat   Flood Risk   Habitat Conservation Plan

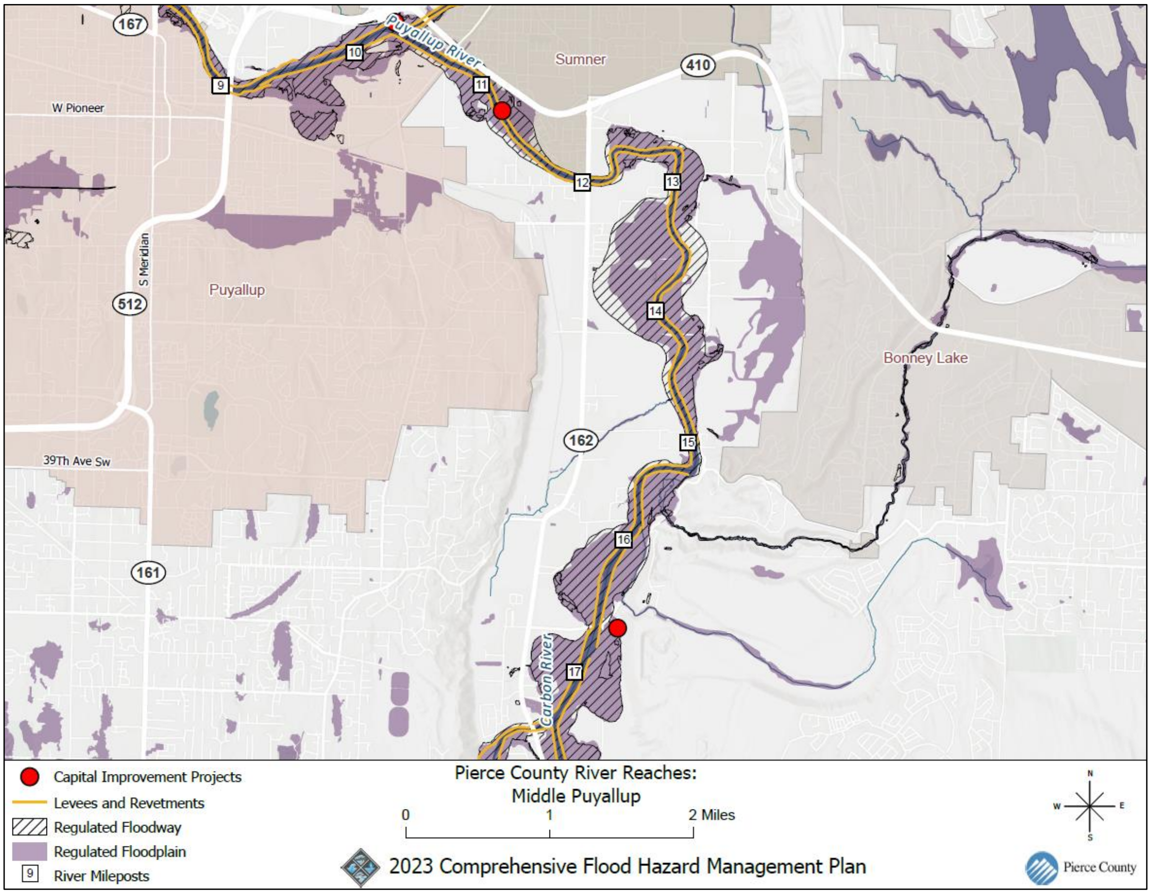
6.4 Middle Puyallup River

6.4.1 Overview

The middle Puyallup River reach begins at the confluence of the White River at RM 10.3 and continues upstream to the confluence with the Carbon River at RM 17.4, downstream of Orting (see Figure 6.18). This river reach covers 42.7 square miles of planning area. Throughout this reach, the river channel is a combination of large meander bends with segments that are straightened and confined by a combination of levees, revetments, and valley walls. The surrounding watershed and land uses are mostly urban near the White River confluence in the cities of Sumner and Puyallup, while predominantly agricultural and rural residential through the Alderton-McMillan communities, and upstream to the Carbon River confluence toward Orting (GeoEngineers 2003).

Several tributaries enter the Puyallup River along this middle reach; these tributaries include Alderton Creek, Van Ogles Creek, Fennel Creek, Ball Creek, and Canyon Falls Creek. The largest tributary, Fennel Creek, drains most of the eastern upland plateau, including much of the city of Bonney Lake. Fennel Creek flows into the Puyallup River near RM 15.2. Chinook, coho, pink, and chum salmon and steelhead, cutthroat, and bull trout use the entire reach of the middle Puyallup River.

Figure 6.18. Planning Area for the Middle Puyallup River Reach



6.4.2 Geology and Geomorphology

The middle Puyallup River valley is a broad, low-gradient alluvial plain in which the river meanders within its corridor confined by levees and revetments and periodically floods. The river is located within a trough-like valley with steep valley walls that widen in the vicinity of Orting. The average channel gradient varies from 0.17 to 0.25 percent between RM 10.3 and RM 17.4. This river reach generally has lower velocities and shallow gradients, thus allowing the river to act primarily as a depositional reach for sediment that enters from the upper Puyallup and Carbon rivers. The channelization and existing levees within the middle Puyallup River were mostly constructed between the 1950s and the 1970.

Prior to channel confinement, the main channel of the Puyallup River in this reach was a freely migrating channel, a natural response of the river to high sediment loads from the upper Puyallup River and Carbon River. The reaches immediately downstream of the Carbon River confluence (RM 14.2–RM 17.4) are braided due to a significant decrease in channel gradient and the high influx of sediment load from the upper Puyallup River and Carbon River. The Puyallup River transitions back to a sinuous meander bend pattern below RM 14.2, which indicates a generally even balance between sediment transport capacity and sediment influx (GeoEngineers 2003).

The channel width is generally confined to between 200 and 300 feet. In 2003, a CMZ analysis delineated severe, moderate, and low-risk CMZs along the middle Puyallup River. The approach was based on the relationships between channel topography, sediment influx, transport capacity, and the type and character of channel migration in each reach prior to confinement (GeoEngineers 2003). The most extensive severe CMZs in the middle Puyallup River are between RM 13.2 and RM 14.3, where the CMZ has a maximum width of 3,500 feet, and between RM 15.8 and RM 16.7, where the CMZ has a maximum width of 2,200 feet.

6.4.3 Hydrology and Hydraulics

Recent hydrologic studies show that with the additional stream flow data from recent floods, the 100-year discharge is approximately 49,000 cfs. This is a significant increase from earlier FEMA Flood Insurance Study reporting that used data ending in the 1970s and 1990s. The USGS stream gauge (#12096500) at Alderton produced a variable period of record, with gaps in the data due in part to flood damage. The Alderton gauge flow data appears to consistently show data that does not correlate to what is expected based on flow data from the lower Puyallup gauge (#12101500). Measuring discharge at this site is difficult due to unstable channel conditions. There have been historical issues with this gauge, so an additional gauge located at Main Street was added on October 2010 to provide more data. Measured discharge persists from the State Route 162 Bridge in Sumner through a series of three 90-degree bends upstream to Riverside County Park. Based on streamflow measurements data, the flood frequency flowers were derived for the middle Puyallup River as show in Table 6.8.

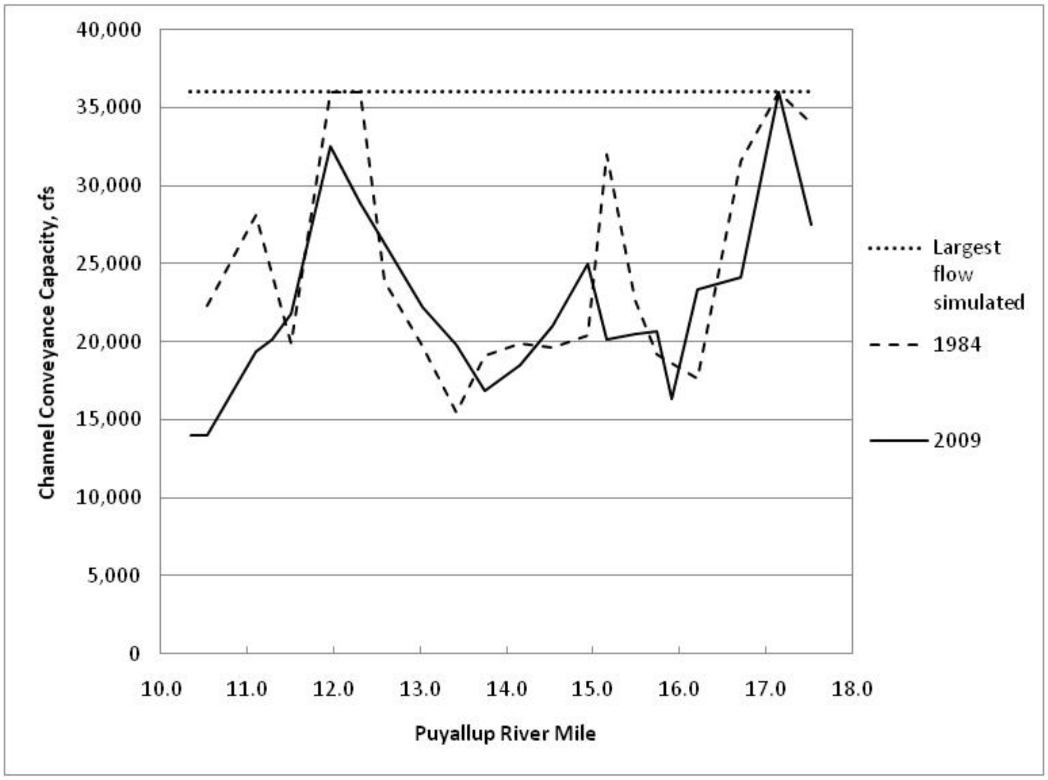
Table 6.8. Flood Frequency Flows for the Middle Puyallup River

	Discharge (cfs)				
Location	10-year Event	50- year Event	100- year Event	500- year Event	Method
Middle Puyallup River Gauge (at Alderton, #12096500)	24,400	33,200	36,800	45,900	1987 FEMA Flood Insurance Study (Log Pearson Type III)
Middle Puyallup River Gauge (at Alderton, #12096500)	27,500	38,600	43,500	55,100	2009 FEMA Flood Insurance Study for Pierce County (NHC 2006)

Source: FEMA Flood Insurance Studies (1987 and 2009)

The USGS study of conveyance capacity (USGS 2010) indicates that the middle Puyallup River channel can convey between 15,000 to 35,000 cfs before overtopping either the left or right bank (see Figure 6.19). The change in conveyance capacity since the 1984 USGS study (Sikonia 1990) has been variable. The variability is largely due to increased sediment deposition within the channel, which has decreased the channel conveyance capacity overall.

Figure 6.19. Channel Conveyance Capacity for the Middle Puyallup River

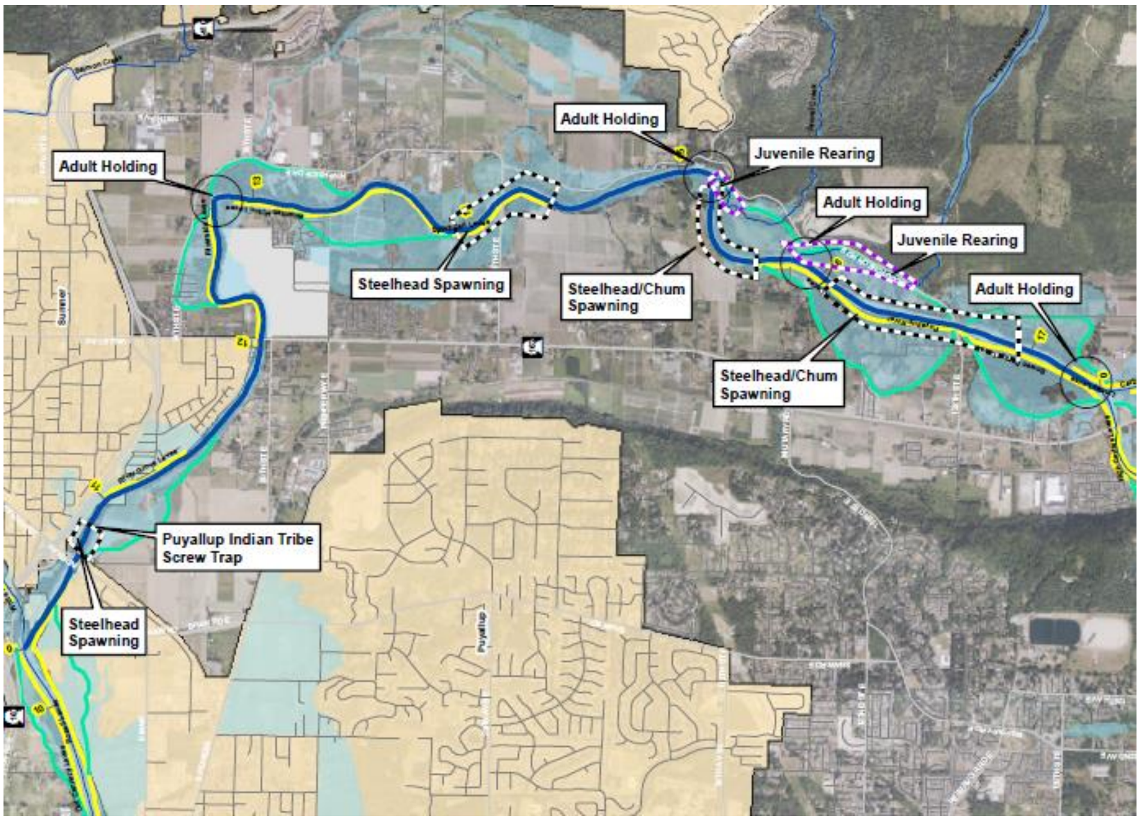


6.4.4 Ecological Context and Salmonid Use

Historically, the middle Puyallup River likely contained the best main channel spawning habitat in the Puyallup River, especially for Chinook. This is due to the mild gradient, wide floodplain, a relatively stable meander pattern, and large gravel bars that created a complex of riffles and pools. Prime spawning-sized gravel characterized this part of the river. Here the bedload transitions from the predominant sand bed in the lower Puyallup River to the cobble of the upper Puyallup River. This reach also historically contained oxbows and remnant channels and perennial side channels, which would have supported wetlands and high-quality rearing habitat for juvenile salmon, especially during the winter when flow velocities are high in the main channel. Along the base of the valley walls were many "wall-based" channels, which are small, cool water, spring-fed streams that create prime summer rearing habitat for juveniles and spawning habitat for coho and chum salmon and cutthroat trout. Beavers were a driving force on the landscape and increased the rearing habitat through construction of dams and creation of ponds within the floodplain.

Today, this section of the river is predominantly a single thread due to levee channelization for protection of farmland, residential, and commercial land uses. The floodplain and associated habitats have become disconnected from the river by levee containment and revetment system and land development. Numerous migration barriers exist that prevent or limit the use of off-main channel salmon habitat. River channelization has increased flow velocities during floods and increased the risk that scour will destroy fish redds. In addition, the lack of a functioning riparian area limits fish habitat by reducing the amount of wood and salmon food sources from entering the river. Despite these challenges, the middle Puyallup River still provides valuable habitat for salmonid spawning and rearing at select locations within the reach (see Figure 6.20)

Figure 6.20. Salmonid Habitat in the Middle Puyallup River



6.4.5 River Management Facilities, Flooding, and Flood Damage

The middle Puyallup River levees and revetments form nearly continuous bank protection from the confluence with the White River at RM 10.3 to the confluence with the Carbon River at RM 17.4. Many levees within the middle Puyallup River system participate in the USACE Public Law (PL) 84-99 Levee Rehabilitation program. Revetment structures make up a significant number of the river management facilities in the middle Puyallup River reach. However, revetments are ineligible for inclusion in the PL 84-99 program.

Pierce County currently owns and maintains approximately 12.4 miles of flood risk reduction facilities along the middle Puyallup River in a combination of levees and revetments.

Table 6.9 contains a list of river management facilities and their ownership.

Table 6.9. Levees and Revetments in the Middle Puyallup River

Name	Location	Ownership
Right Bank		
Traffic Avenue Revetment	RM 10.29 – RM 11.00	Pierce County
River Grove Levee[a]	RM 11.00 – RM 11.48	Pierce County
Riverwalk Revetment	RM 11.48 – RM 12.39	Pierce County
Right Bank (continued)		
Riverside Levee[a]	RM 12.39 – RM 12.79	Pierce County
Riverside Revetment	RM 12.79 – RM 12.81	Pierce County
Van Ogle Revetment	RM 12.81 – RM 14.24	Pierce County
Evanger/White Revetment	RM 14.24 – RM 15.01	Pierce County
Fennel Creek Revetment	RM 15.15 – RM 15.89	Pierce County
Mosby Revetment	RM 15.88 – RM 16.64	Private
128th - McCutcheon	RM 16.64 – RM 16.80	Pierce County
Lindsay Levee[a]	RM 16.89 – Carbon RM 1.20	Pierce County
Left Bank		
Knutson Levee	RM 10.73 – RM 11.63	Pierce County
Knutson Revetment	RM 11.63 – RM 12.04	Pierce County
Washington State University Revetment	RM 12.04 – RM 12.81	Pierce County
Bowman/Hilton Revetment	RM 12.81 – RM 13.17	Pierce County
Bowman/Hilton Levee[a]	RM 13.17 – RM 13.58	Pierce County
Sportsman Levee[a]	RM 13.58 – RM 14.43	Pierce County
Ball Creek Revetment	RM 14.43 – RM 15.72	Pierce County
McMillin Levee[a]	RM 15.72 – RM 16.65	Pierce County
Bowen/Parker Revetment	RM 16.65 – RM 16.72	Pierce County
Bowen/Parker Levee[a]	RM 16.70 – RM 17.49	Pierce County

Source: Pierce County SWM and USACE records.

Note: The Middle Puyallup is made up of 40 percent levees and 60 percent revetments.

[a] PL 84-99 USACE Flood Control and Coastal Emergency Act

RM = river mile

From the late 1920s to 1939, Pierce County river improvements focused on channelization and bank stabilization using wooden bulkheads and debris barriers along the middle Puyallup and Carbon rivers. In 1939, Pierce County approved a plan (Resolution No. 686) for flood control along the Puyallup River above the mouth of the White River. The 1939 flood plan recommended creation of a single channel on the Puyallup River by excavating gravel and river sediments and side casting them to form low levees and revetments. Implementation of the plan began in the summer of 1939 and concluded sometime in the mid-1960s. The newly formed structures were armored with rock riprap to prevent channel migration through the agricultural fields.

6.4.6 Middle Puyallup Flow Warning Matrix

The middle Puyallup River has four flow categories: Phase I, Action Flow; Phase II, Minor flooding; Phase III, Moderate flooding; and Phase IV, Severe flooding. These categories describe the observed or expected severity of the flood impacts in that area. However, the severity of flooding at a given stage is not necessarily the same at all river locations. Most river reaches in Pierce County have a defined flow warning matrix that is used during flood events. Figure 6.21 shows the flow warning matrix table for the Middle Puyallup River.

Figure 6.21. Middle Puyallup River Flow Warning Matrix

Middle Puyallup River

River Mile Range: 10.3 – 17.4
From the mouth of the White River to the mouth of the Carbon River

	Phase I: Action Flow	Phase II: Minor Flooding	Phase III: Moderate Flooding	Phase IV: Major Flooding
Flow / Stage Range	< 20,000 cfs 54.6 ft	20,000 - 30,000 cfs 54.6 – 57.0 ft	30,000 - 45,000 cfs 57.0 – 60.0 ft	> 45,000 cfs 60.0 ft

USGS Gauge Station #:	Gauge Name:	Gauge Location:	River Mile:
12096500	Puyallup River at Alderton, WA	SR 162 bridge near 80th Street E	12.04

Historical Flooding

The middle Puyallup River experienced major flood events in 1996, 2006, 2008, and 2009 (see Figure 6.22). The highest peak flow recorded at the Alderton gauge occurred on January 7, 2009, with 41,600 cfs (based on the USGS calculation), as shown in Table 6.10. However, this is thought to be an overestimate because it is higher than the peak flow measured at the same time downstream at the Puyallup gauge in the lower Puyallup River. The discrepancies between these two measurements are unknown.

Figure 6.22. Middle Puyallup River Flooding at RM 11.8, November 2008

Table 6.10. Historical Major Flooding on the Middle Puyallup River

Date	Puyallup River Flow at Alderton Gauge (cfs)
December 1921	20,000
December 1946	22,600
December 1953	21,900
December 1955	23,300
January 1990	34,600
November 1990	42,300
February 1996	41,500
November 1999	24,800
January 2003	21,000
January 2005	23,300
November 2006	43,300
November 2008	40,200
January 2009	41,600

Source: USGS Alderton gauge flow records.

Flood Damage to Facilities

Damage to the levees and revetments along the middle Puyallup River typically occur following major flooding events. The levees and revetments that have experienced repetitive damage include the Riverside levee, Washington State University revetment, McMillin levee, Bowman/Hilton levee, Sportsman levee, and Bowen/Parker levee. Damages sustained ranged from complete washouts that resulted in the loss of several hundred lineal feet of flood control structure to localized moderate scour and erosion. Segments subject to the most significant and repetitive damages are summarized below in Table 6.11.

Table 6.11. Summary of Damage to Facilities in the Middle Puyallup River 1990–2021

Storm Season/ Segment Name	Bank	River Mile	Damage Lineal Feet	Damage
1995				
Bowen/Parker	Left	16.8	50	Toe/slope failure.
Bowman-Hilton	Left	13.2	150	Partial Washout. Toe and face rock.
Bowman-Hilton	Left	13.2	600	Toe/slope failure.
Mosby - Historic	Right	16.0	400	Toe/slope failure with spots of total failure.
Mosby - Historic	Right	16.2	250	Partial Washout. Toe and face rock.
Riverside Revetment	Right	12.8	600	Some Toe/slope failure.
Van Ogle Revetment	Right	13.4	225	Partial washout. Toe and face rock.
1996				
Bowen/Parker	Left	16.7	100	Total failure.
Bowen/Parker	Left	16.8	200	Toe/slope failure.
Bowen/Parker	Left	17.4	100	Toe/slope failure.
Bowman-Hilton	Left	13.2	500	Toe/slope failure.
Dollar Creek	Right	16.8	800	Toe/slope failure.
McMillin	Left	16.0	600	Toe/slope failure with spots of total failure.
McMillin	Left	16.2	250	Toe/slope failure with spots of total failure.
Mosby - Historic	Right	16.0	400	Toe/slope failure.
Riverside Revetment	Right	12.8	600	Toe/slope failure.
Sportsman	Left	14.2	100	Slope failure.
Washington State University Revetment	Left	12.2	600	Toe/slope failure.

Storm Season/ Segment Name	Bank	River Mile	Damage Lineal Feet	Damage
2002				
Van Ogle Revetment	Right	13.0	50	Toe and face repair.
2004				
Riverside	Right	12.7	100	Partial washout of the toe and levee facing.
2005				
Evanger/White	Right	14.2	450	Repair/replace toe and face rock.
2006				
Bowen/Parker	Left	17.3	220	Face erosion.
Bowman-Hilton	Left	13.2	500	Fracture: scour.
Evanger/White	Right	15.0	300	Face erosion.
River Grove	Right	11.0 - 11.5	0	Overtopping with minor levee damage.
Sportsman	Left	13.6	40	Fracture
Sportsman	Left	14.0	300	Washout
Washington State University Revetment	Left	12.2	300	Face erosion.
2007				
Bowman-Hilton	Left	13.2	880	Repair scour from levee being overtopped.
McMillin	Left	16.3	50	
2008				
128th & McCutcheon	Right	16.7	12	Top of levee/access road scour.
Bowen/Parker	Left	16.8	75	Toe rock failure.
Bowen/Parker	Left	16.81	50	Toe rock failure and partial face rock failure
Bowman-Hilton	Left	13.2	60	Minor top coat damage.
McMillin	Left	15.7	30	Damaged toe and face rock.
McMillin	Left	16.1 - 16.2	30	Toe and face rock failure.
Riverside	Right	12.0	30	Damaged toe and face rock.
Riverside	Right	12.4	236	Damaged toe and face rock.
Riverside	Right	12.7	5	Minor top coat damage.
Sportsman	Left	13.75	0	Blocked culvert.
Van Ogle Revetment	Right	13.5	30	Damaged face rock.

Storm Season/ Segment Name	Bank	River Mile	Damage Lineal Feet	Damage
Washington State University Revetment	Left	12.2	148	Wazzu partial washout.
2009				
128th and McCutcheon	Right	16.75	20	Toe and face rock failure.
2009 (continued)				
Bowen/Parker	Left	16.7	12	Top of levee/access road scour. Tide gate damaged.
Bowen/Parker	Left	16.7	300	Access road scour, face rock failure.
Bowen/Parker	Left	16.8	75	Toe rock failure.
Bowman-Hilton	Left	13.2	200	Scour 200 liner feet facing rock failure.
Bowman-Hilton	Left	13.3	50	Scour 1/2 feet deep for 50 LF.
Evanger/White	Right	15.0	200	Total levee failure/ end of levee.
McMillin	Left	16.1 - 16.2	60	Toe and face rock failure.
River Grove	Right	11.0 - 11.5	0	Overtopping with minor levee damage.
Riverside	Right	12.6	15	Scour over top of revetment. One–two feet
Sportsman	Left	13.75	200	Blocked culvert.
Sportsman	Left	13.9	250	Damaged toe and face rock.
Sportsman	Left	14.00	300	Major scour.
Sportsman	Left	14.10	150	Head cutting on back side of levee.
Washington State University Revetment	Left	12.2	65	Partial washout.
2010				
Riverside Revetment	Right	12.8	50	Minor face rock slippage and possible toe rock misplaced.
Sportsman	Left	14.05 - 14.17	650	Slump and scour near Sportsman Club.
Sportsman	Left	14.05 - 14.17	650	Slump and scour near Sportsman Club.
Van Ogle Revetment	Right	13.65	100	Slump in front of Knobloch residence.
Van Ogle Revetment	Right	14.14	120	Toe rock and face rock failure.
2011				

Storm Season/ Segment Name	Bank	River Mile	Damage Lineal Feet	Damage
128th & McCutcheon	Right	16.8	440	Major scallop scour missing levee.
Evanger/White	Right	14.2	75	Toe rock failure.
Evanger/White	Right	14.9	200	Toe and face rock failure.
Fennel Creek	Right	15.4	45	6-foot deep scour.
River Grove	Right	11.42	50	3-foot slump.
River Walk Revetment	Right	11.9	60	Minor toe scour.
2011 (continued)				
Riverside	Right	12.3 - 12.4	425	Toe rock failure.
Riverside Revetment	Right	12.8	70	Toe and face rock failure.
Sportsman	Left	14.05 - 14.17	650	Slump and scour.
Sportsman	Left	14.2	220	Toe rock failure.
Van Ogle Revetment	Right	13.65 - 13.66	100	Slump in front of Knobloch residence.
Van Ogle Revetment	Right	14.14 - 14.16	120	Toe and face rock failure.
2012				
Ball Creek	Left	15.3	100	Toe and face rock failure.
Bowen/Parker	Left	16.7 - 16.8	300	Face rock failure.
McMillin	Left	16.1	100	Toe and face rock failure.
Riverside	Right	12.3 - 12.4	425	Toe rock failure.
Riverside Revetment	Right	12.8	100	Missing face rock.
Van Ogle Revetment	Right	14.1	120	Toe and face rock failure.
Washington State University Revetment	Left	12.2	50	Over steepened, loss of face and toe rock.
2013				
McMillin	Left	16.1	100	Toe and face rock failure.
Riverside Revetment	Right	12.8	100	Missing face rock.
Washington State University Revetment	Left	12.2	50	Toe and face rock failure.

Storm Season/ Segment Name	Bank	River Mile	Damage Lineal Feet	Damage
2015				
River Grove	Right	11.2	75	Tree root pulled out section of levee.
Sportsman	Left	13.7	250	Partial erosion of revetment face rock.
Washington State University Revetment	Left	12.2	150	Missing rock and over steepened.
Washington State University Revetment	Left	12.2	150	Missing rock and over steepened.
2017				
River Grove	Right	11.2	110	Overly steep. Sloughing. USACE repair.
Washington State University Revetment	Left	12.1	60	Levee damage.
2018				
Washington State University Revetment	Left	12.1	75	Localized Scour.
Sportsman	Left	14.2	330	Missing rock and over-steepened.
Evanger White	Right	14.4	125	Erosion of face rock.
2020				
McMillin	Left	16.2	160	Levee Rehabilitation.
Bowen Parker	Left	16.8	100	Localized Scour.
2021				
McMillin	Left	16.2	180	Levee rehabilitation.

6.4.7 Key Accomplishments since the 2018 Flood Plan Update

Major Projects

Since the 2018 Flood Plan Update was completed, Pierce County has carried out an annual program that includes maintenance and repair of revetments and levees, listed in Table 6.11, as well as the capital projects noted below and major repairs shown in Table 6.12.

Ball Creek Project

This project, which was completed in 2018, replaced a culvert that removed a fish passage barrier and improved over 1,400 feet of the creek channel by realigning and installing habitat improvement structures and features as shown in Figure 6.23. The project also reconnected over 10 acres of Ball Creek with the historical Puyallup River floodplain.

Figure 6.23. Ball Creek Project Site

Table 6.12 shows major repairs, generally considered 750 lineal feet or more in length, along the middle Puyallup River following significantly large storm events. Records maintained by Pierce County SWM Operations and Maintenance show three major repairs have been completed between RM 10.3 and RM 17.3.

Table 6.12. Major Repairs Completed on Middle Puyallup River since 1991 Flood Plan

Segment Name	Location	Damage	Length	Estimated Cost	Storm Event
Bowman-Hilton Levee	RM 13.2 LB	Total levee and toe/ slope failure.	1,100LF	$498,600	November 1995/ February 1996
Bowen/Parker Levee	RM 16.8 LB	Toe/slope failure.	800LF	$249,600	February 1996
Bowman-Hilton Levee	RM 13.2 LB	Scour from levee overtopping.	880LF	$220,000	November 2006

Source: Pierce County Surface Water Management records

LB = left bank; LF = lineal feet

6.4.8 Land Acquisitions

Pierce County acquired 13 acres of property between 2018 and 2021 in the Middle Puyallup reach. This property acquisition supported the Fennel Creek capital project.

6.4.9 Flood and Channel Migration Hazard Mapping

Hazard mapping in the middle Puyallup River includes detailed flood studies (FEMA NHC 2006) and the creation of DFIRMs, which were adopted in March 2017, in order to publish the countywide Digital Flood Insurance Rate maps. Areas that were affected by non-accredited levees were “scheduled” from the map updates. Flood-prone areas along the middle Puyallup River include local roads such as Riverside Drive and McCutcheon Road, the Sumner Wastewater Treatment Plant, several groupings of single family residential structures (including Rainier Manor Mobile Home Park in Sumner), multi-family residential structures, agricultural and rural lands, and other mobile home parks. The DFIRMs for the middle Puyallup River show 1,153 acres within the SFHA or 100-year floodplain. The mapped DFF area is 986 acres.

Severe, moderate, and low CMZs were mapped for the middle Puyallup River (GeoEngineers 2003), and the severe risk area was adopted in November 2004 to be regulated floodway. The CMZ refers to the geographic area where a stream or river has been located in the past and so is susceptible to channel erosion and channel reoccupation (Washington State Department of Ecology 2003). The severe CMZ covers an area of 1,047 acres. Pierce County regulates severe CMZ mapped areas as floodway in accordance with Chapter 18E.70, PCC.

6.4.10 Problem Identification

The following flooding and channel migration related problems were identified in the middle Puyallup River (see Table 6.13).

Table 6.13. Flooding-related Problems Identified in Middle Puyallup River

Location	Problem Description	Source
Levee and Revetment Overtopping and Breaching		
RM 10.4 – RM 10.6 RB	High water surface elevations threaten to flood the Sumner Wastewater Treatment Plant.	City of Sumner
RM 11.0 – RM 11.5 RB	Revetment overtopping floods Rainier Manor and River Grove Apartments and threaten Riverwalk condos.	City of Sumner
RM 12.4 – RM 12.8 RB	Levee/revetment overtopping floods 76th Street E. and homes.	Pierce County
RM 12.8 – RM 13.5 RB	Levee/revetment overtopping floods property and home along Riverside Drive.	Pierce County
RM 13.2 – RM 14.1 LB	Levee/revetment overtopping floods Tree farm, Bowman-Hilton, and Sportsman Club property.	Pierce County
RM 14.2 – RM 14.6 RB	Revetment overtopping floods McCutcheon Road and property, including structures.	Pierce County
RM 15.2 – RM 15.6 LB	Levee/revetment overtopping floods property along 110th Street E. in vicinity of McMillin.	Public Input (March 2010)
RM 15.6 – RM 16.7 LB	Levee/revetment overtopping floods property along 151st Avenue E. and 116th Street E.	Pierce County
RM 15.9 – RM 16.7 RB	Levee/revetment overtopping floods property along 153rd Avenue E. near Canyon Falls Creek.	Pierce County
RM 16.7 – RM 17.2 RB	Levee overtopping floods McCutcheon Road and many properties and structures in the vicinity.	Pierce County

Location	Problem Description	Source
Tributary Backwater Flooding		
RM 12.8 – RM 13.0 RB	Backwater at tributary floods Pierce County's Riverside Park.	Pierce County
RM 15.8- RM 16.4 RB	Canyon Falls backwater floods McCutcheon Road	Pierce County
Public Safety/Emergency Rescues		
RM 11.0 – RM 11.5 RB	Flooding of Rainier Manor and River Grove Apartments resulted in emergency evacuations.	City of Sumner
RM 14.2 – RM 14.9 RB	McCutcheon Road flooding between 96th Street E. and Rhodes Lake Road E. resulted in emergency evacuations in 1996, 2006, and 2009.	Pierce County Sheriff
RM 16.7 – RM 17.3 RB	McCutcheon Road flooding south of 128th E. resulted in emergency evacuations in 2006 and 2009.	Pierce County Sheriff
Flooding of Structures and Infrastructure (Roads/Bridges) [not already noted above]		
RM 10.8 – RM 11.0 RB	Flooding of SR 410 under railway bridge occurred in 1996, 2006, 2008, and 2009.	City of Sumner, WSDOT
RM 12.6 – RM 12.8 RB	Flooding of 76th Street E. & 159th Avenue E. (off Riverside Drive) during major floods closes roads. Highwater also deposits large woody material on roads and threatens adjacent homes.	Pierce County Roads
RM 14.15 RB/LB	Flooding of 96th Street E. and bridge closed roads and wood buildup on bridge piers.	Pierce County Roads
RM 16.7	128th Street E. Bridge woody debris buildup on piers.	Pierce County Roads
RM 16.7	Tacoma Water Line Bridge woody debris buildup on piers	Pierce County
Sediment and Gravel Bar Accumulation		
RM 10.3-10.7	Gravel bar accumulation from the confluence of White River upstream to Main Street bridge.	City of Puyallup
RM 10.3-10.7	Large gravel bar along right bank adjacent to Sumner Wastewater Treatment Plant causes flow constriction.	City of Sumner
RM 12.2-17.4	Gravel accumulation between Sumner and Orting a concern due to reduced conveyance capacity and directing flows at levees, damaging structures	Pierce County
Fish Habitat Problem Areas		
RM 10.7 – RM 11.5 LB	Levee/revetment construction cut off floodplain from river channel, limiting rearing/spawning habitat (Sumner setback levee location).	Puyallup Tribe
RM 12.4 – RM 13.5 RB	Revetment construction cut off floodplain from river channel, limiting rearing/spawning habitat (Riverside Drive and Park setback levee locations).	Puyallup Tribe, Pierce County

Location	Problem Description	Source
Fish Habitat Problem Areas (continued)		
RM 13.2 – RM 14.0 LB	Levee/revetment construction cut off floodplain and oxbow wetlands from river channel, limiting rearing/spawning habitat (Sportsman setback levee).	Puyallup Tribe, Pierce County
RM 15.2 – RM 16.0 RB	Levee/revetment construction cut off floodplain from river channel, limiting rearing/spawning habitat (Fennel Creek setback levee location).	Puyallup Tribe, Pierce County
RM 15.8 – RM 17.4 RB/LB	Levee/revetment construction cut off floodplain from river channel, preventing access to off-channel rearing/spawning habitat (four setback levees).	Puyallup Tribe, Pierce County
Public Access		
RM 10.7 – RM 11.5 LB	Lack of connecting trail between Main Street and Foothills trail at East Puyallup Trailhead.	Pierce County Parks
RM 12.8 – RM 13.4 RB	Desire to maintain public access for boat launch and fishing at Riverside Park if setback levee is constructed.	Pierce County Parks
RM 15-16	Lack of connecting trail between Foothills Trail and Fennel Creek Trail across Puyallup River.	Pierce County Parks

Source: Pierce County Surface Water Management records

LB = left bank; RB = right bank: RM = river mile

6.4.11 River Reach Management Strategies

6.4.11.1 Conditions and Constraints of the Middle Puyallup Reach

- The recommended river reach management strategies for the middle Puyallup River take into account numerous conditions, as described below.
- Development and land use in adjacent floodplain – the middle Puyallup River floodplain is densely developed in Sumner, with rural residential and agricultural development upstream of Sumner in the unincorporated area. The total assessed value of property in the 100-year floodplain is $604.7. million (EcoNorthwest 2022).
- River management facilities – Both the left and right banks of the Puyallup River are constrained by levees and revetments along most of this reach.
- River channel gradient and width – Channel gradient varies from 0.17 to 0.25 percent within this reach, and the width of the channel varies from 205 feet to 300 feet.
- Presence of salmon spawning and rearing habitat – All species of salmon are found in the middle Puyallup River, which provides access for all species of salmon to productive spawning habitat, including Chinook, pink, chum, coho, and sockeye, as well as steelhead, bull, and

cutthroat trout. Coho and chum salmon, steelhead, and cutthroat trout all spawn within this reach.

- The Middle Puyallup is a dynamic reach for sediment transport accumulation and incision. Sediment consists of mostly gravel and sand below RM 12.0 and mixed gravel, cobble, and sand between RM 12.0 and RM 17.4. The average riverbed elevation change from 1984 to 2009 was -0.1 feet to +2.0 feet between RM 10.4 and RM 12.0, -1.5 feet to +3.8 feet from RM 12.0 to RM 15.6, and -1.8 feet to +1.5 feet from RM 15.6 to RM 17.4

The primary objective for the middle Puyallup River is to maintain the structural integrity of the existing levee and revetment system so that the system continues to reduce risks to public health and safety and reduce public and private property damage. Other objectives are to design improvements to the levees and revetments so they provide a 100-year level of protection in Sumner and reduce areas of the floodplain prone to flooding. Capital projects should take advantage of opportunities to improve aquatic habitat through levee setbacks, riparian re-vegetation, and strategic placement of large woody material.

6.4.11.2 Middle Puyallup River Reach Management Strategies

The recommended river reach management strategies for the middle Puyallup are listed below:

Structural Management Strategies:

- RM 10.3 – RM 12.0 right and left banks – The goal for levees should be 100-year design plus three feet of freeboard. Revetments should be designed to resist channel migration.
- RM 12.0 – RM 17.3 right and left banks – The goal for levees should be to maintain the current (2009) level of protection. Revetments should be designed to resist channel migration.

Non-structural Management Strategies:

- Continue to follow floodplain development regulations.
- Acquire, buyout, or purchase development rights.
- Maintain existing interim risk reduction measures until replaced by future capital project.

6.4.11.3 Interim Risk Reduction Measures:

- Continue to have sandbags and a HESCO® barrier wall from RM 10.7 to 11.3.

6.4.12 Recommended Capital Projects

The following capital improvement projects are recommended to address the priority problem areas identified in Table 6.13.

Riverine Flood Project **Project Score: 53**

Project Name: Rainier Manor/Riverwalk/Rivergrove and SR 410 Floodwall and Levee

Project webpage location: Projects in Planning | Pierce County, WA - Official Website (piercecountywa.gov)

Project location: Puyallup River (Right Bank RM 10.7 - RM 12.0) within the Sumner city limits (see Figure 6.24)

Estimated project cost over a 10-year period: $14.5 million

Total project cost: $14.5 million

What is at risk?

Base flood elevation in this section of the Puyallup River ranges from approximately 52 to 62 feet. The existing Knutson revetment and levee on the right bank sits at an elevation of 48 feet to 64 feet. The surrounding development of Rainier Manor Mobile Home Park development sits below the levee. When the levee overtops, the mobile home park and portions of SR 410 are flooded and this area holds the water until floodwaters recede. The flooding causes a portion of SR 410 to close (see Figure 6.25), and traffic is diverted to other routes. The adjacent Rivergrove Apartments and Riverwalk developments experience localized flooding in the first floor units closest to the river.

What is the recommended solution?

A combination of floodwall and flood berm would provide protection to the adjacent SR 410, apartments, and mobile home park (see Figure 6.26). Between RM 10.7 and RM 11.0 and between RM 11.46 and RM 11.8, the levee would be set back and raised. Between RM 11.0 and RM 11.46, a floodwall would be constructed to protect the Rainier Manor Mobile Home Park. The height of the levee and floodwall will vary between 6 feet to 10 feet to provide 3 feet of freeboard from the 100-year flood elevation.

What is the current status of the project?

This project is currently in the scoping and feasibility study phase. This project is projected to begin in 2024.

What will take place with this project from 2023–2033?

Between 2023 and 2033, the following will take place: scoping, completion of a feasibility study, preliminary engineering, land acquisition, and final engineering.

Who will Pierce County coordinate with on this project?

Pierce County will coordinate with the City of Sumner, USACE, NMFS, USFWS, and WDFW for this project.

Figure 6.24. Location of the Rainier Manor/Riverwalk/Rivergrove and SR 410 Floodwall and Levee

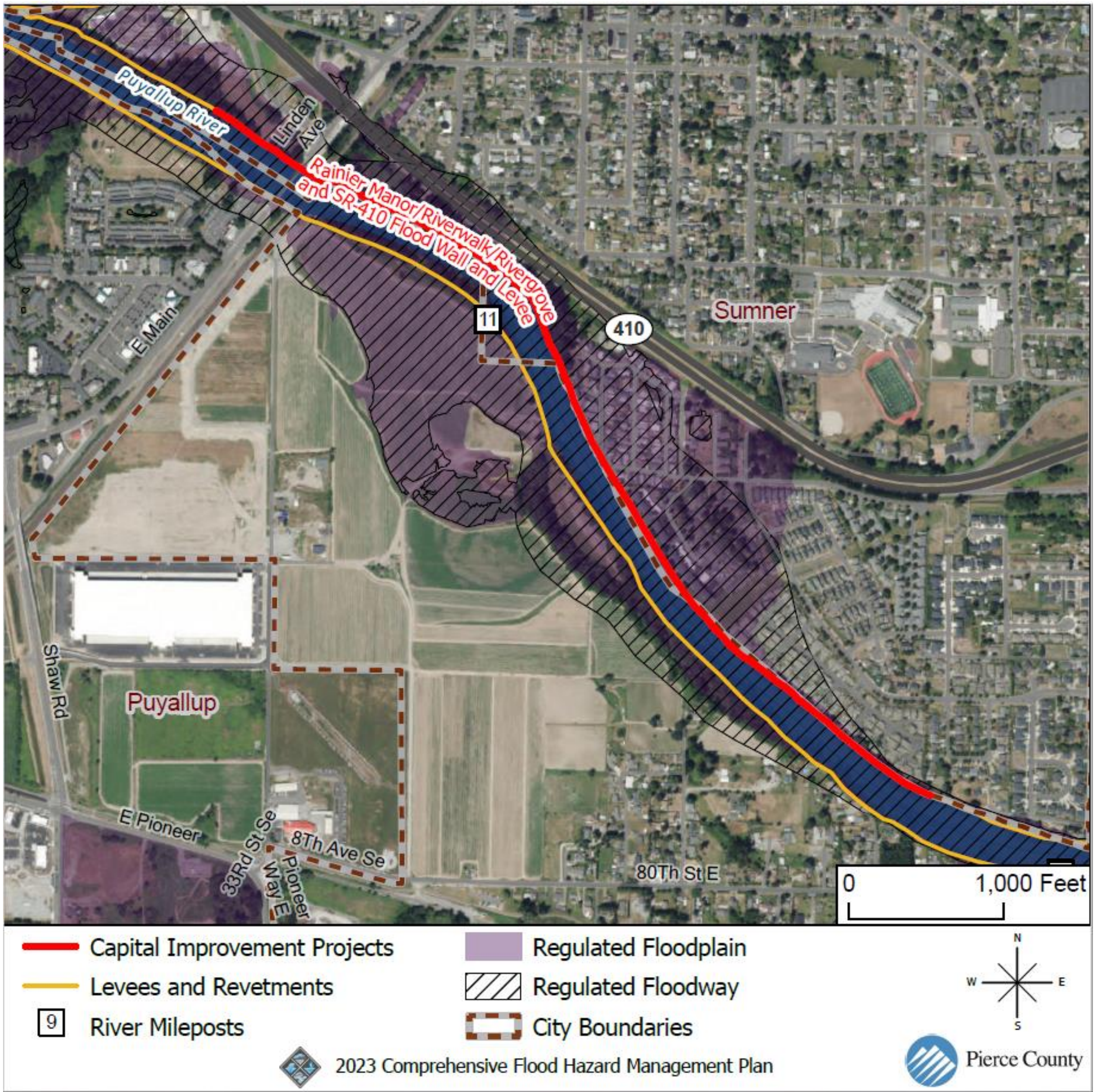


Figure 6.25. Flooding November 7, 2006, SR 410

Figure 6.26. Flooding November 7, 2006, Rainier Manor Mobile Home Park, River Grove Apartments, Riverwalk Condos

What are the environmental considerations?

The proposed project is intended to be outside of the ordinary high water, so it is not expected to need federal permitting. The project will require local permitting, including shorelines substantial development.

Other Information or Needs

The proposed floodwall would increase the river base flood elevation by approximately 0.4 feet. Any increase in excess of 0.001 feet will require mitigation to compensation for lost floodplain storage and the small rise in the base flood elevation.

What are the Project Benefits/Drivers?

Flood Risk

Riverine Flood Project **Project Score: 54**

Project Name: 128th Street Corridor River Improvements

Project webpage location: www.piercecountywa.gov/128Levee

Project location: Between RM 15.8 and RM 17.4.

The 128th Street East bridge crossing over the Puyallup River in which the upstream and downstream reach of the Puyallup River is the study focus area. The study area is bounded by 116 Street East to the north, SR 162 to the west, McCutcheon Road to the east, and the Carbon River confluence to the south (see Figure 6.27).

Estimated project cost over a 10-year period: $10.7 million

Total project cost: $80 million

What is at risk?

Base flood elevation in this section of the river is at approximately 114.9 to 121.1 feet. The surrounding development sits at an elevation of between 112 to 130 feet. The current levee system is intermittent, provides less than a 30-year level of service, and experienced extensive flooding between 1996 and 2009. The existing right bank levee section abruptly ends, leaving a 1,400 foot gap in the right bank protection. This allows flood waters to backwater, thus making the southern end of McCutcheon Road impassible and stranding approximately 20 homes due to water over the roadway (see Figure 6.28). During flooding, these property owners are cut off from emergency services and individuals take risks trying to navigate through flooded roadways.

Additionally, an old levee built in the 1930s is located approximately 350 feet east of the existing right bank levee. The basin created between the old levee and the newer levee captures Dollar Creek and overtops during flood stage. The presence of water on both sides of the newer levee could potentially undermine the existing structure, leading to failure and flooding impacts to public infrastructure (see Figure 6.29) (including roads, bridges, and levees), adjacent improved properties, fish habitat, and water quality.

What is the recommended solution?

Conduct and complete a comprehensive setback levee feasibility study to identify flood reduction alternative measures, score and rank identified alternatives, and recommend preferred alternatives to implement for each the study areas.

Figure 6.27. Location of the 128th Street Corridor River Improvements project

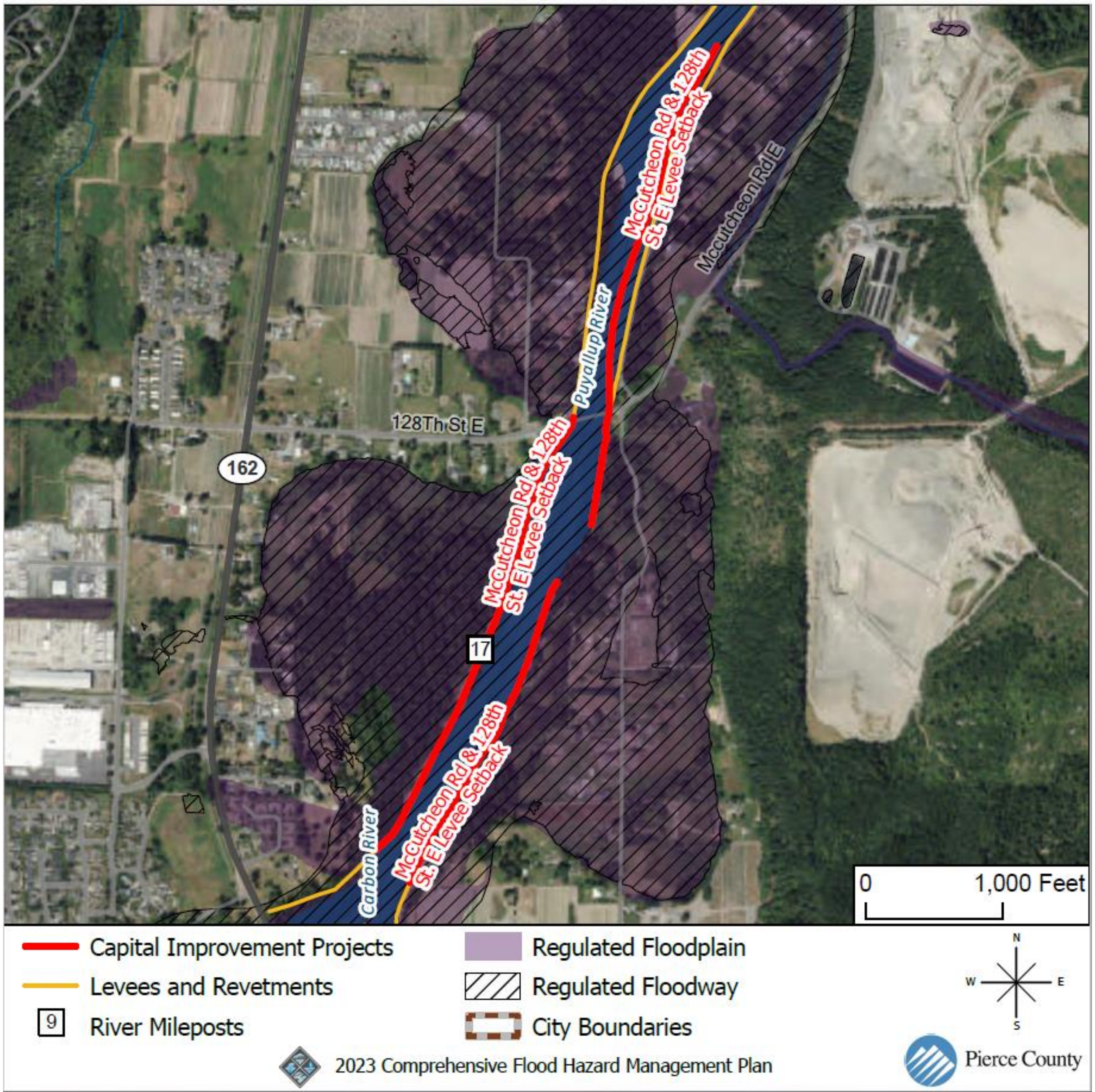


Figure 6.28. Flooding in the study area looking Southeast (upstream) of Puyallup River from north of 115th Street East

Figure 6.29. Flooding in the study area looking East at Puyallup River and 128th Street East Bridge

What is the current status of the project?

A draft report is being prepared that addresses the following:

1. Study area characterization for existing conditions
2. Description of identified and conceptual alternatives for each of the four quadrant areas
3. Hydrologic and hydraulic modeling of existing conditions
4. Hydraulic modeling that incorporates identified alternatives conditions
5. Property acquisition needs
6. General environmental permitting requirements
7. Public and stakeholder outreach review comments
8. Preparing for a final round of public and stakeholder outreach to solicit review comments regarding the proposed identified conceptual alternatives.

What will take place with this project from 2023–2033?

1. Complete the final feasibility study and report in 2023, which will provide recommendations for prioritized recommended alternatives to implement.
2. Commence with preliminary design thereafter of the preferred and prioritized recommended alternative(s).
3. Proceed to and complete 60 percent and final engineering design and construction plans.
4. Continue with needed property acquisition as property owner interest and funding allows.
5. Complete permitting applications and submit upon completion of 60 percent design plans, depending on property acquisition status.
6. Proceed to construction of the selected preferred and recommended alternative.

Who will Pierce County coordinate with on this project?

Pierce County will coordinate with the USFW, NMFS, WDFW, the Puyallup Tribe, USACE, and Tacoma Water on this project.

What are the environmental considerations?

The project area is located in an area used by Endangered Species Act (ESA)-listed Puget Sound Chinook, steelhead, and bull trout and within the Puget Sound Chinook and bull trout critical habitat. A 404 permit (including federal consultation), State Environmental Policy Act (SEPA) documentation, WDFW Hydraulic Permit Approval, PC Shorelines Substantial Development Permit, and Critical Areas Approvals will be required for this project.

Other Information or Needs

Three projects have the potential to change the dynamics of the river in the area of the 128th Street bridge:

- The proposed City of Tacoma Water Pipeline No. 1 project, which will replace the existing double pipeline that has an overwater crossing with a single pipeline crossing under the river. Replacement of the overwater crossing will remove a mid-river pier; this could decrease the base flood elevation.
- The Rhodes Lake Road East, which would construct a new road from the east side of 128th Street East up the hillside and eventually connect to Falling Water Boulevard. The project—which would include a new road between SR 162 and the Tehaleh development, a new bridge over the Puyallup River, and extend another road to the current end of Falling Water Boulevard East—would provide motorists with an alternative to Rhodes Lake Road East. For more information on this project, visit the New Rhodes Lake Road East - SR 162 to Falling Water Blvd (Various CRPs) web page of the Pierce County official website.
- The construction of a new bridge crossing over Canyon Falls Creek at McCutcheon Road. Canyon Falls Creek travels down a steep hill before flowing through a shallow channel beside McCutcheon Road East for about 150 feet. The creek then crosses under the road through a culvert. Over the years, the creek has deposited sediment into the shallow channel, thus raising the creek bed elevation. Currently, the creek is at or near the same elevation of the road, with sandbags preventing water from flowing over the roadway. In order to prevent roadway flooding, Pierce County road maintenance crews previously received permits to remove the sediment and lower the elevation of the creek. A new bridge would be constructed where the creek meets the road, requiring the road to be raised. The creek would flow through a new channel cut into a field located west of the road and reconnect with the existing creek path. The sediment would be deposited in the new channel constructed in the field, reducing sediment build-up. This design may change if the county decides to construct a setback levee along McCutcheon Road East. For more information on this project, visit the Bridge #7195-F McCutcheon Road East/Canyonfalls Creek web page of the Pierce County official website.

- Floodplain connectivity and fish habitat improvements along Fennel Creek, upstream of where it joins the Puyallup River. Previous work has included property acquisition, a 40-plus acre floodplain restoration and channel restoration covering over 1,900 linear feet. Continued habitat improvements and project construction continue into 2024.

What are the Project Benefits/Drivers?

Agriculture

Fish Passage

Flood Risk

Habitat

Water Quality

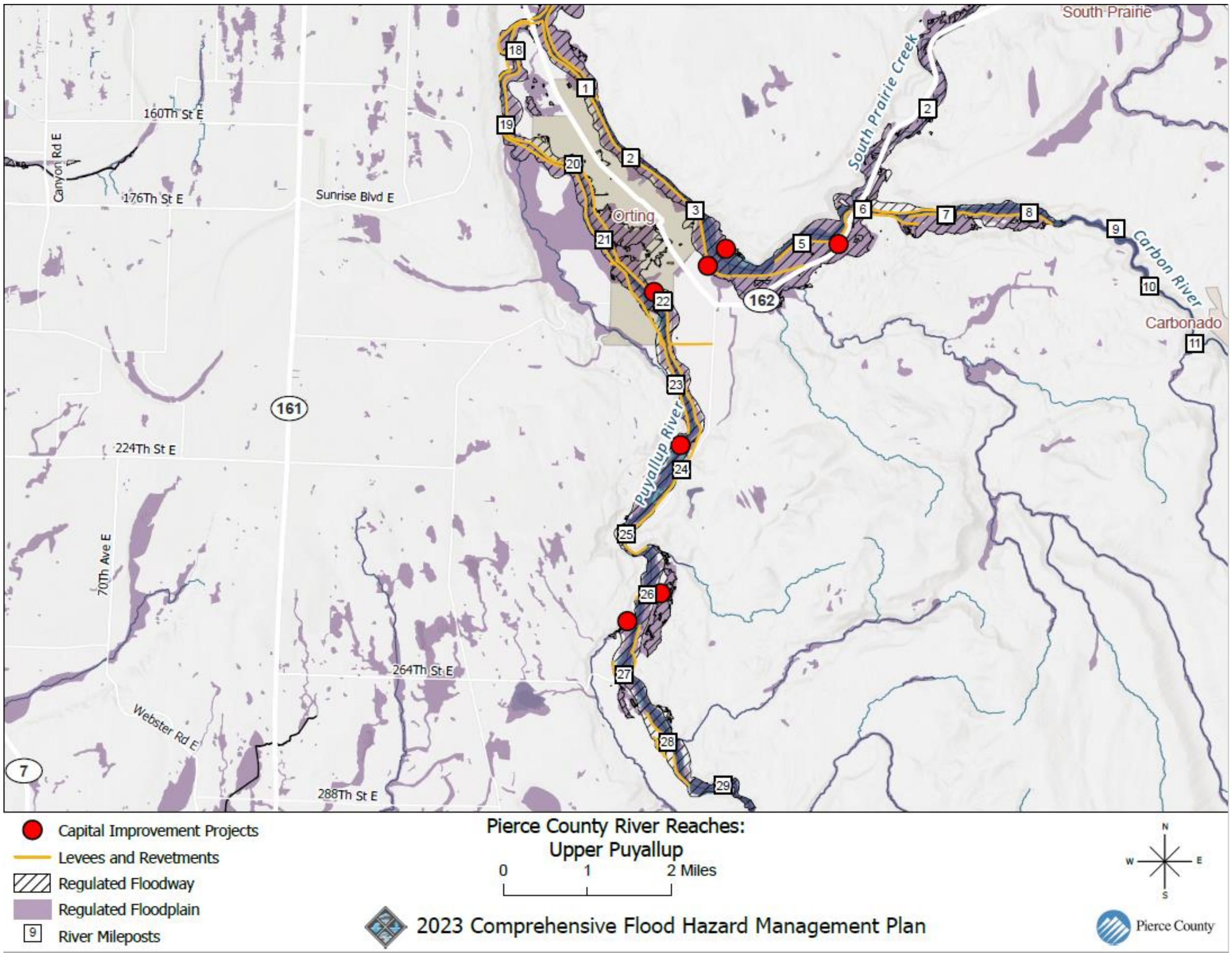
6.5 Upper Puyallup River

6.5.1 Overview

The upper Puyallup River reach begins at the confluence of the Carbon River at River Mile 17.4 and continues upstream to the Champion Bridge at RM 28.6, just downstream of Electron Road, as shown in Figure 6.30. The contributing drainage basin for this reach is approximately 188 square miles. In the lower portion (RM 17.4 - 21.2) of this reach, the river is confined by a combination of levees and revetments. In the middle portion there is less confinement due to the presence of two setback levees, the Soldiers Home setback levee at RM 21.27 to RM 23.08 and Ford setback levee at RM 22.51 to RM 24.80.Levees remain between RM 23.6 and 25.2. Upstream of RM 25.2 to RM 28.6 only one levee remains intact along the right bank. Along the left bank from RM 27.54 - 27.89, an 1,800 foot long of levee remains along with a 1,300 foot segment of revetment from RM 28.34 - 28.58. Between these two segments new setback revetments have been constructed to protect Orville Road. The surrounding watershed and land use is mostly urban on the right bank of the Puyallup near the City of Orting between RM 17.4 to RM 21.8, but predominantly agricultural, rural residential and forested upstream of RM 21.8. Like the middle Puyallup River, by the 1930s much of the valley and surrounding hills in the upper Puyallup River were harvested for timber and the valley cleared for agriculture (GeoEngineers 2003).

Several tributaries enter the upper Puyallup River including Horse Haven Creek, Fiske Creek, Kapowsin Creek, and Fox Creek. The largest tributary, Kapowsin Creek, originates in Lake Kapowsin located approximately 3.7 miles upstream from its confluence with the Puyallup River near RM 26.3. Salmon and trout, including Chinook, coho, pink, chum, and steelhead and bull trout use the entire reach of the upper Puyallup River.

Figure 6.30. Planning Area for the Upper Puyallup River



6.5.2 Geology and Geomorphology

The upper Puyallup River valley is steeper and narrower compared with the lower and middle Puyallup River reaches. Above the confluence with the Carbon River, the width of the Puyallup River channel migration zone is generally defined by the remnants of the Electron mudflow, which was deposited as a thick layer of mud that blanketed the Puyallup valley bottom about 500 years ago. Abandoned channels situated near the main channel reflect relic channel locations, indicating the potential for episodic avulsions (the rapid abandonment of a channel with the formation of a new channel). The Puyallup River prior to Euro-American settlers was a braided river system that nearly occupied the entire floodplain from valley wall to valley wall.

6.5.3 Hydrology and Hydraulics

The upper Puyallup River watershed is approximately 188 square miles and extends from Mount Rainier National Park downstream past Orting. The upper Puyallup River receives flows from the North and South Fork Puyallup Rivers, Mowich River, and several other tributary streams.

The USGS stream gauge (#12093500) upstream of Orting has a long-term record that dates back to 1932. This gauge is located within a channel primarily composed of bedrock, which ensures the gauge data are reliable. Flood frequency flows for the upper Puyallup River from the 1987 and 2009 FEMA Flood Insurance Studies and calculated by SWM through the 2009 water year are presented in Table 6.14. The November 2006 flood on the upper Puyallup River resulted in a peak flow of 21,500 cfs. Based on the Pierce County 2009 flood frequency discharge (how often or frequent the discharge magnitude occurs) forecast, this was considered to have a recurrence interval of approximately 160 years.

Table 6.14. Flood Frequency Flows for the Upper Puyallup River

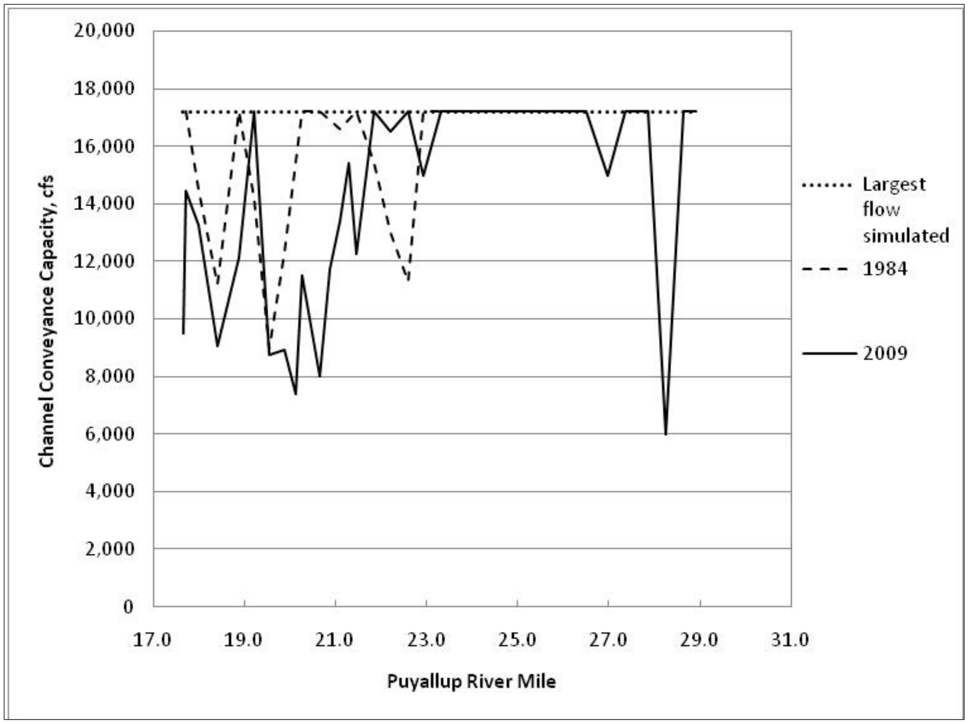
	Discharge (cfs)				
Location	**10-year Event**	**50-year Event**	**100-year Event**	**500-year Event**	**Method**
Upper Puyallup River gauge (above Orting, #12093500)	11,700	16,400	18,400	23,400	1987 FEMA Flood Insurance Study (Log Pearson Type III)
Upper Puyallup River gauge (above Orting, #12093500)	12,200	16,800	18,600	22,600	2017 FEMA Flood Insurance Study for Pierce County (and NHC 2002 hydrology report)
Upper Puyallup River gauge (above Orting, #12093500)	13,100	18,900	21,400	-	SWM 2022[a] (Adjusted for precipitation and drainage area)

Source: FEMA and Pierce County Surface Water Management (based on United States Geologic Survey records)

[a] SWM regression analysis (not official or formal published data)

The USGS channel conveyance capacity study (USGS 2010) indicates that the upper Puyallup River between RM 17.4 and RM 28.6 can convey flows ranging from 6,000 to 17,200 cfs before overtopping either the left or right bank (see Figure 6.31). The change in conveyance capacity since a 1984 flood conveyance capacity USGS study has been variable for the channel reach between RM 17.4 and RM 22.8. Overall, the trend mostly shows channel conveyance capacity to be decreasing between 1984 and 2009, except for the segment of channel between RM 22.0 and RM 23.0, where conveyance capacity has increased.

Figure 6.31. Channel Conveyance Capacity for the Upper Puyallup River

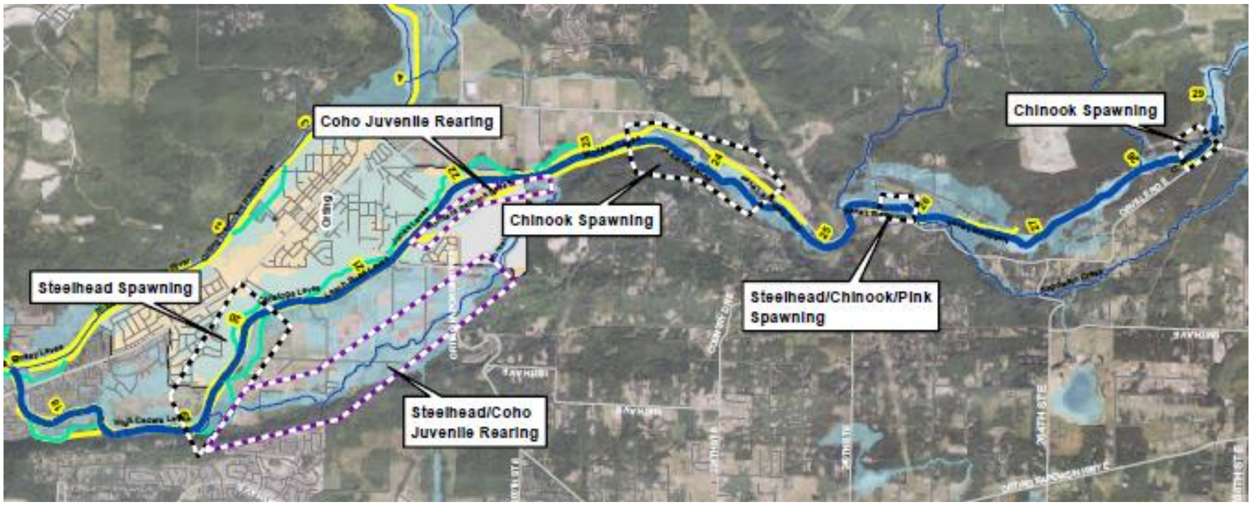


No cross-section measurements were made upstream of RM 22.8 in 1984, so there is no point of comparison available.

6.5.4 Ecological Context and Salmonid Use

Along the upper Puyallup River, the floodplain narrows, the gradient steepens, and the channel becomes increasingly braided. The substrate changes from gravel to cobble and boulders in the upper segment. Side channels flow through immature stands of alder and provide some of the most stable fish habitat within this reach. All species of salmonids use the upper Puyallup River. The best habitat is found in side channels and at the mouths of tributaries. For spawning and rearing, Chinook salmon and steelhead prefer the large side channels and stable main channel areas near large pools with wood. Coho and chum salmon and cutthroat trout occupy smaller side channels or along the margins of the main channel. Figure 6.32 shows some of the key habitat features for salmonids in the upper Puyallup River, including rearing and spawning habitat for coho, pink, Chinook, and steelhead.

Figure 6.32. Salmonoid Habitat in the Upper Puyallup River



As a result of the last three recent major floods since 2006, the upper Puyallup River has experienced rapid channel migration and bed load aggradation, which has led to an unstable environment for spawning and rearing salmon. The river delivers large amounts of wood and sediment to this reach from the glacier and forests upstream and deposits them into the levee-constricted channel. Because the channel is constricted in most locations, the energy of the river is not distributed across the floodplain, and salmon redds located in the main channel may have low survival due to scour or excessive sediment deposition.

In the upper portions of this reach, the levees become less continuous and maintained. Some of the bank hardening remains from an old railroad grade. Due to dwindling development upstream of Orting, this reach holds high potential for restoration activities and floodplain reactivation.

6.5.5 River Management Facilities, Flooding, and Flood Damage

Levees and revetments form nearly continuous bank protection in the lower segment of the upper Puyallup River system between RM 17.4 and RM 23.6. Near Orting, flood risk reduction facilities help protect residential, commercial, and agricultural areas and public facilities. Above RM 23.6, the levee segments were heavily damaged by major flood events between 1990 and 2009.

Pierce County currently owns and maintains approximately 16.12 miles of flood risk reduction facilities along the upper Puyallup River in a combination of levees and revetments Table 6.15 contains a list of river management facilities in this reach, including ownership.

Table 6.15. Levees and Revetments in the Upper Puyallup River

Name	Location[a]	Ownership
Right Bank		
Bartroff Revetment	RM 17.38 – RM 17.53	Pierce County
High Cedars Levee	RM 17.53 – RM 19.89, PL 84-99	Pierce County

Name	Location[a]	Ownership
Calistoga Levee	RM 19.89 – RM 21.26, PL 84-99	Pierce County
Right Bank (continued		
Jones Levee	RM 21.27 – RM 22.50, PL 84-99	Pierce County
Ford Levee	RM 22.51 – RM 24.80, PL 84-99	Pierce County
High Bridge Revetment	RM 24.80 – RM 25.44	Pierce County Roads
Neadham Road Levee	RM 26.38 – RM 27.02, PL 84-99	Pierce County
Left Bank		
South Fork Levee	RM 17.52 – RM 18.49	Pierce County
Leach Road Levee	RM 19.11 – RM 21.26, PL 84-99	Pierce County
Soldier's Home Levee	RM 21.27 –RM 23.08, PL 84-99	Pierce County
McAbee Levee	RM 23.03 – RM 23.59, PL 84-99	Pierce County
Larson Revetment	RM 26.04 – RM 26.08	Pierce County
Orville Road Revetment - Phase 1	RM 26.85 – RM 26.98	Pierce County
Orville Road Revetment - Phase 2	RM 27.23 – RM 28.33	Pierce County
Champion Bridge Levee/Revetment	RM 28.33 – RM 28.58	Pierce County

Source: Pierce County SWM records

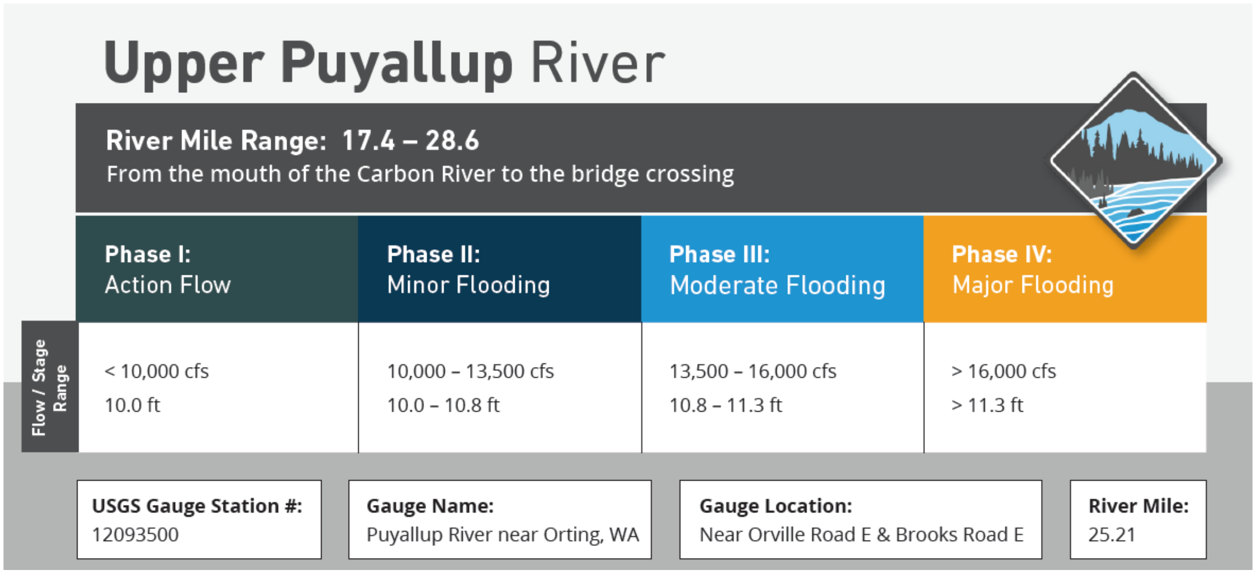
[a] PL 84-99 USACE Flood Control and Coastal Emergency Act

RM = river mile

6.5.6 Upper Puyallup River Flow Warning Matrix

The upper Puyallup River has four flow categories: Phase I, Action flow; Phase II, Minor flooding; Phase III, Moderate flooding; and Phase IV, Severe flooding. These categories describe the observed or expected severity of the flood impacts in that area. However, the severity of flooding at a given stage is not necessarily the same at all river locations. Most river reaches in Pierce County have a defined flow warning matrix that is used during flood events. Figure 6.33 shows the flow warning matrix table for the upper Puyallup River.

Figure 6.33. Upper Puyallup Flow Warning Matrix



Historical Flooding

The upper Puyallup River has experienced multiple high-water events during the period of record (1932 – present) that have resulted in flooding (see Table 6.16). The largest flood event on record at the USGS gauge near Orting occurred on November 6, 2006, with a flow of 21,500 cfs, estimated to be an approximately 160-year event in the upper Puyallup River.

Table 6.16. Historical Flooding in Upper Puyallup River

Date	Puyallup River Flow at Orting Gauge (cfs)
November 1932	11,800
December 1933	12,800
December 1955	12,100
November 1959	12,900
November 1962	15,300
January 1965	12,200
December 1977	12,100
January 1990	11,600
February 1996	18,300
November 1999	11,600
November 2006	21,500
November 2008	15,200
January 2009	16,900
November 2014	16,500
December 2015	17,200

October 2017	11,900
February 2020	16,600
November 2021	15,100
February 2022	12,400

Flood Damage to Facilities

Flood damages to upper Puyallup River flood risk reduction facilities have been extensive in the past three decades. Five significant flood events of more than 16,000 cfs have occurred along the study reach since 1990. Damages sustained ranged from full washout of the flood risk reduction structure over several hundred lineal feet to localized moderate scour and erosion. Damages from the floods and high water events have resulted in approximately 243 identified damage locations along 11.2 miles of levees and revetments. Damages have been estimated at nearly $41.62 million (based on 2017 dollars). The upper portion of this Puyallup River reach between RM 25.4 and RM 28.6 has historically been the most vulnerable to significant repetitive damages that require repair and implementation of capital solutions to reduce flood risk.

Table 6.17 includes current damages to facilities from 1990 to 2021.

Table 6.17. Damage to Facilities along the Upper Puyallup River 1990 – 2021

Storm Season/ Segment Name	Bank	River Mile	Damage Lineal Feet	Damage
1990				
McAbee	Left	23.6	100	Reshape and replace riprap and toe rock.
Ford - Historic	Right	24.0	100	Reshape and replace riprap and toe rock.
The Country - Remnant	Left	24.7	200	Partial washout.
High Bridge Revetment	Right	25.1	600	Restore damaged riprap.
Fiske Creek Revetment	Right	25.5	800	Reconstruction.
Neadham Road-Historic I	Right	25.9	280	Reconstruction.
Neadham Road-Historic I	Right	26.0	900	Reconstruction.
Orville-Kapowsin	Right	26.2	800	Reconstruction.
Orville-Kapowsin	Left	26.2	150	Reconstruction.
Orville-Kapowsin	Left	26.4	501	Reconstruction.
Orville-Kapowsin	Right	26.4	700	Reconstruction.
Orville-Kapowsin	Left	26.6	600	Washout.
Orville-Kapowsin	Left	26.6	900	Reconstruction.

Storm Season/ Segment Name	Bank	River Mile	Damage Lineal Feet	Damage
Orville-Kapowsin	Left	26.8	350	Partial washout.
Neadham Road	Right	26.8	250	Reconstruction.
Orville-Kapowsin	Left	27.0	800	Reconstruction.
Stehn Large Lot	Left	R27.2	500	Washout.
Stehn Large Lot	Left	27.4	632	Reconstruction.
Griessel	Left	27.6	1,000	Reconstruction.
Griessel	Left	27.7	200	Partial washout.
Champion Bridge	Left	28.5	400	Washout, restore channel alignment.
1991				
Neadham Road	Right	26.8	250	Reconstruction.
1992				
High Bridge Revetment	Right	25.4	160	Reconstruction.
Neadham Road-Historic Ii	Right	26.2	150	Reconstruction.
1994				
Jones	Right	21.8	20	Repair of levee damages.
Ford - Historic	Right	23.6	20	Repair of levee damages.
Ford - Historic	Right	23.8	20	Repair of levee damages.
1995				
Calistoga	Right	19.8 - 20.2	500	Total levee failure.
Calistoga	Right	20.0	375	Partial washout.
Leach Road	Left	20.0	195	Reshape and replace riprap and toe rock.
Leach Road	Left	20.2	300	Mostly toe failure with some slope failure.
Calistoga	Right	20.7	100	Partial washout.
Leach Road	Left	20.7	200	Partial washout.
Calistoga	Right	20.9	200	Toe/slope failure.
Jones	Right	22.3	250	Toe/slope failure.
Jones	Right	22.4	200	Toe/slope failure.
Soldiers Home - Historic	Left	22.5	200	Partial washout.
Soldiers Home - Historic	Left	22.5	50	Total failure.
Soldiers Home	Left	22.9	200	Partial washout.

Storm Season/ Segment Name	Bank	River Mile	Damage Lineal Feet	Damage
Ford - Historic	Right	23.6	900	Total failure.
Ford - Historic	Right	23.7	200	Partial washout.
1995 (continued)				
The Country - Historic Ii	Left	24.0	200	Partial washout.
The Country - Historic Ii	Left	24.0	800	Total failure.
Mint Creek	Left	25.1	300	Partial washout.
Neadham Road - Remnant I	Right	25.6	200	Partial washout.
Orville-Kapowsin	Left	26.2	1,500	Full levee washout
Orville-Kapowsin	Left	26.5	225	Partial washout.
Orville-Kapowsin	Left	26.6	200	Partial washout.
Neadham Road	Right	26.8	500	Partial washout.
Orville-Kapowsin	Left	27.0	500	Full levee washout.
Griessel	Left	27.6	400	Full levee washout.
Griessel-Historic	Left	28.1	300	Cutoff levee, full washout.
Griessel-Historic	Left	28.1	700	Full levee washout.
1996				
High Cedars	Right	17.6	400	Toe failure.
High Cedars	Right	18.0	500	Toe failure.
High Cedars	Right	18.0	400	Total failure.
South Fork	Left	18.2	200	Levee access road damage.
High Cedars	Right	19.0	100	Toe/slope failure.
Calistoga	Right	19.8 - 20.2	500	Total levee failure.
Calistoga	Right	19.8 - 20.2	1,200	Total levee failure.
Calistoga	Right	20.0	375	Toe/slope failure.
Calistoga	Right	20.2	200	Mostly toe failure, with some slope failure.
Leach Road	Left	20.5	300	Toe/slope failure.
Calistoga	Right	20.7	300	Toe failure.
Calistoga	Right	20.8	100	Toe failure.
Calistoga	Right	20.9	300	Toe/slope failure.
Calistoga	Right	21.2	200	Toe/slope failure.

Storm Season/ Segment Name	Bank	River Mile	Damage Lineal Feet	Damage
Soldiers Home - Historic	Left	21.9	400	Toe/slope failure.
Jones	Right	22.3	250	Toe/slope failure.
1996 (continued)				
Jones	Right	22.4	200	Toe/slope failure.
Jones	Right	22.5	200	Total failure.
Ford	Right	22.9	300	Toe/slope failure.
Ford	Right	23.1	200	Total failure.
Ford - Historic	Right	23.6	900	Total failure.
McAbee	Left	23.6	1,200	Total failure.
The Country - Historic Ii	Left	24.0	500	Total failure.
The Country - Historic Ii	Left	24.1	300	Total failure.
Ford - Historic	Right	24.6	1200	Total failure.
High Bridge Revetment	Right	25.1	200	Total failure.
Mint Creek	Left	25.15	250	Toe/slope failure.
Neadham Road - Remnant I	Right	25.6	1,300	Total failure.
Neadham Road- Historic Ii	Right	26.2	2,000	Total failure.
Neadham Road	Right	26.4	600	Total failure.
Neadham Road	Right	26.6	1,000	Total failure.
Orville-Kapowsin	Left	26.6	900	Toe/slope failure.
Orville-Kapowsin	Left	26.7	1,200	Toe/slope failure.
Neadham Road	Right	26.8	1,000	Total failure.
Orville-Kapowsin	Left	26.8	2,000	Total failure.
Griessel	Left	27.6	2,000	Toe/slope failure.
Griessel-Historic	Left	28.0	2,500	Toe/slope failure.
Orville-Kapowsin	Left	26.7 - 27.6	3,000	Total failure.
2003				
Calistoga	Right	21.0	300	Partial washout of the toe and levee facing.
Soldiers Home	Left	22.8	220	Partial washout of the toe and levee facing.
Orville-Kapowsin	Left	26.2	360	Partial washout of the toe and levee facing.

Storm Season/ Segment Name	Bank	River Mile	Damage Lineal Feet	Damage
Champion Bridge	Left	28.2	40	Partial washout of the toe and levee facing.
2004				
High Cedars	Right	17.8	1,300	Partial washout of the toe and levee facing.
High Cedars	Right	19.6	250	Partial washout of the toe and levee facing.
Leach Road	Left	20.7	10	Re-establish heavy riprap around outfall pipe.
Soldiers Home - Historic	Left	22.3	250	Partial washout of the toe and levee facing.
2005				
Soldiers Home - Historic	Left	22.3	100	Repair/replace toe and face rock.
2006				
South Fork	Left	17.7	40	Washout.
High Cedars	Right	18.0	50	Washout.
South Fork	Left	18.0	350	Washout.
High Cedars	Right	19.4	150	Washout.
Leach Road	Left	19.4	50	Washout.
Calistoga	Right	19.8	100	Washout.
Leach Road	Left	19.8	200	Washout.
Soldiers Home	Left	22.6	100	Face erosion.
Ford	Right	22.8	350	Washout.
McAbee	Left	23.6	600	Washout.
Orville-Kapowsin	Left	26.3	415	Washout.
Champion Bridge	Left	28.4	450	Washout.
Champion Bridge	Left	28.6	150	Washout.
Champion Bridge	Left	28.6	700	Washout.
Neadham Road-Historic Iii	Right	26.7 - 27.0	1,500	Washout.
2007				
High Cedars	Right	18.0	70	Washout.
Jones	Right	22.0	200	Repair.
Orville-Kapowsin	Left	25.7	500	Washout.
Orville-Kapowsin	Left	26.2	200	Washout.
Neadham Road	Right	26.7	330	Cut-off construction.
Neadham Road	Right	26.4 - 26.8	1,600	Washout - USACE assistance.

Storm Season/ Segment Name	Bank	River Mile	Damage Lineal Feet	Damage
2008				
High Cedars	Right	18.2	75	Toe rock failure and partial face rock failure.
High Cedars	Right	18.5	175	Toe rock & partial face failure.
Leach Road	Left	19.3	250	Top of levee/access road scour.
Leach Road	Left	19.75	350	Partial washout of the toe and levee facing.
Jones	Right	21.7 - 22.4	600	Partial washout of the toe and levee facing.
The Country - Historic I	Left	23.6 - 23.8	620	Washout.
Calistoga	Right	19.82	200	Top surface access road scour.
Calistoga	Right	20.78	130	Potential toe rock failure and face rock failure.
Calistoga	Right	21.15	120	Potential toe rock failure and face rock failure.
Jones	Right	21.3	450	Toe rock failure.
Soldiers Home	Left	21.30	120	Toe rock failure.
Jones	Right	22.0	300	Toe rock failure.
Jones	Right	22.05	100	Toe rock failure.
Ford	Right	22.8	150	Toe rock failure.
Soldiers Home	Left	23.0	600	Toe rock failure.
McAbee	Left	23.6	150	Partial levee core failure.
Ford	Right	24.6	100	Toe rock failure.
Neadham Road-Historic Ii	Right	26.3	738	Complete washout.
Champion Bridge	Left	28.3	127	Toe and face rock failure.
Champion Bridge	Left	28.5	299	Partial washout.
2009				
High Cedars	Right	18.2	75	Toe rock failure and partial face rock failure.
High Cedars	Right	18.8	700	High cedars facing rock failure.
Leach Road	Left	19.3	250	Top of levee/access road scour.
High Cedars	Right	19.4	120	Face rock failure.
Leach Road	Left	19.8	520	Revetment 30 percent of facing rock missing.
Jones	Right	22.1	200	Primarily face scour loss of face rock.
Jones	Right	22.35	60	Primarily face scour loss of face rock.
Ford	Right	22.7	150	Primarily face scour loss of face rock.
Soldiers Home	Left	22.7	141	Primarily scour along the lower portion of the face rock.

Storm Season/ Segment Name	Bank	River Mile	Damage Lineal Feet	Damage
2009 (continued)				
McAbee	Left	23.3	200	Primarily face scour loss of face rock.
McAbee	Left	23.6	150	Partial levee core failure.
Neadham Road	Right	26.8	130	Cut-off extension.
Champion Bridge	Left	28.15	150	Complete washout of levee.
Champion Bridge	Left	28.2	168	Primarily face scour loss of face rock.
Champion Bridge	Left	28.25	300	Primarily face scour loss of face rock.
Champion Bridge	Left	28.3	135	Toe scour causing face rock to slough away.
Champion Bridge	Left	28.5	435	Primarily face scour loss of face rock.
2010				
High Cedars	Right	18.18	10	Small face scour pocket.
Leach Road	Left	19.8	550	Toe and face scour - USACE assistance.
Soldiers Home	Left	21.3	150	Slope and toe scour - USACE assistance.
Jones	Right	21.4	500	Toe and partial embankment scour - USACE assistance.
Soldiers Home	Left	22.5	140	Slope and toe scour - USACE assistance.
Soldiers Home	Left	22.7	175	Slope and toe scour - USACE assistance.
Neadham Road	Right	26.8 - 27.0	550	Levee extension.
2011				
Leach Road	Left	19.9	60	Partial failure.
Ford	Right	23.4	120	Face and toe rock failure.
Ford	Right	24.7	300	Lower face scour.
High Bridge Revetment	Right	25.3	90	Major face scour/scarp.
Neadham Road	Right	26.45	120	Face and toe rock failure.
Champion Bridge	Left	28.3	100	Face rock failure & sloughing.
Champion Bridge	Left	28.15 - 28.3	700	Face and toe rock failure.
2012				
High Cedars	Right	19.3	75	Toe scour.
Leach Road	Left	19.9	60	Partial failure upstream end.
Calistoga	Right	20.7	25	Knick point.
Soldiers Home	Left	21.45	50	Lower face and possible toe scour.
Soldiers Home	Left	22.6	50	Lower face erosion.

Storm Season/ Segment Name	Bank	River Mile	Damage Lineal Feet	Damage
2012 (continued)				
Ford	Right	23.5	200	Toe scour.
McAbee	Left	23.6	80	End of levee at rock point washed out to river mile post sign.
Soldiers Home	Left	23.6	80	End of levee at rock point washed out to river mile post sign.
Ford	Right	24.7	200	Toe scour and loss of lower face.
High Bridge Revetment	Right	25.2	30	Knick point in revetment.
High Bridge Revetment	Right	25.4	50	Over steepened w/ lots of rock missing.
Neadham Road	Right	26.5	240	Face rock sloughing along entire length due to lost toe rock or toe being lost.
Neadham Road	Right	26.65	210	Toe rock missing, causing face to slough.
Neadham Road	Right	26.7	75	Several upper-level toe rocks rolled out.
Champion Bridge	Left	28.15	200	Continued damage from last year.
Champion Bridge	Left	28.45	100	Sloughing moving upstream.
Champion Bridge	Left	28.1- 28.2	700	Sloughing.
2013				
High Cedars	Right	18.70	30	Toe rock and face rock missing with some core erosion.
High Cedars	Right	19.4	75	Knick point. Toe rock loss and face sloughing.
Ford	Right	23.50	200	Toe scour.
Neadham Road	Right	26.65	210	Toe rock missing causing face to slough.
Neadham Road	Right	26.70	60	Toe rock is being scoured and causing the face to slough.
Champion Bridge	Left	28.3	100	Revetment repair.
2014				
Soldiers Home	Left	21.45	100	Lower face scour.
Neadham Road	Right	26.4	300	Thalweg against toe causing scour along the lower face and toe.
Neadham Road	Right	26.6 and 26.7	285	Toe scour causing lower face to slough.
Champion Bridge	Left	28.2 - 28.3	400	Toe rock rolling out and face sloughing.

Storm Season/ Segment Name	Bank	River Mile	Damage Lineal Feet	Damage
2015				
High Cedars	Right	18.15	100	Maintenance.
High Cedars	Right	18.25	160	Missing face rock.
High Cedars	Right	18.3	130	Missing face rock.
High Cedars	Right	19.4	200	Maintenance.
Leach Road	Left	19.4	200	Overtopping and scour over access road.
Leach Road	Left	19.6	150	Overtopping and facing rock damaged.
Leach Road	Left	20.3	10	Tree pulled in a chunk of levee.
Leach Road	Left	21.0	75	Toe and face rock missing.
Soldiers Home	Left	21.45	40	Levee rehabilitation.
McAbee	Left	23.2	100	Core exposed.
Ford	Right	23.60	100	Missing face and toe rock.
McAbee	Left	23.6	100	Buttress end has started to erode.
Ford	Right	24.70	300	Full washout over 200 LF. Orville road only 40 feet away.
Ford	Right	24.70	400	Washout of levee. Emergency repair.
High Bridge Revetment	Right	25.2	60	Face scour, sloughing, loss of toe rock.
High Bridge Revetment	Right	25.35	350	Face scour and loss of toe rock.
Neadham Road	Right	26.4	150	Missing face rock.
Griessel	Left	27.7	30	Access road at culvert damaged.
Champion Bridge	Left	28.15	40	Erosion at end of Champion Bridge Levee.
Champion Bridge	Left	28.2	110	Missing toe and face rock.
Champion Bridge	Left	28.2	220	Severe face scour.
Champion Bridge	Left	28.2	450	Emergency - levee rehab
Champion Bridge	Left	28.25	150	Missing face rock and over steepened.
Champion Bridge	Left	28.25	100	Project has grown from 150 to 250 from November Flood.
Neadham Road	Right	26.6 & 26.7	80	Levee rehabilitation.
2017				
High Cedars	Right	17.6	1	Over steepened.
High Cedars	Right	18.6	100	Toe and face rock failure.
High Cedars	Right	18.77	40	Toe and face rock failure.

Storm Season/ Segment Name	Bank	River Mile	Damage Lineal Feet	Damage
Leach Road	Right	19.3	800	Access road damage.
2017 (continued)				
Soldiers Home	Left	22.8 - 22.9	900	Levee rehabilitation.
Leach Road	Right	19.9	25	Scour at top of levee.
Leach Road	Left	20.2	60	Localized scour. Missing toe and face rock.
Leach Road	Left	20.7	50	Localized scour. Missing toe and face rock.
Leach Road	Left	21.0	310	Face and toe rock failure.
Jones	Right	22.2	500	Toe rock failure.
McAbee	Left	23.6	160	Further erosion of buttress.
Ford	Right	24.6	400	Levee washout.
High Bridge Revetment	Right	25.4	50	Upstream end of past repair project is damaged.
Neadham Road	Right	26.65	125	Thalweg against toe causing scour along the lower face and toe.
Champion Bridge	Left	28.2	150	Emergency - levee rehabilitation.
Champion Bridge	Left	28.2	175	Further damage at end of levee.
Champion Bridge	Left	28.25	50	Project has grown from 150 linear feet to 250 liner feet from the November flood.
Champion Bridge	Left	28.25	50	More toe and face rock missing.
2018				
Leach Road	Left	21.0	465	Erosion and bank caving.
Jones	Right	22.2	300	Erosion and bank caving.
Ford	Right	24.6	400	Emergency – levee rehabilitation.
2019				
High Cedars	Right	17.6	400	Erosion of face and toe rock.
High Cedars	Right	18.6	466	Over-steepened and rock missing.
High Bridge	Right	25.4	202	Levee rehabilitation.
2020				
Leach Road	Left	20.6	800	Levee rehabilitation.
Ford	Right	24.5	200	Emergency – levee rehabilitation.

6.5.7 Key Accomplishments since the 2018 Flood Plan Update

Major Projects

Since the 2018 Flood Plan Update was completed, Pierce County has carried out an annual program that includes maintenance and repair of revetments and levees, listed in Table 6.15, as well as the capital projects noted below and major repairs shown in Table 6.18.

South Fork Floodplain Restoration Project

This project, which was completed in 2018, reconnected about 42 acres of floodplain and constructed a 4,200-foot-long major side channel that includes many engineered log jam structures, pools, riffles, and other natural wood features. Figures 6.34 and 6.35 shows the flood flows along South Fork since the completion of the project. The benefits of this project include the following:

- Flood risk reduction for neighborhoods along the east side of the Puyallup River.
- Restoration of the floodplain, which allows the river to function more naturally by providing flood storage in a new side channel.
- Provides salmon habitat for spawning during the summer and fall for juvenile salmon rearing during the winter. This is especially beneficial to endangered chinook salmon.

This project was funded by grants from the Department of Ecology, Salmon Recovery Funding Board, Floodplains by Design, and Pierce County Real Estate Excise Tax. Additional information on this project can be found at Completed Project web page of the Pierce County website.

Figure 6.34. Flood flows Entering South Fork from the Puyallup River

Figure 6.35. Bypass Channel on South Fork during Flood Flows

Orville Road Revetment and Channel Migration Protection

Pierce County has completed multiple phases of setback revetments between RM 27.9 and RM 28.35 since 2013. The last phase along this reach was completed in 2022 and reconnected approximately 70 acres of floodplain. The project was constructed to remove repetitive loss properties from the floodplain, protect Orville Road, and reconnect critical salmon habitat to the floodplain. Additional information on this project can be found online at the Puyallup River Flood Protection at Orville Road web page of the Pierce County website.

Table 6.18 shows major repairs, generally 400 lineal feet or more in length, along the upper Puyallup River following significantly large storm events. Records maintained by Pierce County show several major repairs have been completed between RM 17.3 and RM 28.6.

Table 6.18. Major Repairs Completed on Upper Puyallup River since 2018 Flood Plan

Storm Season/ Segment Name	Bank	River Mile	Damage Lineal Feet	Damage
2014				

Storm Season/ Segment Name	Bank	River Mile	Damage Lineal Feet	Damage
Champion Bridge	Left	28.2 - 28.3	400	Toe rock rolling out, face sloughing. Face scour, face rock missing, and sloughing.
2015				
Ford	Right	24.70	400	Washout of levee. Emergency repair.
Champion Bridge	Left	28.2	450	Emergency levee rehabilitation.
2017				
Soldiers Home	Left	22.8 - 22.9	900	Levee rehabilitation.
Jones	Right	22.2	500	Toe rock failure 300 -500LF.
Ford	Right	24.6	400	Levee washout.
2020				
Leach Road	Left	20.6	800	Levee rehabilitation.

6.5.8 Land Acquisitions

About 14 acres of property was acquired between 2018 and 2021 along the Upper Puyallup reach. These property acquisitions supported the Neadham Road capital project.

6.5.9 Flood and Channel Migration Hazard Mapping

Hazard mapping in the upper Puyallup River includes detailed flood studies (FEMA/NHC 2006) and the creation of DFIRMs, which became effective as of March 2017. Flood-prone areas along the upper Puyallup River include the High Cedars Golf Club, local roads such as Orville Road and Neadham Road, numerous roads and structures in the Village Green area of Orting, agricultural and rural lands and structures in unincorporated Pierce County, and Orting School District property.

In order to publish the countywide DFIRMs, areas that were affected by non-accredited levees were “secluded” from the map update. This means that most of the Puyallup valley in the vicinity of Orting is still showing the same flood risk as it was understood in the 1970s. The DFIRMs in the vicinity of Orting show 1,830 acres within the SFHA or 100-year floodplain, and unincorporated Pierce County regulates an additional 212 acres as flood fringe. The mapped 119 acres of DFF water floodway area is only in the unincorporated areas. From 2016 to 2019, FEMA, Pierce County, and the City of Orting participated in a levee analysis and mapping process. The resulting study completed in 2019 shows an increased area of flooding in Orting. FEMA has indicated they will update the FIRM after a levee analysis and mapping process study is completed on the Carbon River.

Severe, moderate, and low CMZs were mapped for the upper Puyallup River (GeoEngineers 2003), and the severe risk area was adopted in November 2004 as floodway. The severe CMZ covers an area of 1,325 acres. Pierce County regulates severe CMZ mapped areas as floodway in accordance with PCC Chapter 18E.70. Active erosion has been occurring upstream of Orting in the last few years.

6.5.10 Problem Identification

Table 6.19 identifies flooding and channel migration-related problems in the upper Puyallup River.

Table 6.19. Flooding-related Problems Identified in Upper Puyallup River

Location	Problem Description	Source
Levee and Revetment Overtopping and Breaching		
RM 18.0 – RM 19.2 RB	Levee overtopping floods, High Cedars Golf Course.	Pierce County
RM 19.2 – RM 19.8 LB	Levee overtopping damaged levee and levee access road.	Pierce County
RM 22.5 – RM 22.55 RB	Levee overtopping floods, Calistoga Street and baseball fields.	City of Orting
Tributary Backwater Flooding		
RM 25.3 RB	Backwater flooding at Fiske Creek results in flooding of Brooks Road bridge, causing road closure.	Pierce County
RM 26 LB	Kapowsin Creek backwater flooding impacts Orville Road bridge over creek.	Pierce County
Public Safety/Emergency Rescues		
RM 25.8 – RM 26.5 RB	Emergency evacuations of Neadham Road area occurred during 1996 flood event	Pierce County
Channel Migration Problem Areas		
RM 23.6 – RM 23.9 LB	Channel migration occurred numerous times since 1995, eroding left bank levee upstream of Rock Point.	Pierce County
RM 23.9 – RM 25 LB	Channel migration causes bank erosion, threatening six to eight homes in "The Country."	Pierce County
RM 26.1 – RM 26.3 LB	Channel migration upstream of high bridge eroding bank near Brooks Road and upstream during 2006, 2008, and 2009.	Pierce County
RM 26.4 – RM 26.8 LB	Channel migration threatens Orville Road.	Pierce County
RM 28.1 – RM 28.4 RB	Channel migration downstream of Champion Bridge threatens forested area.	Pierce County
Flooding of Structures and Infrastructure (Roads/Bridges) [not already noted above]		
RM 20.6 – RM 21.25 LB	Leach Road E. flooding north of Calistoga bridge.	Pierce County Roads

Location	Problem Description	Source
RM 21.25 LB/RB	Calistoga bridge is a constriction point for flow (gravel deposition, large woody material impacting bridge).	Pierce County Roads
RM 25.4 – RM 27.0 RB	Neadham Road E. flooding causes road and infrastructure damage during major floods.	Pierce County Roads
Sediment and Gravel Bar Accumulation		
RM 19.4-21.25	Gravel bar accumulation downstream of Calistoga bridge reduces conveyance capacity.	City of Orting
RM 22.5-28.64	Gravel accumulation upstream of Calistoga bridge reduces conveyance capacity and threaten levee integrity.	Pierce County
Facility Maintenance and Repair Needs		
RM 17.4 – RM 19.8 RB	High Cedars levee suffers damage during every large flood (1990, 1995, 1996, 2006, 2008, 2009).	Pierce County
RM 19.8 – RM 28.6	Numerous locations along levees and revetments have required repairs following many flood events.	Pierce County
Fish Habitat Problem Areas		
RM 17.8 - RM 18.1 LB	Historical side channel habitat and wall-based cool water channel has been cut off from Puyallup River by revetment construction.	Puyallup Tribe
RM 19.2 – RM 20.2 LB	Levee/revetment construction cut off floodplain from river channel, limiting rearing/spawning habitat (Horsehaven and 150th St. setback levee locations).	Puyallup Tribe, Pierce County
RM 21.3 – RM 23.0 RB	Levee/revetment construction cut off floodplain from river channel, limiting rearing/spawning habitat (190th Ave. upstream/downstream levee setback locations).	Puyallup Tribe, Pierce County
RM 24.8 – RM 25.2 LB	Mint Creek wetland cutoff from Puyallup River by remnant left bank levee preventing off-channel rearing.	Puyallup Tribe
RM 27.0 – RM 28.2 RB	Remnant railroad bed limits channel migration which degrades riparian habitat and connection with floodplain.	Puyallup Tribe
Public Access		
RM 17.5 – RM 17.6 RB	McMillan trailhead – Lack of public access to water (e.g., for fishing or viewing).	Pierce County Parks
RM 29 – RM 30 RB	Lack of access to river/water; interest in new regional park in Kapowsin vicinity near river.	Pierce County Parks

Source: Pierce County SWM records.

LB = left bank; RB = right bank; RM = river mile.

6.5.11 River Reach Management Strategies

6.5.11.1 Conditions and Constraints of the Upper Puyallup River

- The recommended river reach management strategies for the upper Puyallup River take into account numerous conditions, as follows.
- Development and land use in adjacent floodplain – The upper Puyallup River floodplain is densely developed along the right bank in Orting, but otherwise rural residential and agricultural in land use. The total assessed value of property in the 100-year floodplain is $127.2 million (EcoNorthwest 2022).
- River management facilities – Both the left and right banks of the Puyallup River are constrained by levees and revetments downstream of RM 23.6. Above RM 23.6 to the Champion Bridge, there are limited facilities.
- River channel gradient and width – Channel gradient varies from 0.16 to 1.14 percent. Channel width varies from 130 feet to 1,200 feet, with the widest segments of the channel between Orville Road and Neadham Road and in the area of the two levee setbacks at Ford and Soldiers Home.
- Presence of salmon spawning and rearing habitat – Most species of salmon are found in the upper Puyallup River, including Chinook, pink, chum, and coho, as well as steelhead, bull, and cutthroat trout. Both spawning and rearing habitats are present.
- Sediment transport accumulation and incision – This reach is dominated by sand, gravel, and cobble, with extensive boulders above RM 22.5. The average riverbed elevation change is from 0 feet to +4.0 feet between 1984 and 2009 from RM 17.4 to RM 22.5 and -0.5 feet to +7.5 feet from RM 22.5 to RM 25.7.

The primary objective for the upper Puyallup River is to maintain the structural integrity of the levee and revetment system so the system continues to reduce risks to public health and safety and reduce property and infrastructure damage. Since the 2013 Flood Plan was completed, the City of Orting has constructed a setback levee that is adjustable to meet the changing level of design. The existing recommended design and management strategy has the ability to be retrofitted to adapt to future conditions.

6.5.11.2 Upper Puyallup River Reach Management Strategies

The recommended river reach management strategies for the upper Puyallup River are presented below:

Structural Management Strategies:

- RM 17.4–RM 19.4 left bank; RM 19.1–RM 22.5 left bank; RM 22.5–RM 28.6 right and left bank – Goal for levees is to preserve the existing infrastructure.

- RM 19.4–RM 22.5 (right bank) – The goal for levees should be 100-year design plus three feet of freeboard.
- Revetments should be designed to resist channel migration.
- New revetments designed and constructed to protect Orville Road will implement a preventative design strategy.

Non-structural Management Strategies:

- Continue to follow floodplain development regulations.
- Acquire, buy out, or purchase development rights.
- Develop a legal process to remove or modify flood risk reduction infrastructure.

6.5.11.3 Interim Risk Reduction Measures.

- There are no IRRMS on the Upper Puyallup reach.

6.5.12 Recommended Capital Projects

The following capital improvement projects are recommended to address the priority problem areas identified in Table 6.19.

Riverine Flood Project Project Score: **53**

Project Name: Ford Levee Setback - Capital Maintenance

Project webpage location: [Ford Setback Levee Preservation | Pierce County, WA - Official Website (piercecountywa.gov)]Project location: Puyallup River Right Bank, RM 23.5–RM 24.9 (see Figure 6.36)

Estimated project cost over a 10-year period: $2.0 million

Total project cost: $2.3 million

What is at risk?

Repetitive damages to setback levee resulting from channel migration as seen in Figures 6.37 and 6.38. The frequency and severity of damages have been increasing over the past decade. Failure of this levee has a high likelihood of negatively impacting Orville Road and local residents.

What is the recommended solution?

Rebuild and improve the levee within its existing footprint to resist channel migration and to withstand increasing flow events and their intensity and volume.

What is the current status of the project?

This project is currently in the planning alternative analysis phase.

What will take place with this project from 2023–2033?

Planning, design, and permitting will take place. Construction currently is estimated for 2025.

Who will be involved in project coordination?

Pierce County will coordinate with the USACE, NMFS, USFWS, Ecology, WDFW, Pierce County, Muckleshoot Indian Tribe (Muckleshoot Tribe), and Puyallup Tribe for this project.

What are the environmental considerations?

The project site is within an area identified as Chinook salmon spawning habitat. Several side channels currently exist in the project area and most likely provide juvenile rearing and adult spawning habitat. The best habitat in the main channel is provided near the large stable log jams. The site is also used extensively by bald eagles.

What are the Project Benefits/Drivers?

Flood Risk

Figure 6.36. Location of the Ford Levee Setback-Capital Maintenance Project

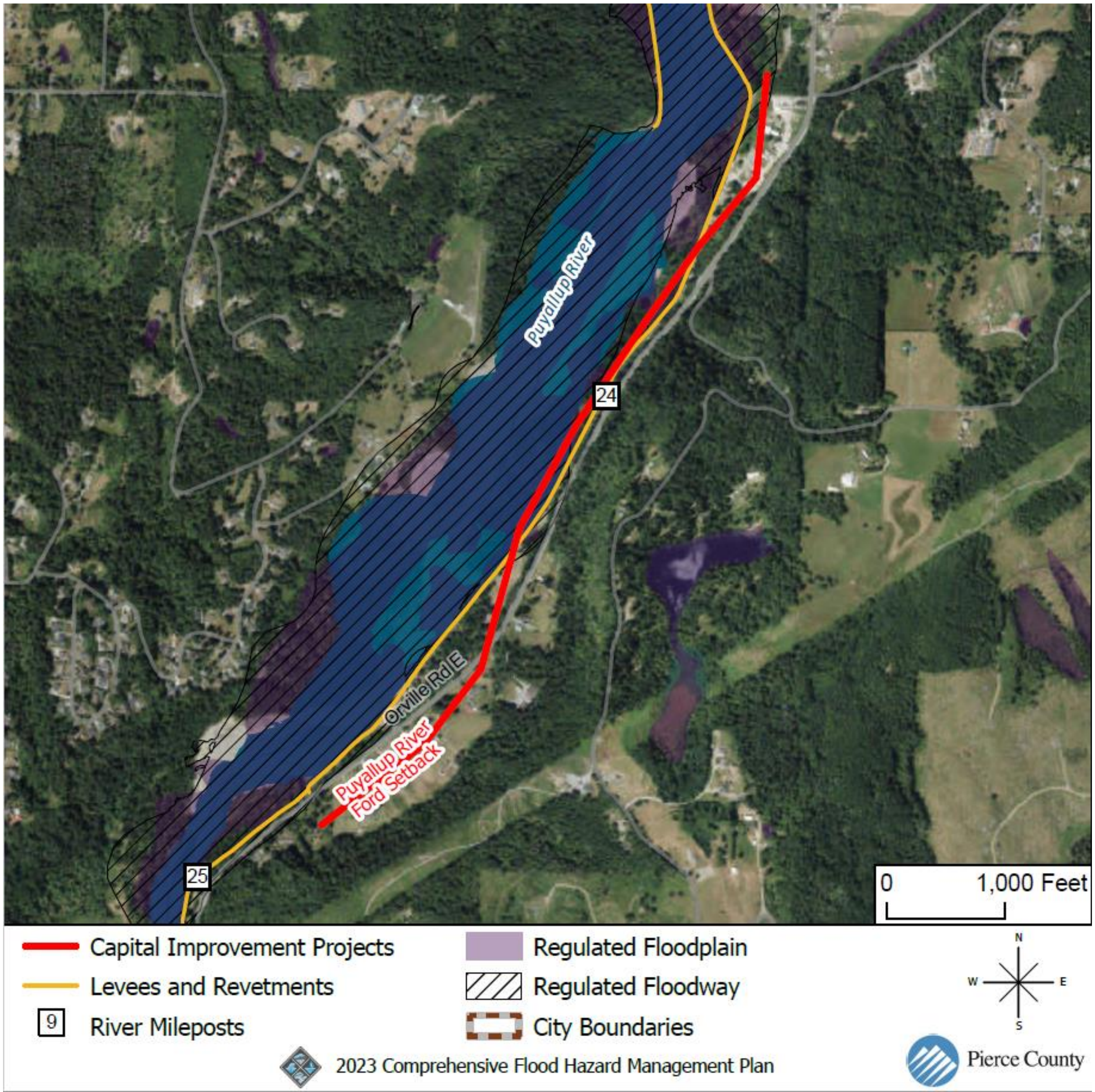


Figure 6.37. Flooding on the Ford Levee, October 22, 2017

Figure 6.38. Flooding on the Ford Levee, February 7, 2022

Riverine Flood Project Project Score: 54

Project Name: Neadham Road Floodplain Reconnection

Project webpage location: https://www.piercecountywa.gov/DocumentCenter/View/110020/FINAL-2022-2027-SWIP?bidId=

Estimated project cost over a 10-year period: $3.1 million

Total project cost: $10.5 million

Project location: The project is located on the right bank of the Puyallup River from RM 25.3 to RM 27.0 (see Figure 6.39).

What is at risk?

This section of the upper Puyallup River is highly dynamic and is actively migrating toward the right bank. The existing levee system provides less than a 100-year level of flood protection and has experienced substantial damages from past flood events, particularly since the November 2006 flood event (see Figure 6.40). The levee segment from RM 25.55 to RM 26.4 has been completely destroyed by the river. The remaining levee segment extends from RM 25.55 to RM 26.9 (see Figure 6.41). The base flood elevation for this river segment lies between 374 feet at RM 25.3 and 467 feet at RM 27.0. The adjacent residential properties within the floodplain lie approximately two feet below the surrounding flood elevation. Additionally, during periods of high flows, Fiske Creek is unable to discharge to the Puyallup River, which leads to flooding of Brooks Road and Neadham Road that makes the roads impassable and cuts off the homes that remain. As of 2022, only 3,379 feet of levee remain.

What is the recommended solution?

Pierce County continues to actively purchase properties in the area with the ultimate goal of removing all residences within the flood hazard areas, including the AE zone (areas subject to inundation by the one percent annual chance flood event), CMZ, and area(s) of DFF waters. The long-term goal is to minimize and/or eliminate Pierce County's responsibility to maintain an area that experiences repetitive flood damages along the Neadham Road corridor. Neadham Road would be abandoned in place, and protective measures would be constructed to preserve Brooks Road.

Who will Pierce County coordinate with on this project?

Pierce County will coordinate with the USACE, NMFS, USFWS, Ecology, WDFW, Pierce County, Muckleshoot Tribe, and Puyallup Tribe for this project.

Figure 6.39. Location of the Neadham Road Floodplain Reconnection Project

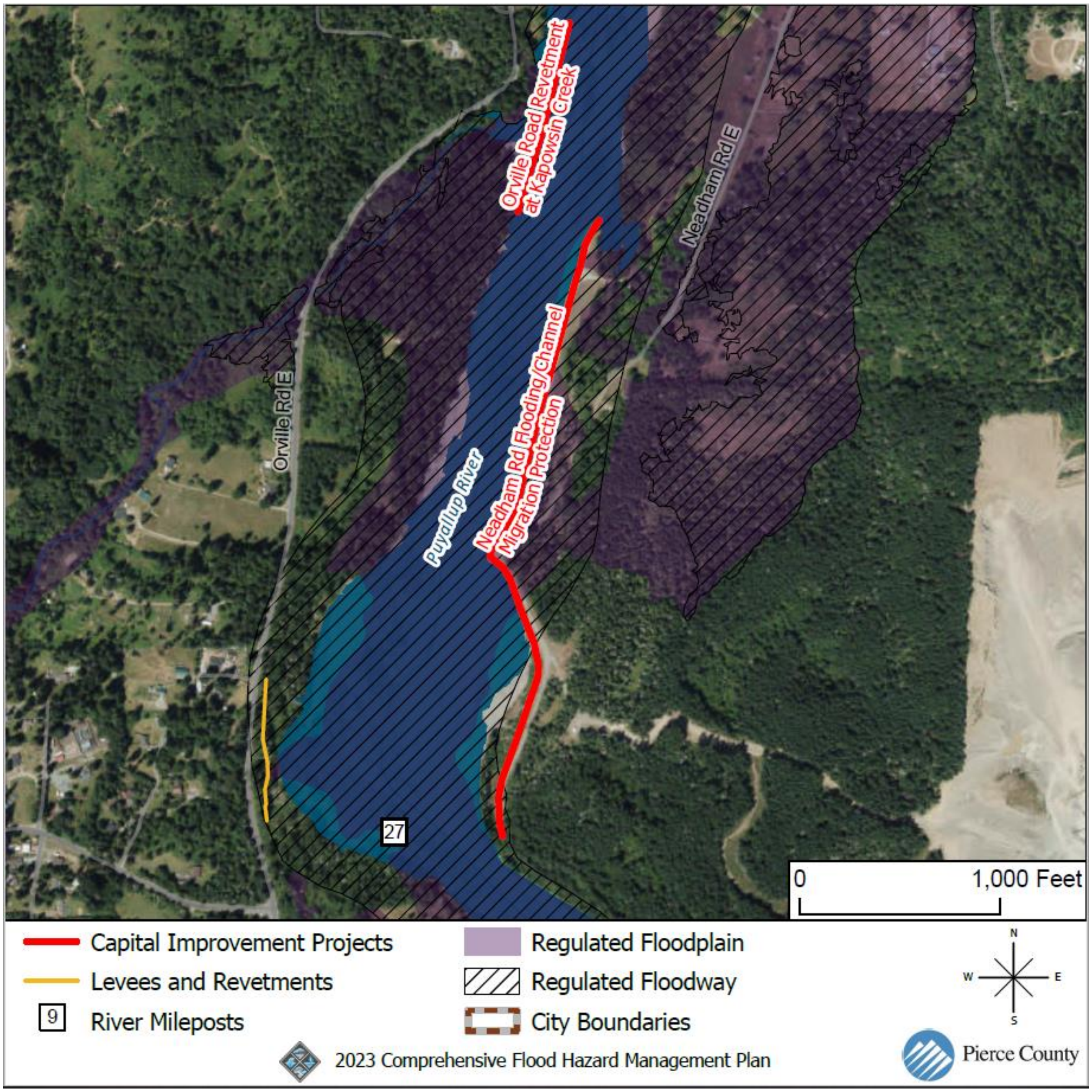


Figure 6.40. 2006 Flooding of Neadham Road Area

Figure 6.41. Levee Remnant at RM 26

What are the environmental considerations?

The upper Puyallup River supports a variety of salmonid species, including ESA-listed Puget Sound Chinook, Puget Sound steelhead, and bull trout. Reconnection of the floodplain will increase habitat in this reach of the river system. In the short term, the construction of the setback levee will require a Shoreline Substantial Development permit and Critical Areas approval from Pierce County and a Hydraulic Project Approval from the WDFW. This project will not require a Section 404 permit from the USACE.

Other Information or Needs

Kapowsin Creek flows north along the west side of the project area and enters the Puyallup River at RM 26.3. Kapowsin Creek is the largest and most productive Chinook and steelhead spawning tributary in the upper Puyallup River.

What is the current status of the project?

The project is in the final stages of acquiring the two remaining properties and in preliminary design phase for the protection of Brooks Road. When these properties are acquired, the county will abandon Neadham Road and remove the existing levee to allow the river to flow more naturally.

What will take place with this project from 2023–2033?

The project will be in the design, permitting, construction, and post construction monitoring phases during this period.

What are the Project Benefits/Drivers?

Habitat

Habitat Conservation Plan

Riverine Flood Project **Project Score: 53**

Project Name: Orville Road Revetment at Kapowsin Creek

Project webpage location: www.piercecountywa.gov/6316/Orville-Road-at-Kapowsin-Creek

Project location: Puyallup River left bank from RM 26.3 to 26.8 (see Figure 6.42)

Estimated project cost over a 10-year period: $3.8 million

Total project cost: $8.4 million

What is at risk?

This stretch of the upper Puyallup River left bank levee has been severely damaged in numerous locations by channel migration and erosion, which threatens approximately two miles of Orville Road, a major north-south arterial highway in eastern Pierce County (see Figure 6.43). Prior to the flood event of 2006, the existing levee provided less than 20-year protection (see Figure 6.44). At present, it provides no flood protection. During the 2006 event, over 2,000 lineal feet of the levee was washed away. On the downstream portion of the levee, the Puyallup River breached the levee and sent flows behind the remaining levee segment and into the Kapowsin Creek channel. Since the river occupied the Kapowsin Creek channel, it migrated over 200 feet to the left bank and is now eroding away hillside and is moving towards Orville Road. The base flood elevation in this area ranges from 420 to 430 feet. There is now risk that channel migration will affect Orville Road East, which is an important primary arterial for eastern Pierce County.

What is the recommended solution?

A combination of setback revetment through a portion of the project reach, combined with engineered log jams installed throughout the floodplain. The project will provide approximately 26 acres of floodplain reconnection and contribute to decreased floodwater elevation and velocities. The project will also provide critical off-channel salmon habitat.

Who will Pierce County coordinate with on this project?

Pierce County will coordinate with the USACE, NMFS, USFWS, Ecology, WDFW, Pierce County, Muckleshoot Tribe, and Puyallup Tribe for this project.

What are the environmental considerations?

The Puyallup River supports a variety of salmonid species, including ESA-listed Puget Sound Chinook, Puget Sound steelhead and bull trout. Kapowsin Creek flows enter the Puyallup River at RM 26.3. Kapowsin Creek is the largest and most productive Chinook and steelhead spawning tributary in the upper Puyallup River.

What is the current status of the project?

This project is currently in the preliminary design stage. Completion of 60 percent plans and submission of environmental permit applications is anticipated in 2023.

Figure 6.42. Location of the Orville Road Revetment at Kapowsin Creek Project

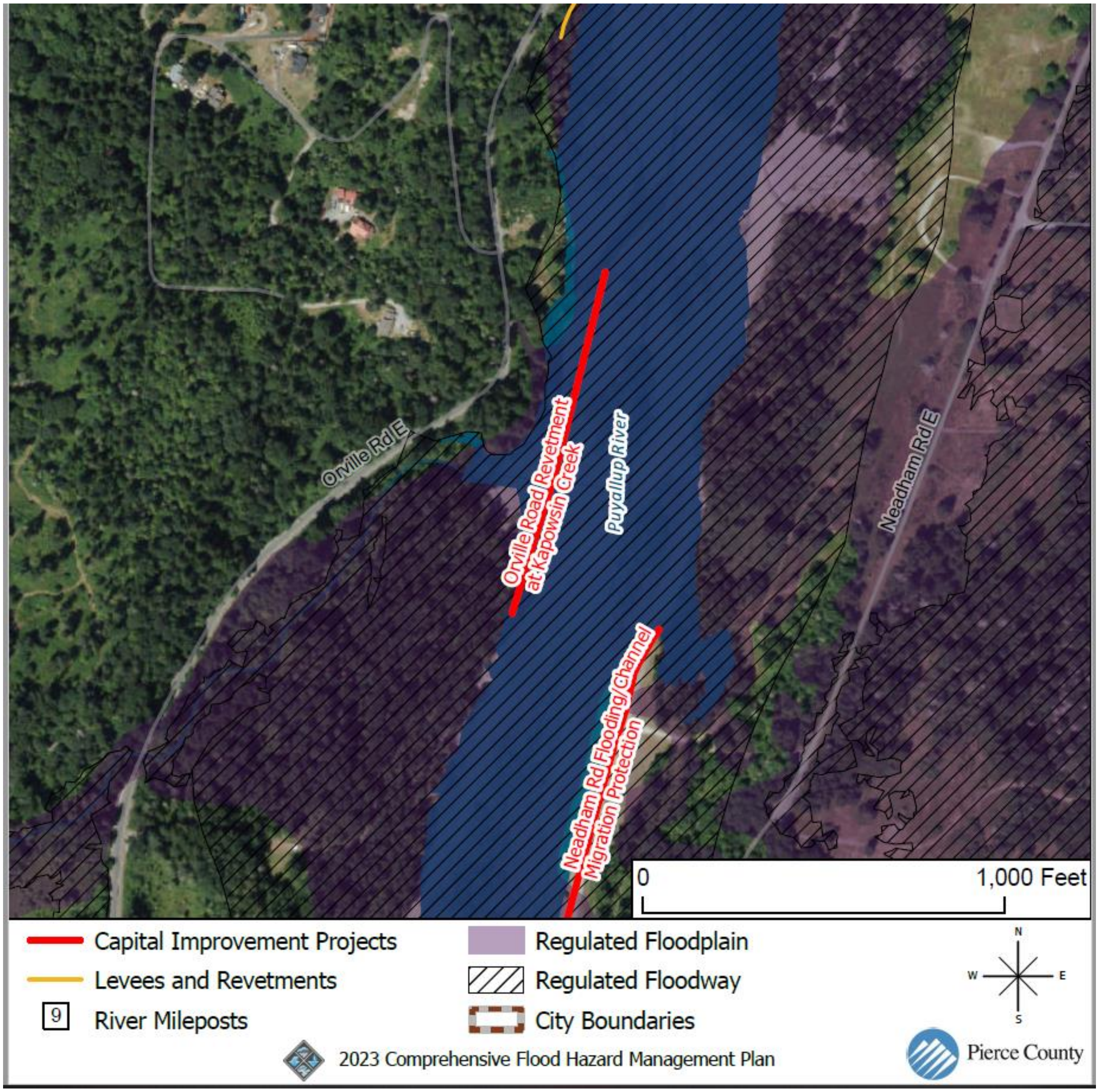
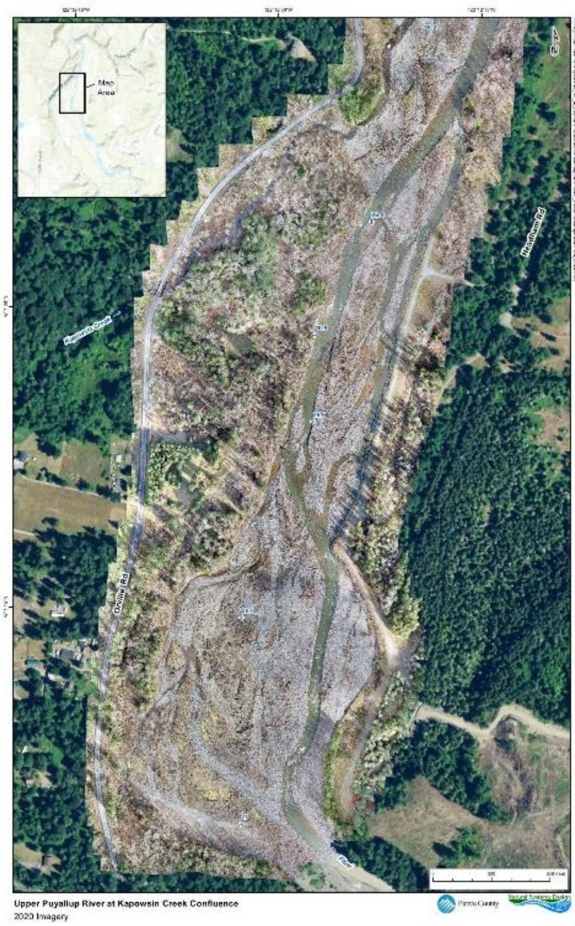


Figure 6.43. Photo showing damage to Orville Road

Figure 6.44. 2020 Aerial Image of Orville Road Revetment Project Reach
Source: NSD 2022



What will take place with this project from 2023–2033?

Final design, permitting, and project implementation will take place.

What are the Project Benefits/Drivers?

Habitat

Riverine Flood Project **Project Score: 59**

Project Name: Jones Setback Levee

Project webpage location: www.piercecountywa.gov/7179/Jones-Levee-Setback

Project location: The project is located on the right bank of the Puyallup River from RM 21.2 to 22.5 upstream of Calistoga Bridge in Orting (see Figure 6.45.

Estimated project cost over a 10-year period: $20.2 million

Total project cost: $26.1 million

What is at risk?

The base flood elevation for this area is between 199 feet and 235 feet and the surrounding development is approximately between 198 and 240 feet. The existing levee system between RM 21.2 and RM 22.5 provides less than 100-year protection and is not accredited by FEMA. Should the levee overtop, the water will flow behind the newly built Calistoga/Ken Wolf levee and enter back into the river at approximately RM 19.8, thus flooding Orting west of SR 162. Since 1990, major flood events occurred in 1990, 1996, 2006, 2009, 2014, 2015, 2017, and 2020.

What is the recommended solution?

The Jones Levee project (see Figure 6.45) will extend the Calistoga/Wolfe Levee farther upstream, ending at high ground. This will prevent flood waters from getting behind Calistoga/Wolfe Levee and greatly reduce Orting's flood risk. Both of these projects are designed as "setbacks," which means the river is given more room to naturally meander. This extra room is also useful during a flood, by lowering the flood levels and taking pressure off of the levee system. The project will also include breaches in the existing levee to allow the river to move debris and sediment downstream naturally and slowly.

Who will Pierce County coordinate with on this project?

Pierce County will coordinate with the City of Orting, Pierce County, Puyallup Tribe, Ecology, WDFW, USFWS, NMFS, USACE, and WSDOT for this project.

What are the environmental considerations?

The Puyallup River supports a variety of salmonid species, including ESA-listed Puget Sound Chinook, Puget Sound steelhead, and bull trout. Implementation of this project will significantly increase their habitat in this stretch of the river system.

What is the current status of the project?

Currently the project is in the feasibility engineering phase. The work for this phase is complete and the internal USACE review and approval to proceed with the design phase is currently occurring.

Figure 6.45. Location of the Jones Setback Levee Project.

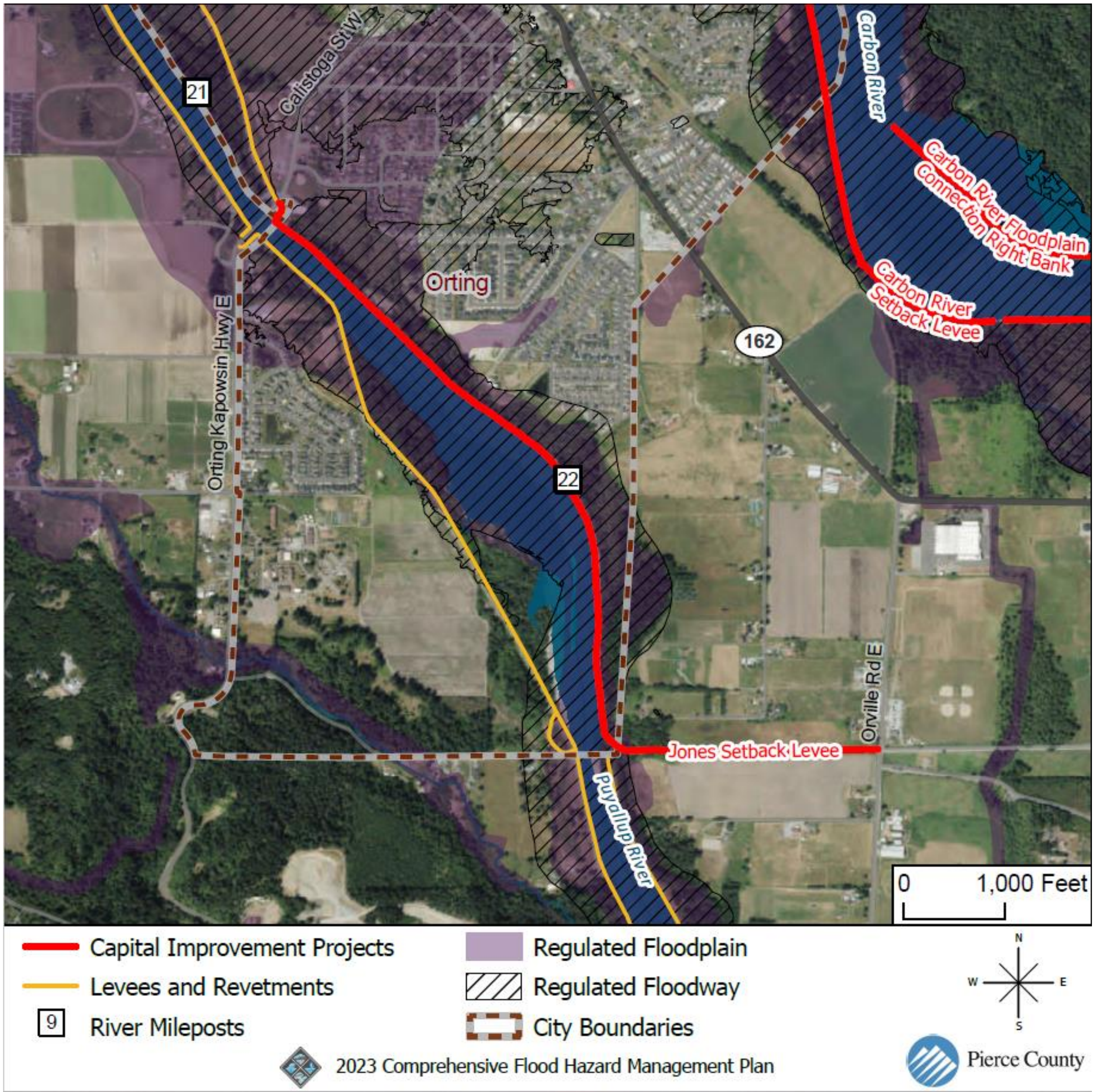


Figure 6.46. Existing Jones Levee looking downstream

What will take place with this project from 2023–2033?

Actions that will take place during this period include design, final design, construction, and project monitoring.

What are the Project Benefits/Drivers?

Flood Risk

Habitat

Other information or Needs

Pierce County requested USACE assistance to address flood risk in the watershed. Modifications to Jones Levee (see Figure 6.45) to protect Orting were originally evaluated as part of the Puyallup River General Investigation Study from 2009 to 2018 by the USACE Seattle District in partnership with Pierce County.

The USACE released a Draft Integrated Feasibility Report and Environmental Impact Statement (FR/EIS) for the General Investigation Study in 2016, which recommended raising Jones Levee. Significant public comments and concerns were put forward, with the raise-in-place recommendation due to environmental impacts associated with the levee modification.

The Puyallup River General Investigation Study was cancelled in 2018 due to economic infeasibility (costs outweighed benefits), so the USACE recommended Pierce County pursue the current Jones Levee project path.

6.6 Lower White River

6.6.1 Overview

The lower White River reach begins at the confluence with the Puyallup River and extends upstream to near RM 5.5 at the Pierce County/King County line, as shown in Figure 6.47. The lower White River flows through the cities of Auburn, Pacific, and Sumner before joining the Puyallup River at RM 10.3. Several tributaries enter the lower White River in this reach, including Bowman Creek, Government Ditch, Soatan-Jovita Creek, and Salmon Creek. This watershed is approximately 496 square miles.

Prior to 2004, the majority of flow in the White River was diverted by Puget Sound Energy's Buckley Diversion Dam located near RM 23.0. The Buckley Diversion Dam sent flow to Lake Tapps for power generation. Return flows from Lake Tapps enter the White River near RM 3.6. The dam is now owned by the Cascade Water Alliance and no longer produces energy.

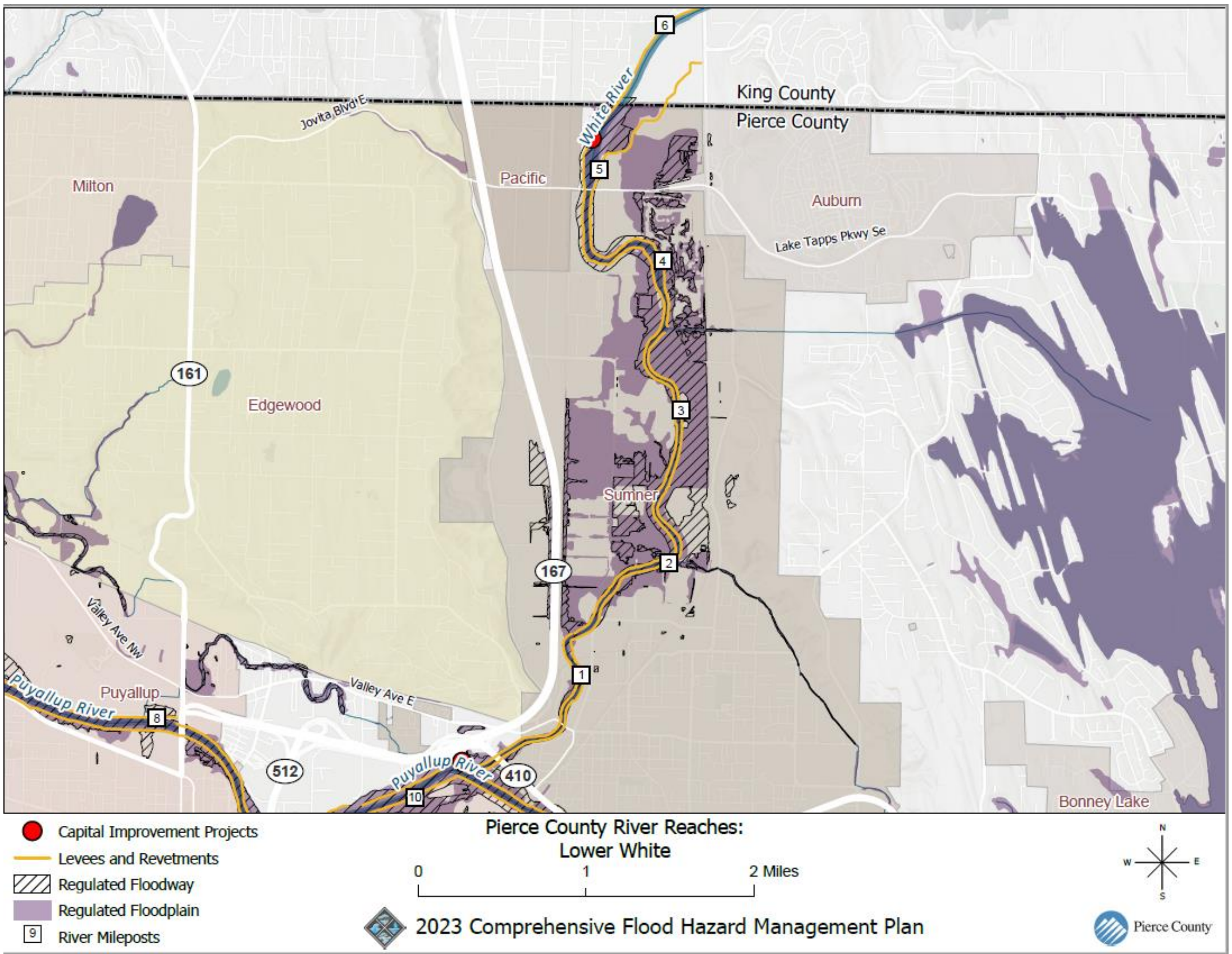
The White River is well known for its large sediment discharge and high turbidity levels. The heavy sediment load is the combined result of a relatively young channel and glacial headwaters (King County 1988).

Prior to 1906, the White River (Stuck River) flowed north past Auburn, where it joined the Green River and flowed to Elliott Bay in Seattle. Record flood flows in November 1906 caused a massive log jam that pushed flood flows into the Stuck River channel to the south and out through the Puyallup River to Commencement Bay. This became permanent in 1914 with the construction of a diversion dam in Auburn near RM 8.0. Between 1914 and the mid-1930s, the lower White River was channelized and confined by a combination of revetments or levees.

Prior to development, the Stuck (lower White River) valley was flat, swampy lowland positioned between the Puyallup River and White River. Lower White River valley soils are composed of fine sand, silt, and peat, which suggests that the area was subject to periodic flooding and backwater ponding. During periods of high flows, the White River would be diverted by wood debris jams into the Stuck River valley (GeoEngineers 2003).

Today, substantial residential, industrial, and commercial development exists along the lower White River valley within Sumner and Pacific. Salmon and trout, including bull trout, cutthroat spring, fall Chinook, coho, sockeye, pink, chum, and steelhead, use the entire reach of the lower White River.

Figure 6.47. Planning Area for the Lower White River



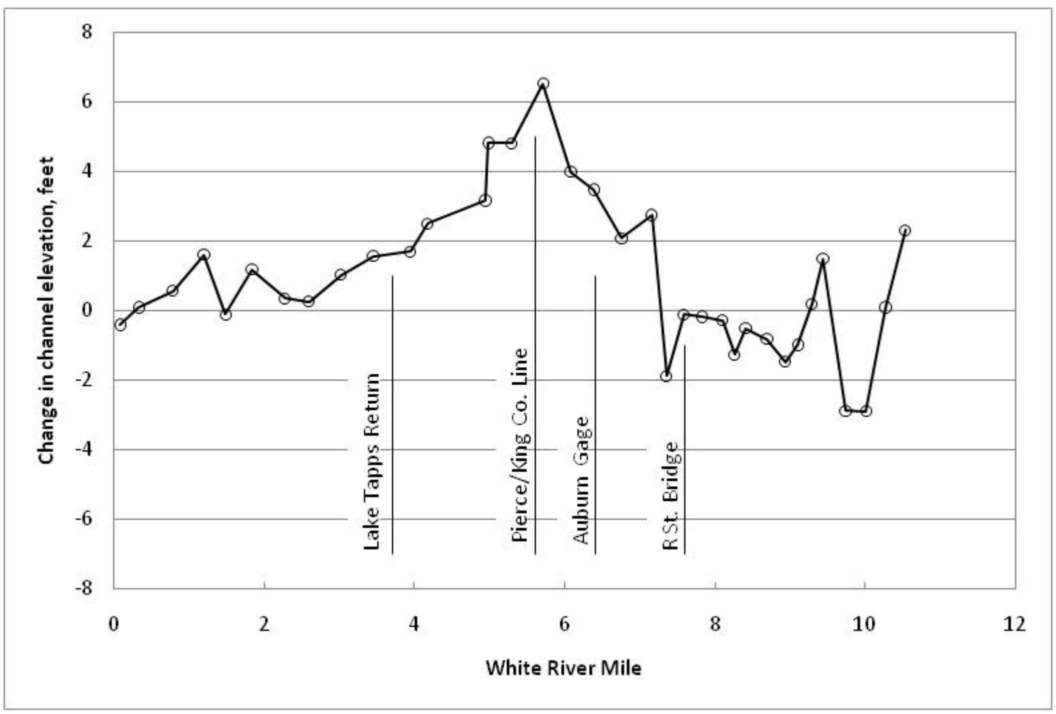
6.6.2 Geology and Geomorphology

> **Alluvial Fan**
>
> **A sedimentary deposit located at a topographic break, such as the base of a mountain front, escarpment, or valley side, that is composed of streamflow and/or debris flow sediments and which has the shape of a fan, either fully or partially extended.**

The White River flows in a lightly meandering pattern in a southwesterly direction from the Muckleshoot Indian Reservation to the county line, RM 8.8 to RM 5.5. Above this point, the White River flows through a canyon the river has cut within the late Holocene (last 5,000 years) into glacial and volcanic lahar sediments (Collins and Sheikh 2004). Sediment generated from incision of the White River canyon augmented sediment from the Osceola and later lahars to build a large alluvial fan in Auburn and Pacific, mostly downstream of RM 7.6. The White River consists of several meander bends from the Pierce County line at RM 5.5 to the Lake Tapps return flow at RM 3.6. The meander bends appear to be relatively stable, primarily due to the construction of revetments after the 1914 diversion of the White River. Aggradation documented by recent monitoring in this section of the river indicates that sediment flux and transport capacity are not in balance. Channel gradient decreases steadily from 0.19 to 0.23 percent in a downstream direction from RM 5.6 to RM 3.6. From RM 3.6 to RM 0.0, the gradient varies from 0.03 to 0.1 percent. Downstream of RM 3.6, the channel is generally straight and incised, with incision increasing downstream (GeoEngineers 2003). The lower 1.4 miles of the river is entrenched by as much as 15 feet and entirely disconnected from its floodplain. The mapped severe CMZ is narrow in the incised reach from RM 0.0 to RM 3.2.

Analysis by the USGS as part of a conveyance capacity study (USGS 2010) indicates an average river bed elevation change of -0.5 feet to +2.0 feet between 1984 and 2009, from the mouth of the White River at RM 0.0 to approximately RM 4.0 (see Figure 6.48). Between RM 4.0 and RM 5.5, the average bed elevation has increased from +2.0 to +5.0 feet, with even larger increases (+6 feet) occurring north into King County.

Figure 6.48. Change in Average Riverbed Elevation between 1984 and 2009 on the Lower White River



6.6.3 Hydrology and Hydraulics

The White River flows about 75 miles from its source at the Emmons and Winthrop glaciers on Mount Rainier’s northeast side to its confluence with the Puyallup River in Sumner. The river’s several major tributaries include West Fork White River, Huckleberry Creek, Greenwater River, and Clearwater River. Mud Mountain Dam at RM 28.2 influences the hydrology of the White River during flood events.

Releases from Mud Mountain Dam are based on maintaining a maximum flow of 45,000 cfs at the Puyallup River gauge located near Milroy Bridge in Puyallup. The target flood control parameter for the Mud Mountain Dam is authorized by Congress. Detention at the dam delays peak flows of the White River, typically one to two days behind Puyallup River peak flows. In the original USACE Mud Mountain Dam 1948 Water Control Plan, water stored in Mud Mountain Reservoir was to be discharged to the White River at up to 17,600 cfs (USACE 2002) because the river channel capacity downstream was estimated to be at least 20,000 cfs. Field observations in the 1970s noted that the threshold for flooding on the White River had declined to 12,000 cfs. The reduction of flood conveyance capacity was attributed to multiple factors, including encroachment into the floodplain by development, excessive vegetation along the channel, sediment in the channel, and restrictions on channel dredging (USACE 2002).

Flows on the White River can be better controlled during moderate storms than large ones, when the reservoir nears capacity and local inflows increase. In recent years, discharge from Mud Mountain Dam was limited to 12,000 cfs when operations allow. Further reduction in target discharge for moderate events, between 6,000 - 8,000 cfs, was planned in 2010 and beyond. Table 6.20 below presents flood frequency flows from the 1987 and 2009 Flood Insurance Studies. Flows reflect operating policy changes and peak lag time due to detention at Mud Mountain Dam.

The change in conveyance capacity since the 1984 USGS study (Sikonia 1990) has been significant, particularly in the reach from RM 2.0 to RM 5.5.

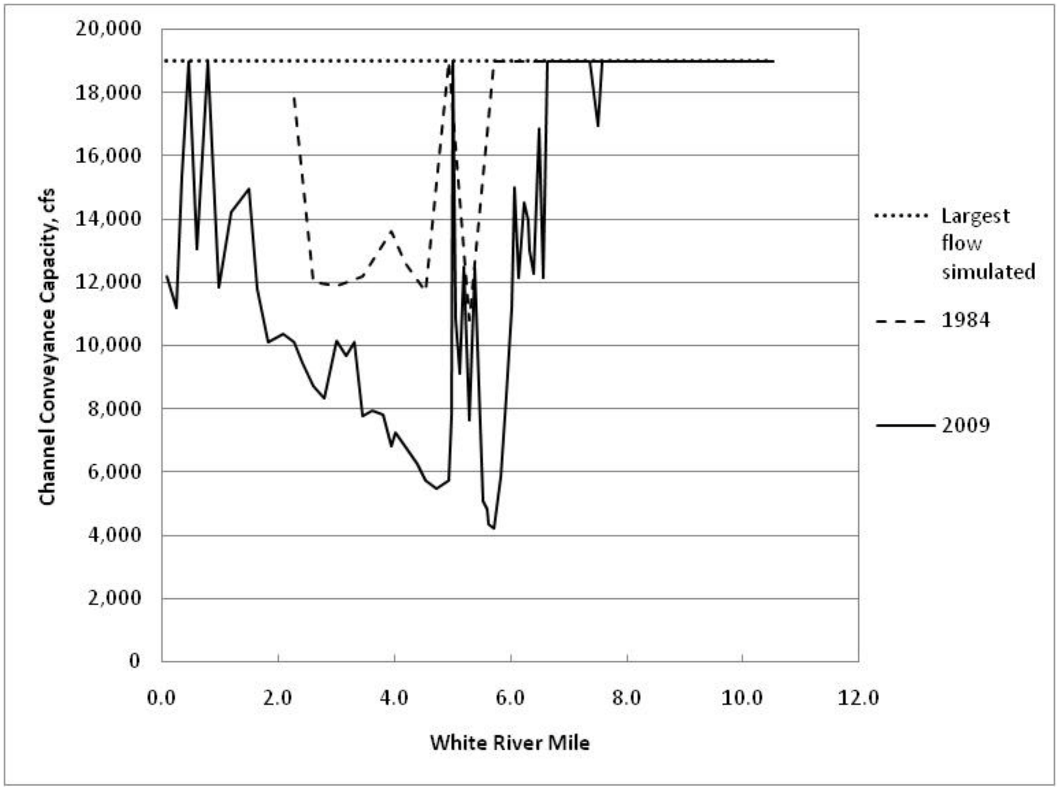
The 2010 USGS conveyance capacity study indicates that the lower White River channel can convey between 10,100 to 19,000 cfs before overtopping either the left or right bank between the mouth and RM 2.3 (see Figure 6.49). From RM 2.3 to RM 5.5 at the Pierce County/King County line, conveyance capacity ranges from 5,000 to 9,500 cfs. The change in conveyance capacity since the 1984 USGS study (Sikonia 1990) has been significant, particularly in the reach from RM 2.0 to RM 5.5.

Table 6.20. Lower White River Flood Frequency Flows at the USGS Auburn Gauge

	Discharge (cfs)				
Location	10-year Event	50-year Event	100-year Event	500-year Event	Method
White River at the mouth at Puyallup River confluence	16,400	18,300	19,100	21,600	1987 FEMA Flood Insurance Study (Log Pearson Type III)
White River at the mouth at Puyallup River confluence	14,000	15,300	15,500	19,000	2009 FEMA Flood Insurance Study for Pierce County (NHC 2006)

Source: 1987 and 2009 FEMA Flood Insurance Study based on USGS data.

Figure 6.49. Channel Conveyance Capacity for the White River
Source: USGS 2010



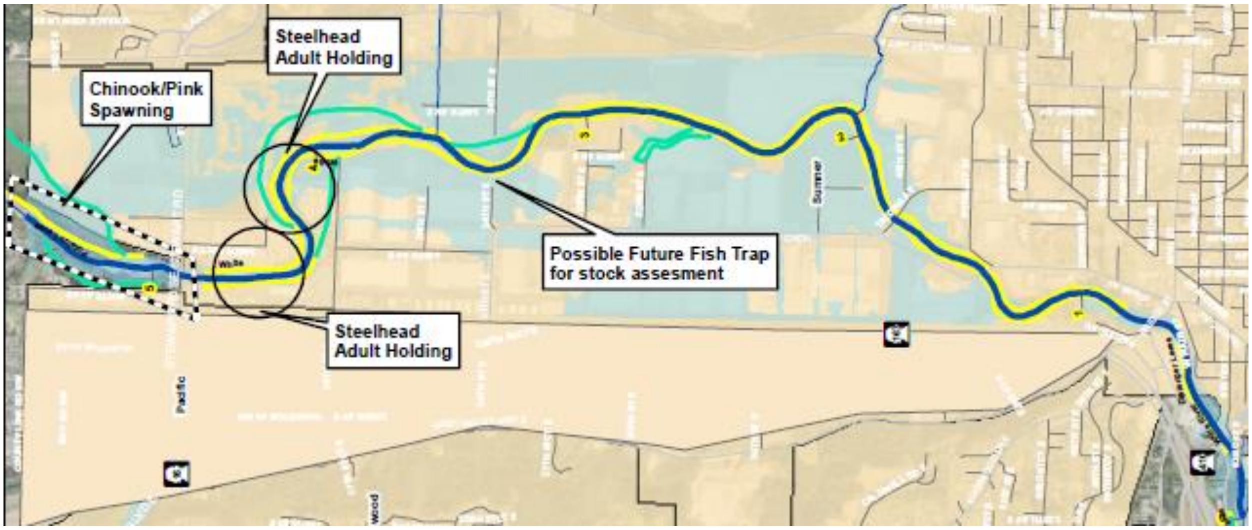
6.6.4 Ecological Context and Salmonid Use

The lower White River is the most heavily modified reach in the planning area. The system today is less than 100 years old. The White River predominantly flowed into the Green River until 1906, when it was directed into its present-day channel. The reach also has been affected by Lake Tapps water withdrawals, dredging, levees, revetments, and flushing of sediment from the Mud Mountain Dam.

All species of salmonids in the Puyallup River basin use the lower White River, which provides primarily migratory habitat for adult salmon and steelhead, and rearing habitat for juvenile salmonoids and foraging habitat for bull trout. Particularly important is the stock of White River spring Chinook, which were on the brink of extinction in the mid-1980s. The stock has rebounded due to WDFW and tribes' brood stock program. Recovery of the White River spring Chinook stock is integral to the recovery of the entire ESA-listed Puget Sound Chinook population.

There is significant incision and floodplain isolation from RM 0.0 to RM 2.6, where the river is confined in a dredged channel and the bed is composed of sand. The reach is primarily a transport area for salmonids, and it provides little rearing or spawning opportunity (see Figure 6.50. Enhancement in this reach is difficult because 15 feet of entrenchment would require major excavation to broaden the floodplain and provide salmonid habitat attributes, such as cover and side channels.

Figure 6.50. Salmonid Habitat in the Lower White River



From RM 2.6 to RM 8.8, the river channel is incised several feet and steepens to approximately a two percent gradient. The bed is composed of cobble and gravel, with some gravel bars and tight braids becoming formed. Due to the constricted channel, scouring of redds can be expected during high flows. This area lends itself better to restoration activity since the mainstem incision is not as severe as the downstream areas and the floodplain can be reasonably accessed by salmon when restored (i.e., levee setback). King County completed a levee setback project near RM 5.5 that enhanced salmon-rearing habitat and reduced flooding. A new 6,000-foot-long setback levee was built. The new levee is protected by a 5,780-foot-long wood structure called a biorevetment and several engineered log jams.

Downstream from King County's countyline levee setback, the City of Sumner is currently spearheading a White River Restoration Project that is hoped to start in 2023. The White River Restoration is a four-step project that aims to restore wetland habitat while also protecting Sumner from river flooding. It will include the following:

- Constructing a new, higher bridge over the White River
- Creating a 20-acre setback levee, which would hold floodwaters and function as a salmon habitat.
- Acquiring 10 properties to restore 25 acres of floodplain.
- Restoring 170 acres of land currently owned by the City, thus making new side channels to store floodwaters and even more salmon habitat.

6.6.5 River Management Facilities, Flooding, and Flood Damage

The lower White River revetments and levees form nearly continuous bank protection from RM 0.0 at the Puyallup River to the Pierce County-King County line at RM 5.5. The facilities on each bank extend upstream into King County and tie into the railroad grade along the A Street SE alignment near RM 6.2. Flood risk reduction facilities protect property and improvements in the floodplain.

Pierce County currently owns and maintains approximately 11.05 miles of flood risk reduction facilities along the lower White River in a combination of levees and revetments The facilities are owned and operated by Pierce County, as summarized in Table 6.21.

Table 6.21. Levees and Revetments in the Lower White River

Name	Location	Ownership
Right Bank		
Sumner Industrial Revetment[a]	RM 10.27 (PR) – RM 1.25	Pierce County
Sumner Commercial Revetment	RM 1.26 – RM 3.30	Pierce County
Sumner Commercial Levee	RM 3.30 – RM 3.92	Pierce County
Pacific Point Bar Revetment	RM 3.92 – RM 4.87	Pierce County
Butte Pit Revetment	RM 4.88 – RM 5.12	Pierce County
Pacific Park Revetment	RM 5.15 – RM 6.23	King County
Left Bank		
Fleishman Revetment	RM 0.04 – RM 2.06	Pierce County
Haywood Revetment	RM 2.06 – RM 2.79	Pierce County
24th Street East Revetment	RM 2.79 – RM 3.57	Pierce County
Dieringer Revetment	RM 3.61 – RM 4.87	Pierce County
Countyline Setback	RM 4.88 – RM 6.23	King County

Source: Pierce County SWM records.

[a] This facility functions as a revetment, but the facility was originally constructed as a levee and has been subsequently backfilled during development by adjacent industrial and commercial property owners.

RM = river mile.

In 1914, the ICRI constructed a diversion dam to prevent the White River from avulsing (separating from current channel) back into its pre-1906 channel and partially channelized the White River to the Puyallup River confluence between 1914 and the1920s (GeoEngineers 2003). Aerial photos in 1931 and 1940 show riprap and concrete levees and revetments protecting the river banks and three bridges located near Sumner. In the lower 1.5 miles of the lower White River, the river is entrenched by as much as 15 feet, which is apparent from the 1920s-era concrete slabs placed to protect the now elevated upper banks (GeoEngineers 2003).

6.6.6 Lower White River Flow Warning Matrix

The lower White River has four flow categories: Phase I, Action flow; Phase II, Minor flooding; Phase III, Moderate flooding; and Phase IV, Severe flooding. These categories describe the observed or expected severity of the flood impacts in that area. However, the severity of flooding at a given stage is not necessarily the same at all river locations. Most river reaches in Pierce County have a defined flow warning matrix that is used during flood events. Figure 6.51 shows the flow warning matrix table for the lower White River.

Figure 6.51. Lower White River Flow Warning Matrix

Lower White River

River Mile Range: 0.0 – 6.2
From the confluence with the Puyallup River to "A" Street Bridge

	Phase I: Action Flow	Phase II: Minor Flooding	Phase III: Moderate Flooding	Phase IV: Major Flooding
Flow / Stage Range	5,000 cfs 114.1 ft	5,000 – 7,500 cfs 114.1 – 115.2 ft	7,500 – 12,000 cfs 115.2 – 116.8 ft	> 12,000 cfs 116.8 ft

USGS Gauge Station #:	Gauge Name:	Gauge Location:	River Mile:
12100490	White River at "R" Street near Auburn, WA	"R" Street Bridge	7.50

Historical Flooding

In the last 30 years, major flooding in the lower White River occurred in 1990, 1996, 2006, and 2009 (see Table 6.22). The largest flood on record occurred in December 1933, prior to the construction of Mud Mountain Dam. Increased flood risk in the lower White River has resulted from the reduction of channel capacity. Thresholds for flood warnings has decreased from 10,000 cfs to 5,500 cfs. Since 2013, these events have occurred multiple times a year.

Table 6.22. Historical Flooding in Lower White River

Date	White River Flows near Auburn[a] (cfs)
December 1933	>28,000
December 1946	>12,300
December 1955	>13,700
November 1959	>13,000
December 1977	>14,800
January 1986	>14,000

Date	White River Flows near Auburn[a] (cfs)
November 1986	>15,200
January 1990	14,500
February 1996	15,000
December 1996	13,600
January 2006	12,400
November 2006	14,700
January 2009	12,000

Source: USGS data

Note: Mud Mountain Dam was constructed on the White River in 1948.

[a] Auburn Gauge #12100496 was installed by 1990 event. Prior to 1990, Buckley Gauge #12098500 data is shown, which reflects a slightly lower value than seen at Auburn.

Flood Damage to Facilities

Flood damages to lower White River flood risk reduction facilities in the past three decades have not been significant. Damages from major floods and high-water events between 1990 and 2017 have resulted in approximately 17 identified damage locations that comprise 0.7 mile of levees and revetments. Damages have been estimated at nearly $1.54 million (based on 2017 dollars).

Since 1990, the levees and revetments along the lower White River have been stable and only requiring minimal repairs. However, in 2009, sediment accumulation became more apparent as there was a rapid diminishment of channel capacity that resulted in increased flood risk. In 2017, King County constructed a new setback levee to improve channel capacity and habitat. The new County Line Setback levee was constructed on the left bank between RM 4.88 and RM 6.23. It was designed to provide capacity for the one percent chance storm event with sufficient freeboard. King County is scheduled to monitor and maintain the project into the future. Segments subject to the most significant and repetitive damages are summarized below in Table 6.23.

Table 6.23. Summary of Damage to Facilities in the Lower White 1990–2021

Storm Season/ Segment Name	Bank	River Mile	Damage Lineal Feet	Damage
1990				
Sumner Commercial Revetment	Right	RM2.0 – RM3.8	400	Partial washout.
1993				
Sumner Commercial Levee	Right	RM 3.4	100	Toe and face scour.
2008				
Potelco	Left	RM 5.4	20	Damage face rock.

Storm Season/ Segment Name	Bank	River Mile	Damage Lineal Feet	Damage
2009				
Potelco	Left	RM 5.25	20	Damaged face rock.
2011				
Potelco	Left	RM 5.05 – RM 5.15	650	Levee overtopping from wetland.
Potelco	Left	RM 5.35 – RM 5.5	570	Levee overtopping flowing to wetland.
2011 (continued)				
Sumner Commercial Levee	Right	RM 3.85	100	Levee core erosion, toe and face rock failure.
Sumner Industrial Revetment	Right	RM 0.03	30	Culvert replacement.
2012				
Sumner Commercial Levee	Right	RM 3.85	400	Levee core erosion, toe and face rock failure.
Sumner Industrial Revetment	Right	RM 0.03	30	Culvert replacement.
2013				
Dierenger	Left	RM 4.0	135	Erosion and scour protection installed by the City of Sumner.
2014				
Dierenger	Left	RM 4.0	50	Erosion and scour of the City of Sumner's soft armoring.
Potelco	Left	RM 5.35 – RM 5.5	570	Levee overtopping flowing to wetland.
2015				
Potelco	Left	RM 5.3	50	Repairs spots where trees overtopped and damaged levee.
2017				
Dierenger	Left	RM 4.0	75	Old Sumner Levee repair site.
Sumner Commercial Levee	Right	RM 3.8	530	Levee damage.

6.6.7 Key Accomplishments since the 2018 Flood Plan Update

Lower White River Restoration/24th Street Setback

As part of a reach-scale project to create sustainable salmon habitat and reduce flood risk within the Sumner city limits, the White River Dialogue group (consisting of the City of Sumner, Puyallup

Tribe, Muckleshoot Tribe, Pierce County, BNSF, Cascade Water Alliance, City of Pacific, WDFW, Ecology, and more) created four separate project components: the 24th Street Setback, Pacific Point Bar/Left Bank Setback, and the Stewart Road Bridge . The largest component of this overall project is the 24th Street section, which will reconnect more than 169 acres of currently disconnected floodplain.

The 24th Street section on its own will significantly improve the available salmon habitat in the lower White River, leading to more than three additional miles of off-channel habitat through a newly reconnected forested floodplain. This reconnected floodplain will create almost one million cubic feet of additional floodwater storage within the lower White River, causing lower flood depths throughout the Sumner-Pacific Manufacturing and Industrial Center. To learn more about this project please visit the City of Sumner's White River Restoration web page. The following key accomplishments have happened since 2018:

- Completed 90 percent design and provided review comments on the restoration design.
- Submitted complete USACE 404 Permit application in June 2021.
- Began ESA consultations.
- Completed SEPA for restoration project.
- Started utility relocations.

Pacific Point Bar/Left Bank Setback Sumner

The Pacific Point Bar/Left Bank Setback project includes acquiring 10 properties to restore 25 acres of floodplain and add a levee to protect the regional job center. The following key accomplishments have happened since 2018:

- The City of Sumner acquired four parcels and demolished three at risk properties.
- Design is at 30 percent completion.

Stewart Road Bridge

The Stewart Road Bridge project will replace a two lane bridge with a higher and wider bridge which will allow the river to migrate. The following key accomplishments have happened since 2018:

- 90 percent design is completed.
- Environmental permitting has been completed.
- Expected to be constructed in summer of 2023.

Sumner Commercial Levee, Capital Maintenance

Damage to the Sumner Commercial Levee segment near RM 3.85 was identified in 2011 during an annual condition assessment. Over the course of the following storm season, the damage rapidly increased in length and severity. This levee was repaired in 2020 by Pierce County. The repair entailed the installation of 780 lineal feet of toe and face armoring on the backside of the levee to eliminate instream impacts. The armoring was placed as an intermediate risk reduction measure while long-term river reach solutions are being planned for future improvement.

The Pacific Right Bank Flood Protection Project (RM 6.3 – RM 5.5)

The Pacific Right Bank Flood Protection Project is the second of two projects along the county line reach of the White River. This project will be designed to reduce flood risk to homes and properties along the river's right (northwestern) bank in Pacific. It will also provide habitat for threatened Chinook salmon. Currently, this project is still in the scoping and design phase with an estimated project completion date of 2024/2025. For more information about this project, please see the King County Natural Resources and Parks webpage at White River Pacific Right Bank Flood Protection Project - King County.

6.6.8 Land Acquisitions

About 2.4 acres of property was acquired between 2018 and 2021 in the Lower White River reach. These property acquisitions support the Butte Pit capital project.

Additionally, the City of Sumner acquired 21 acres of property between 2018 and 2021 from RM 3.8 to RM 4.9. These properties were acquired for future use as a part of the three Lower White River restoration projects. Additional information for these projects can be found at the City of Sumner's White River Restoration web page.

6.6.9 Flood and Channel Migration Hazard Mapping

Flood Hazard Mapping

Hazard mapping in the lower White River includes detailed flood studies (FEMA 2009, NHC 2006), which are shown on the DFIRMs, which became effective March 2017. Flood-prone areas along the lower White River include extensive industrial, commercial, and residential land uses along the right and left banks in the cities of Sumner and Pacific, and a small area of unincorporated Pierce County. This new mapping has been shown to be out of date due to increasing sediment load that has decreased the channel capacity. The DFIRMs for the lower White River show 1,043 acres within the special flood hazard area, or 100-year floodplain. The mapped DFF area is 312 acres.

Channel Migration Hazard Mapping

Severe, moderate, and low risk CMZs were mapped for the lower White River as part of the upper Puyallup River study (GeoEngineers 2003), and the severe risk area was adopted in November 2004 for the small area of unincorporated Pierce County. While the CMZ study identified 227 acres at a severe risk of channel migration, only 57 acres are in Pierce County and regulated under Chapter 18E.70 of the PCC.

6.6.10 Problem Identification

Table 6.24 identifies flooding and channel migration problems identified in the lower White River floodplain.

Table 6.24. Priority Problems Identified in Lower White River

Location	Problem Description	Source
Levee and Revetment Overtopping and Breaching		
RM 3.3 – RM 3.9 RB	Levee/revetment overtopping caused damage to City of Sumner trail and flooding of industrial and commercial parking areas/loading docks.	City of Sumner
RM 3.9 – RM 4.5 RB	Levee/revetment overtopping causes flooding of residential and industrial areas and 116th Street E.	City of Sumner, Pierce County
RM 3.8 – RM 4.0 LB	Revetment overtopping causes flooding.	City of Sumner
RM 4.9 – RM 5.5 RB	Levee/revetment overtopping caused flooding of homes in King and Pierce counties, and business and equipment flooding along Butte Avenue in 2009.	Pierce County, City of Pacific
RM 5.1 – RM 5.3 LB	Levee overtopping causes flooding of Stewart Road and downstream areas (up to three feet in 2009).	City of Sumner, Pierce County
Tributary Backwater Flooding		
RM 4.9 – RM 5.5 RB	Backwater from ditches causes backwater flooding at Countyline ditch (RM 5.5), government ditch (RM 5.35) and Stewart Road ditch (RM 4.9).	City of Pacific, Pierce County
Public Safety/Emergency Rescue		
RM 5.4 – RM 5.5 RB	Evacuation of children from vicinity of 701 Butte Avenue due to deep, fast flowing water (2-2.5 feet).	City of Pacific
Flooding of Structures and Infrastructure (Roads/Bridges)		
RM 0.1 – RM 0.2 LB	Flooding of State Street (access to Sumner wastewater treatment plant).	City of Sumner
RM 3.4 – RM 3.5 LB	Flooding of roadways at 24th Street E. and 148th Avenue.	City of Sumner
Sediment and Gravel Bar Accumulation		
RM 3.5 – RM 4.5	Gravel bar accumulation from Dieringer flume to river meander at RM 4.5.	City of Sumner
RM 3.6 – RM 5.5	Concern about debris and log jams at (a) RM 5.0-5.5, (b) Stewart Road bridge during floods, and (c) log jam at golf course (RM 3.6–3.9).	City of Sumner
RM 4.9 – RM 5.5	Gravel bar accumulation from Stewart Rd. crossing to county line has led to reduced conveyance capacity, as low as 5500 cfs (USACE 2009).	City of Pacific, City of Sumner, Pierce County

Location	Problem Description	Source
Facility Maintenance and Repair Needs		
RM 4.3 LB	Repetitive plugging of culvert by sediment and debris at Sumner golf course in 2007 and 2009.	Pierce County
Fish Habitat Problem Areas		
RM 1.25 RB	Soaten Creek (aka Jovita Creek) refuge habitat is degraded at mouth with White River.	Puyallup Tribe
Fish Habitat Problem Areas (continued)		
RM 3.2-3.6 LB	Revetment construction cut off floodplain from river channel, preventing off-channel rearing.	Puyallup Tribe, Pierce County
RM 3.6-4.5 LB/RB	Revetment/levee construction cut off floodplain from river channel, preventing off-channel rearing.	Puyallup Tribe, Pierce County
RM 4.2 LB	Fish passage barrier[a] at 8th Street Creek inflow to White River cuts off coho spawning habitat.	Puyallup Tribe
RM 4.9 – RM 5.35 LB/RB	Revetment/levee construction cut off floodplain from river channel, preventing off-channel rearing.	Puyallup Tribe, Pierce County
RM 4.9 – RM 5.5 RB	Butte Pit wetland and side channel habitat impacted by sediment deposition (2006, 2008, 2009) impacting function and value of habitat.	City of Pacific
Public Access		
RM 0.5 – RM 5.0 LB	Four gaps in the public trail along the White River.	City of Sumner
RM 4.9 – RM 5.5 RB	Improved access to Butte wetland for passive recreation.	City of Pacific

[a] A fish passage barrier is an obstacle that prevents fish from moving either upstream or downstream, such as certain dams, weirs, floodgates, roads, bridges, causeways and culverts.

LB = left bank; RB = right bank; RM = river mile

6.6.11 River Reach Management Strategies

6.6.11.1 Conditions and Constraints of the Lower White River

The recommended river reach management strategies for the lower White River take into account numerous conditions:

- Development and land use in adjacent floodplain – The lower White River floodplain is the second-most developed in the planning area, with extensive industrial, commercial, and residential land uses and an assessed value of $561.5 million in the 100-year floodplain (EcoNorthwest 2022).
- River management facilities – Both the left and right banks of the lower White River are constrained by revetments along the entire reach, with levees in some locations.

- River channel gradient and width – Channel gradient varies from 0.03 to 0.23 percent. The river channel width varies from 160 feet to 280 feet.

- Presence of salmon spawning and rearing habitat – All species of salmon are found in the lower White River, including Chinook (spring and fall stocks), pink, chum, coho, and sockeye as well as steelhead, bull, and cutthroat trout. Both spawning and rearing habitats are present.

- Sediment transport accumulation and incision – Mostly sand and silt accumulate between RM 0.0 and RM 3.0. From RM 3.0 to RM 5.5, there is a mix of cobble, gravel, and sand. The average riverbed between RM 0.0 and RM 4.0 changed in elevation from -0.4 feet to +2.0 feet between 1984 and 2009. Upstream of RM 4.0 to the county line at RM 5.5, the average bed elevation changed from +2.0 feet to +4.8 feet during the same period.

- Flow Management strategies for Mud Mountain Dam – The USACE, in cooperation with downstream stakeholders, is continually assessing the channel conditions and release rates associated with risk.

In the near term, the primary objective for the lower White River is to maintain the structural integrity of the revetment and levee system so that the facilities continue to reduce flood and channel migration risks to public health and safety and reduce damage to property and infrastructure. Another goal is to make improvements to the facilities over time through construction of setback levees or revetments so that the level of service is increased to meet a 100-year storm event. The final management strategy objective is to realize capital projects that enhance and create aquatic habitat through levee or revetment setbacks, riparian revegetation, and strategic placement of large woody material.

6.6.11.2 Lower White River Reach Management Strategies

The recommended river reach management strategies for the lower White are listed below:

Structural Management Strategies:

- RM 0.0–RM 5.5 left bank, RM 0.0–RM 3.3, and RM 3.92–RM 4.87 right bank – The goal for revetments should be channel migration resistance design.

- RM 3.3–RM 3.92 and RM 4.87 to the county line, right bank – The goal for levees and flow conveyance should be 100-year design plus three feet of freeboard (King County 2006).

Non-structural Management Strategies:

- Floodplain development regulations should be implemented by the Cities of Sumner and Pacific consistent with Pierce County critical area regulations for flood hazard areas.

- Acquire repetitive loss properties or purchase development rights to prevent new floodplain development.

6.6.11.3 Interim Risk Reduction Measures.

- Install HESCO barriers downstream of Stewart Road bridge.
- Install HESCO barriers downstream of A Street bridge near Pacific City Park and White River estates.

6.6.12 Recommended Capital Projects

The following capital improvement projects are recommended to address the priority problem areas identified in Table 6.24.

Riverine Flood Project **Project Score: 59**

Project Name: Butte Pit Setback Project

Project location: The project is located on the lower White River just south of the King County-Pierce County line on the right bank between Stewart Road SE and Countyline Road SE (RM 4.8 to RM 5.5) (see Figure 6.52).

Estimated project cost over a 10-year period: $26.4 million

Total project cost: $30.6 million

Project webpage location: www.piercecountywa.gov/6217/Butte-Pit-Flooding-Project

What is at risk?

During high flow periods on the White River, Government Ditch backwaters (see Figure 6.53) flood Butte Avenue (see Figure 6.54), White River Estates, the surrounding industrial area, and several single-family homes. Low points in the existing berm allow floodwater from the White River to cross over Butte Avenue and flood properties between the existing road and the Union Pacific Railway tracks.

What is the recommended solution?

Pierce County is taking a pathways approach to address this flood risk. There are several potential solutions being evaluated to address the problem, including both structural and non-structural options). This project connects to the Pacific Right Bank Flood Protection Project being developed by King County to the north, which proposes the installation of a pump station on Government Ditch which will address some of the backwater issues in the project area. At the downstream end, the project will connect to the improved Stewart Road SE completed by the City of Pacific and the proposed City of Sumner Stewart Road Bridge project, which is expected to be constructed in 2025.

Coordination

The Butte Pit Setback project is located near the Pierce County/King County line. Coordination with City of Sumner and King County on the setback levee on the right bank will be necessary during final design. Coordination for this project includes the Muckleshoot Tribe, Puyallup Tribe, Pierce County, King County, WDFW, and USACE.

Environmental Considerations

Salmonids found within the lower White River include the spring and fall Chinook, pink, chum, and coho salmon. Other species include the bull, steelhead, and cutthroat trout. The native White River spring Chinook salmon, steelhead, and bull trout are listed as threatened under the ESA. The river at this location is a transportation corridor with main and side channel rearing and high-flow refuge for adult and juvenile salmon.

Figure 6.52. Location of the Butte Pit Setback Project

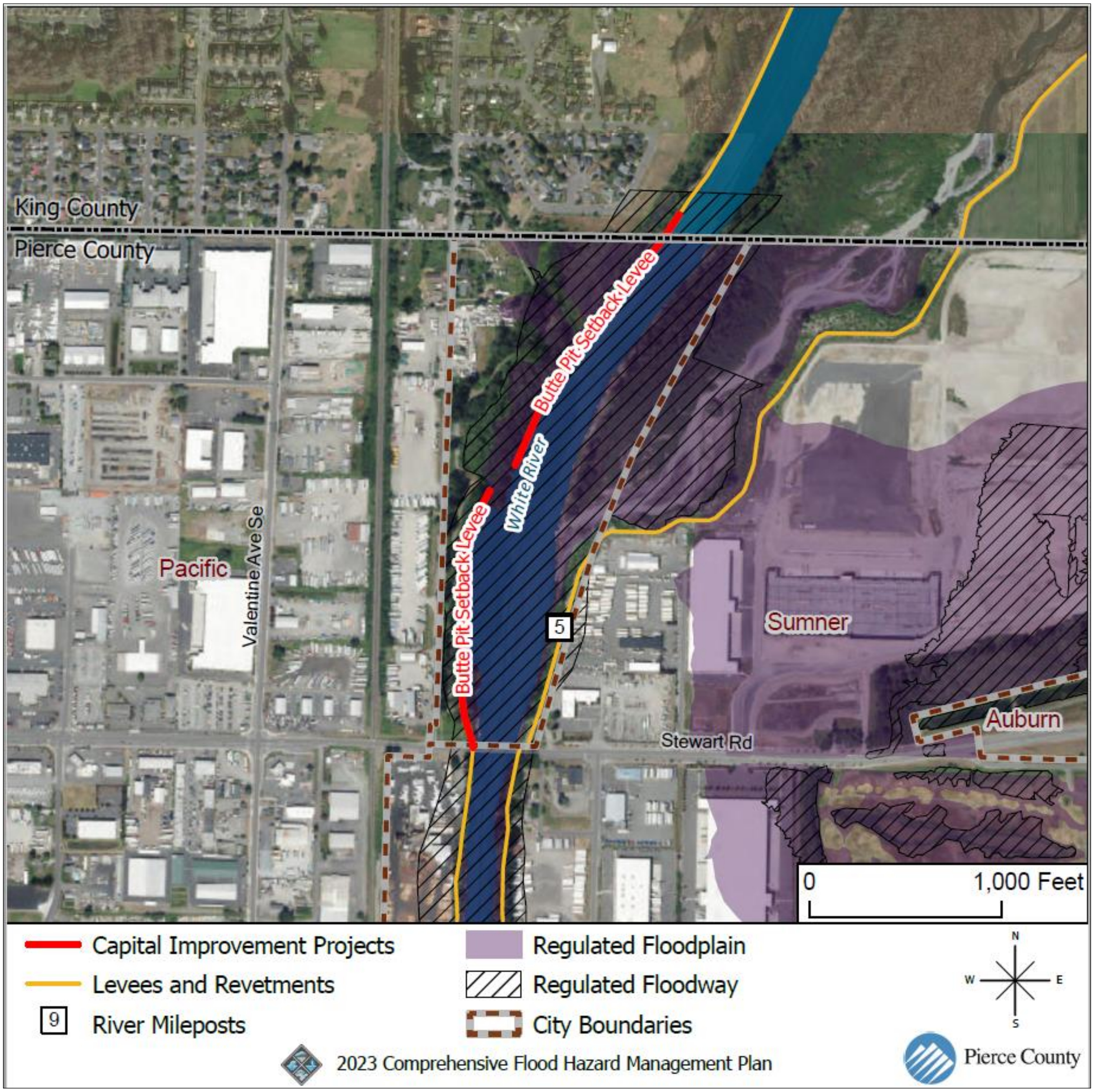


Figure 6.53. Butte Avenue during a High Water Event, December 2015 (Looking North)

Figure 6.54. Temporary Flood Control Measure, Government Ditch, and the White River, 2016

What is the current status of the project?

This project is currently in the property acquisition phase, with two remaining properties in unincorporated Pierce County left to purchase. Following the project pathway, the properties will be purchased when there are interested sellers.

Studies are being completed to help assess what pathway will be selected as the projects upstream and downstream of the project site are designed and constructed.

What will take place with this project from 2023–2033?

In the short term, property acquisition will continue, temporary flood control measures will be maintained, and studies will be completed to assess the current site conditions, including the stability of the existing dredge pile berm located within the project site.

If the structural pathway is selected, the first phase of the setback levee will be designed, permitted, and constructed on the north side of the project site connecting to the proposed Pacific Right Bank project and down to the existing berm. This will allow the temporary flood control measures will be removed.

The second phase of the project will either set back the levee or improve the existing berm as needed to meet project goals and to follow the developed project pathway.

What are the Project Benefits/Drivers?

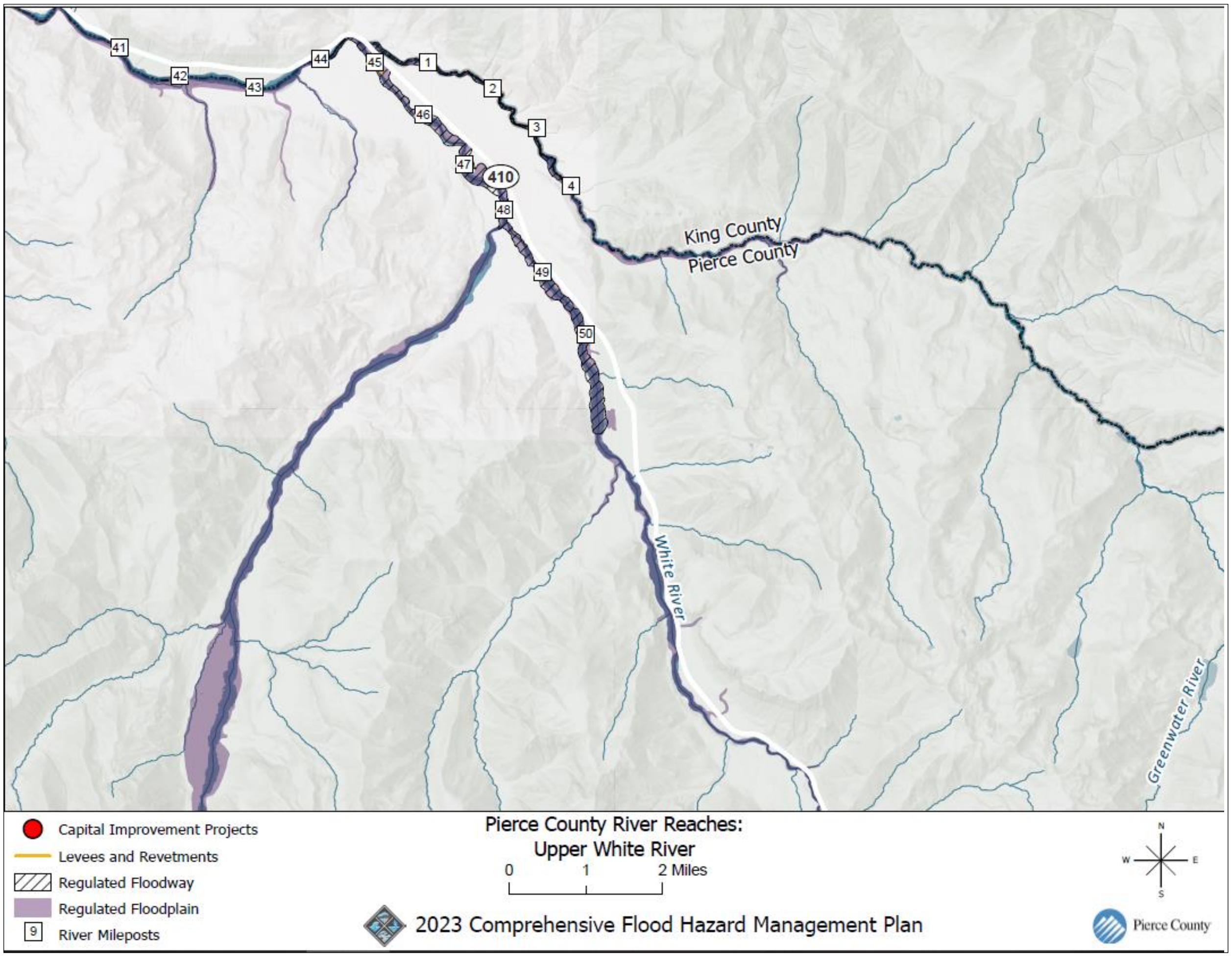
Habitat

6.7 Upper White River

6.7.1 Overview

The upper White River reach in the study area extends from approximately RM 43.2 to RM 50.5, from downstream of the community of Greenwater to upstream of Crystal Village and Crystal River Ranch, as seen in Figure 6.55. State Route 410 parallels the river throughout this reach. Large tributaries include the Greenwater River, which enters the White River at RM 44.7 and the West Fork White River, which enters the White River at RM 48.2. Land uses in the reach include two residential communities, Greenwater Village and Crystal Village, which are supported by several commercial businesses located in Greenwater. Privately owned revetments have been constructed on the right bank of the river at RM 46.2 and in Crystal Village near RM 50.0. One Pierce county-owned levee segment was constructed in Greenwater Village along 583rd Avenue East near RM 45.1. The upper White River has a large sediment discharge and high turbidity levels due to the proximity to its glacial headwaters. Salmon and trout, including spring Chinook, coho, and pink salmon and steelhead, bull trout, and cutthroat use this reach of the White River.

Figure 6.55. Planning Area for the Upper White River



6.7.2 Geology and Geomorphology

The White River is unconfined within this reach; however, the valley bottom expands in the downstream direction to the community of Greenwater (WRIA 10, WDFW 1977). Generally, the terrain slopes moderately upward away from the river and in some areas meeting sharply rising mountainside slopes of nearly 5,000 feet. The glacier-fed White River has a braided bed-form, with channel slopes ranging from 0.8 percent to 1.0 percent. The channel is generally straight, which is characteristic of rivers with high sediment loads. Bank erosion occurs throughout the reach; however, the extent is generally localized. River banks are mostly natural earth or rock cuts. Constructed bank protection along this reach is limited to three known locations. The protection was installed to resist channel migration threatening developed communities along the river.

6.7.3 Hydrology and Hydraulics

The upper White River above the confluence with the Greenwater River at RM 44.7 consists of flows primarily from the West Fork White River, White River (mainstem), and Huckleberry Creek. A

USGS river gauge originally existed on the upper White River, but it often experienced problems. There are 35 water years of data, when gauge #12098500 functioned from 1929 to 1968. The best available estimates of flood frequency flows are from the 1987 Flood Insurance Study (see Table 6.25). The table does not reflect more recent peak flows from 1990, 1996, 2006, and 2009.

Table 6.25. Upper White River Flood Frequency Flows upstream and Downstream of the Confluence with the Greenwater River

Location	Discharge (cfs) 10-year Event	50-year Event	100-year Event	500-year Event	Method
White River at Greenwater River per 1987 Flood Insurance Study (drainage area = 294 sq. mi.).	18,600	25,800	28,900	36,700	Log Pearson III Fit of gauge data with adjustment for precipitation and drainage area.
White River, upstream of confluence with Greenwater River per 1987 Flood Insurance Study (drainage area = 217 sq. mi.).	13,500	18,700	20,900	26,400	Log Pearson III Fit of gauge data with adjustment for precipitation & drainage area.

Source: 1987 FEMA Flood Insurance Study based on USGS flow records.

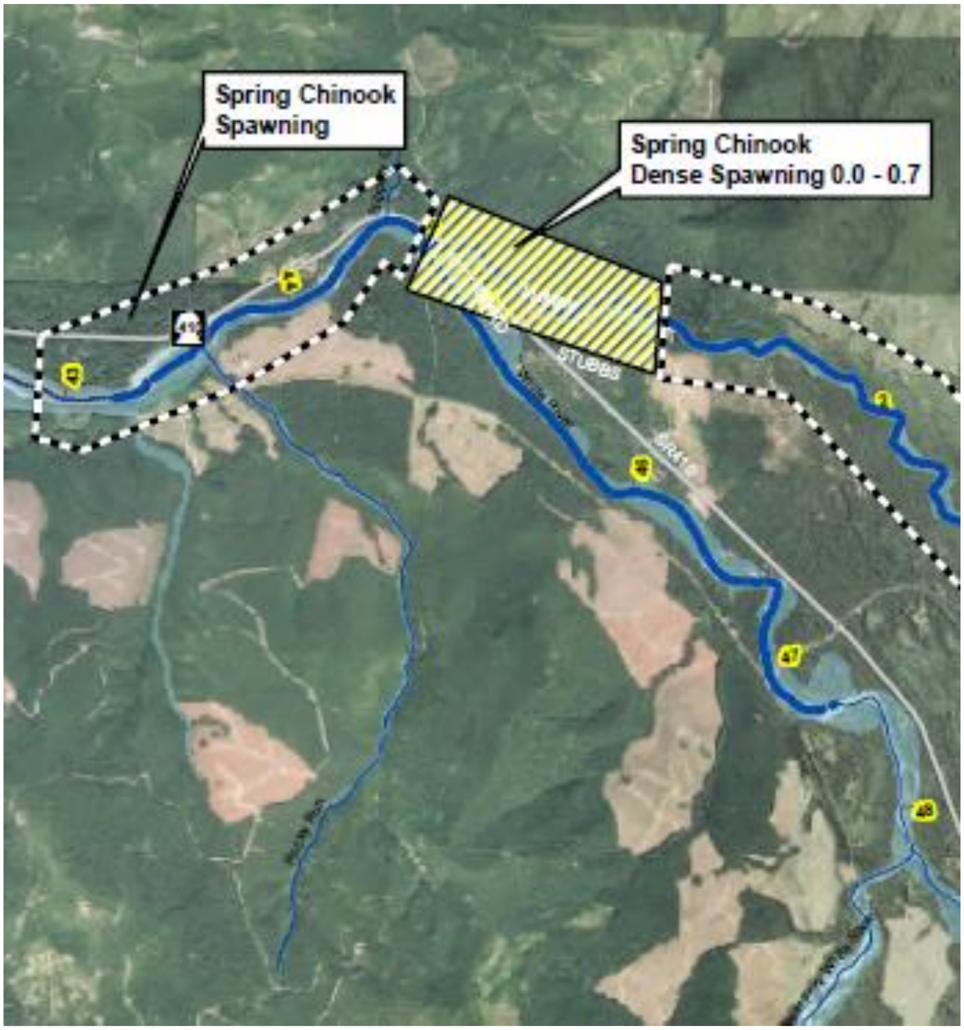
6.7.4 Ecological Context and Salmonid Use

The upper White River reach is particularly important ecologically because it provides spawning habitat for all three ESA-listed species in the Puyallup River watershed (bull trout, steelhead, and Chinook salmon). The stock of spring Chinook that spawn in this reach and its tributaries have been identified by NMFS as a priority for the Puget Sound and bear regional significance. The upper White River is relatively undeveloped when compared to most watersheds and for this reason is earmarked for preservation by salmonid recovery groups.

This reach of the White River is steep—about a 0.90 percent gradient (Williams 1975)—and the bed is composed primarily of medium to large gravel, cobble, and boulders. Large amounts of glacier-derived sediment are deposited in this reach, and the channel forms into a meandering series of primarily fast-flowing riffles and pools. Patches of suitably sized spawning gravel occasionally appear near the confluence with other streams and at the tail out of pools that provide substrate for the construction of redds.

Spring Chinook and steelhead are the species most likely to use the main channel for spawning, but they primarily spawn in the tributaries of the upper White River (see Figure 6.56). Coho and bull trout could use the main channel for spawning, but like the spring Chinook and steelhead, are found in the tributaries. Pink salmon are using the reach in increasing numbers and use the low-velocity main channel areas or the tributary streams for spawning. Due to the normally turbid conditions of the main channel, spawning ground counts are often imprecise and likely underestimated for this reach. Juvenile steelhead, spring Chinook, bull trout, and cutthroat use this reach for rearing year-round.

Figure 6.56. Spring Chinook Spawning on the White River, RM 43.0 to RM 44.6



6.7.5 River Management Facilities, Flooding, and Flood Damage

The upper White River has a single levee in the vicinity of 583rd Avenue East, just upstream of RM 45.0 on the right bank (Figure 6.57). The levee is owned and operated by Pierce County, as summarized in Table 6.26.

Figure 6.57. RM 46.2 Right Bank Levee at 583rd Avenue East along the White River

Table 6.26. Levees in the Upper White River

Name	Location	Ownership
Greenwater Village Levee	RM 45.02 – RM 45.17 RB, PL 84-99	Pierce County

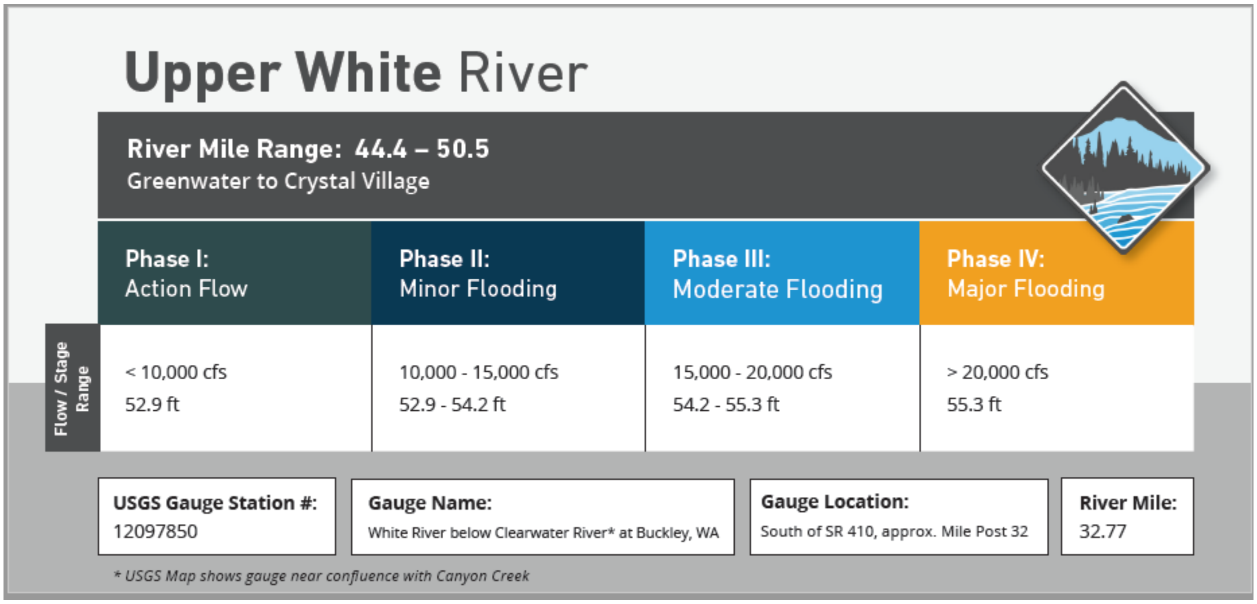
Source: Pierce County Surface Water Management records.

[a]RM = river mile; RB = right bank.

6.7.6 Upper White River Flow Warning Matrix

The upper White River has four flow categories: Phase I, Action Flow Phase II, Minor flooding; Phase III, Moderate flooding; and Phase IV, Severe flooding. These categories describe the observed or expected severity of the flood impacts in that area. However, the severity of flooding at a given stage is not necessarily the same at all river locations. Most river reaches in Pierce County have a defined flow warning matrix that is used during flood events. Figure 6.58 shows the flow warning matrix table for the upper White River.

Figure 6.58. Upper White River Flow Warning Matrix



Historical Flooding

The White River gauge downstream of the Clearwater River confluence has operated intermittently from 1975 to the present, with several data gaps resulting from damage during large floods. In the last 50 years, major flooding in the upper White River occurred in 1977, 1995, 1996, 2006, and 2008 (see Table 6.27). Flow values in the table are shown as “less than” due to the larger drainage area for the Clearwater River gauge.

Table 6.27. Historical Flooding in Upper White River

Date	White River Flows Downstream of Clearwater River Gauge (#12097850) (cfs)
December 1975	22,800
January 1990	17,200
November 1990	18,400
November 1995	20,500
February 1996	<30,000[a]
November 2008	18,100
November 2006	Not Available
January 2009	<18,100
January 2011	28,600
February 2012	19,400
January 2015	22,000
December 2015	31,900

February 2020	25,200

Source: Pierce County SWM and USGS

[a] Estimated value at Mud Mountain Dam inflow by USACE.

Flood Damage to Facilities

The Greenwater Village Levee continues to experience partial toe rock displacement. Since the last update, the residents of Crystal Village Ranch funded, permitted, and installed a buried rock groin along the left bank of the White River. The groin was installed to address the residents concern about the possibility of channel migration continuing to impact their development.

> **Rock Groins**
>
> **Rock groins are structures that are perpendicular to the river and are designed to reduce the potential of erosion along the shoreline.**

Table 6.28 shows the most significant and repetitive damages along the upper White River from 1996 to 2015.

Table 6.28. Damage to Facilities along the Upper White River 1996–2015

Storm Season/ Segment Name	Bank	River Mile	Damage Lineal Feet	Damage
1996				
Greenwater	Right	46.2	150	Toe/slope failure.
Greenwater	Right	46.2	100	Toe failure.
2006				
Greenwater	Right	46.2	300	Face erosion.
2007				
Greenwater	Right	45.0-45.2	750	Face erosion.
2015				
Greenwater	Right	45.2	30	Partial toe rock displacement and missing face rock.
Greenwater	Right	45.2	20	Missing toe rock.

6.7.7 Key Accomplishments since the 2018 Flood Plan Update

Major Projects

Pierce County is committed to practices such as CMZ studies that reduce risks to residents, businesses, and infrastructure, while protecting and improving fish and wildlife habitat that rely on our river systems. The Upper White Channel Migration Zone Study (between RM 44.5 and RM 51.5) was completed in 2020. This was the last CMZ study needed to enable Pierce County to develop zoning maps based on science within the study to guide development away from high-risk areas. This study conducted extensive stakeholder outreach prior to and during the study to gather information and feedback from those residents most affected. Outreach included meeting with the homeowner associations of the Crystal River Ranch and Crystal Village communities, Tribal fisheries staff, regulatory staff, and other partners. Pierce County Council formally adopted the study in 2022. A copy of the CMZ study can be found online at Channel Migration Zone (CMZ) | Pierce County, WA - Official Website (piercecountywa.gov).

6.7.8 Land Acquisitions

Pierce County acquired a small 0.21-acre parcel in 2019 in the community of Greenwater. This property acquisition supports future capital project development.

6.7.9 Flood and Channel Migration Hazard Mapping

Flood Hazard Mapping

The 2017 FEMA DFIRM did not update the flood risk mapping in the upper White River, so the most recent risk assessment continues to be the one completed in the late 1970s. Flood-prone areas along the upper White River include SR 410, Pierce County roads and bridges, and moderate-density residential recreation areas. The DFIRMs for the upper White show 443 acres within the SFHA, or 100-year floodplain.

Channel Migration Hazard Mapping.

A CMZ study was completed in 2019 for the upper White River. The study identified areas at severe, moderate, and low risk for migration. The study found a valley dominated by Osceola deposits that are more resistive to erosion than typical river bank alluvium. As a result, there was a smaller area identified at severe risk of migration than anticipated at the outset of the project. The CMZ study was adopted into the Pierce County Code, Title 18E.10.140 Mapping Source, by the County Council in November 2021. Areas identified at severe risk are now regulated as floodway.

6.7.10 Problem Identification

Table 6.29 identifies the flooding and channel migration problems identified in the upper White River floodplain.

Table 6.29. Priority Problems Identified in Upper White River

Location	Problem Description	Source
Channel Migration Problem Areas		
RM 45.0- RM 45.2 RB	Channel migration threatens 583rd Avenue East, where there is an existing levee and revetment.	Pierce County
RM 49.0- RM 50.5 LB/RB	Channel migration at Crystal River Ranch and Crystal Village on both sides of the White River threatens property and homes near Crystal Lane and Crystal Drive, and riverward of Alpine Drive East.	Pierce County
RM 49.4- RM 49.8 LB	Channel migration and toe scour of riverbank during November 2006 flood threatened homes and public drinking water facilities.	Pierce County

Location	Problem Description	Source
Flooding of Structures and Infrastructure (Roads/Bridges)		
RM 43.5-RM 43.8 RB	Flooding and channel migration along this segment of White River threatens SR 410, resulting in heavy damage on several occasions.	WSDOT
RM 48.9	Crystal River Ranch Road bridge (there are two bridges) – old bridge accumulates large woody material on bridge piers; new bridge has abutments vulnerable to washout.	Pierce County Roads
Fish Habitat Problem Areas		
RM 49.1-RM 50.5 LB/RB	Crystal River Ranch and Crystal Village – Armoring and groin construction reduces channel migration that limits habitat formation.	Puyallup Tribe

Source: Pierce County SWM records.

LB = Left Bank; RB = Right Bank; RM= River Mile.

6.7.11 River Reach Management Strategies

6.7.11.1 Conditions and Constraints of the Upper White River

In conjunction with updated flood hazard mapping, the recommended river reach management strategies for the upper White River take into account numerous conditions described below:

- Development and land use in adjacent floodplain – The upper White River floodplain has light residential development and a major highway (SR 410) along the entire reach. The assessed value within the upper White and Greenwater 100-year floodplain is $36 million.
- River management facilities – There is a single levee and revetment along the right bank at RM 45.02 to RM 45.17 owned by Pierce County. Bank armoring protects portions of SR 410 maintained by WSDOT. Limited armoring at the Crystal River Ranch Road Bridge is maintained by Pierce County Transportation Services.
- River channel gradient and width – Channel gradient varies from 0.8 to 1.03 percent. River channel width varies from approximately 100 feet to 660 feet.
- Presence of salmon spawning and rearing habitat – Species of salmon found in the upper White River include Chinook, pink, and coho as well as steelhead, bull, and cutthroat trout. Both spawning and rearing habitats are present.
- Sediment transport accumulation and incision – Riverbed sediment is dominated by gravel and cobble, with some sand and boulders. Portions of this reach are aggrading and others degrading, but there is no clear trend toward long-term aggradation.

The primary objective for the upper White River reach management strategy is to maintain the structural integrity of the levee to minimize risks to public health and safety and reduce public infrastructure and private property damage.

6.7.11.2 Upper White River Reach Management Strategies

Recommended river reach management strategies for the upper White River are listed below.

Structural Management Strategies:

- RM 45.02 to RM 45.17, right bank – The goal for the existing levees should be to maintain the existing levee prism.
- RM 44.4 to RM 50.5, right bank – The goal for the non-county-maintained system should be to communicate risk to property owners.

Non-structural Management Strategies:

- Floodplain development will continue to be implemented by Pierce County.
- For additional information regarding non-structural management strategies for the upper White River, please refer to the 2006 King County Flood Hazard Management Plan and the 2013 King County Flood Hazard Management Plan Update and Progress Report.

6.7.11.3 Interim Risk Reduction Measures

- There are no IRRMs on the upper White River reach.

6.7.12 Recommended Capital Projects

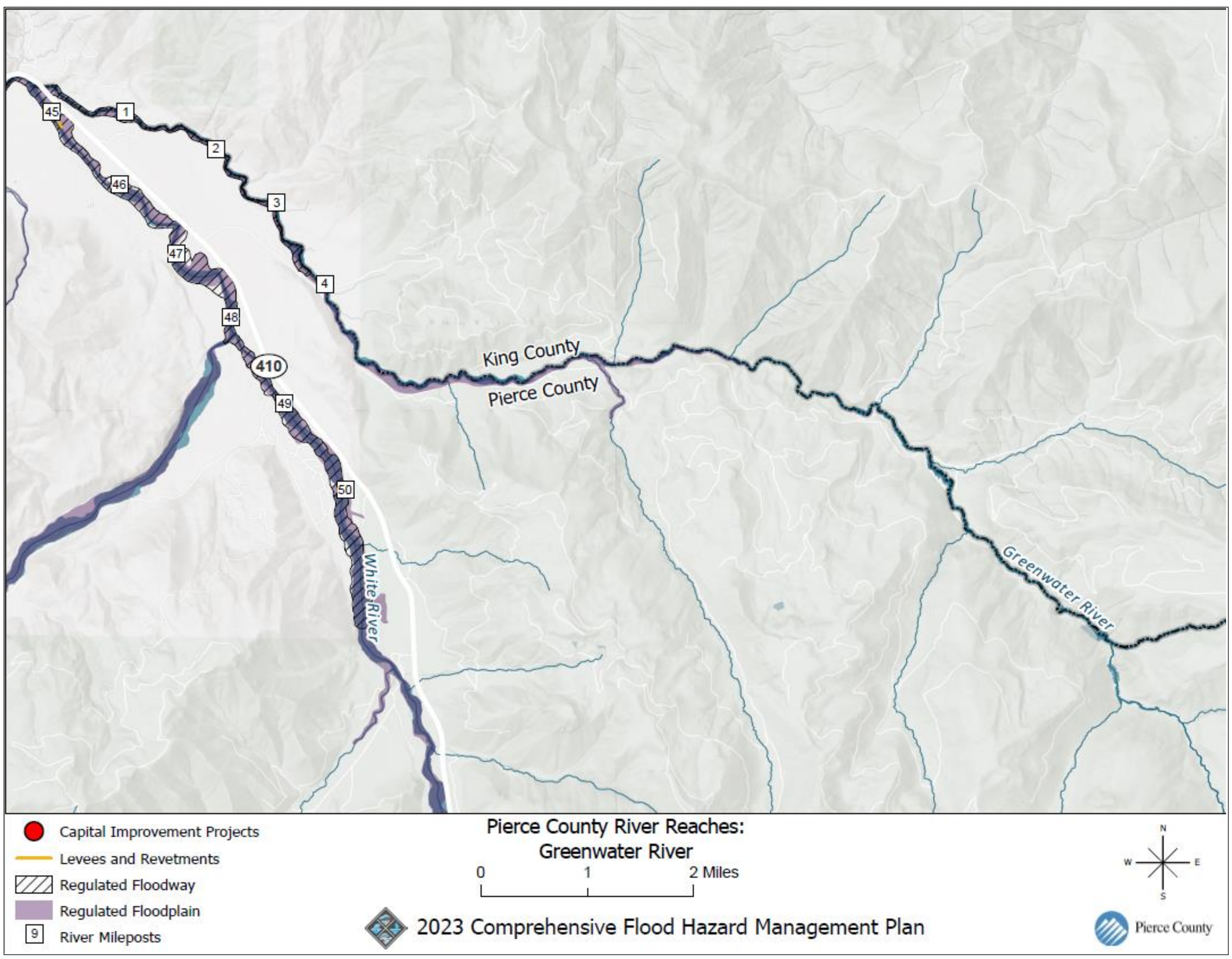
There are no capital projects proposed for the upper White River.

6.8 Greenwater River

6.8.1 Overview

The Greenwater River lies in northeastern Pierce County and enters the White River at RM 44.7, as shown in Figure 6.59. The headwaters of the Greenwater River are in the Norse Peak Wilderness area on Castle Mountain (elevation 6,700 feet), and the river flows northwest for 21 miles to the community of Greenwater. The drainage basin is approximately 76 square miles. Primary tributaries include Maggie, Lost, Pyramid, and Twenty-Eight Mile creeks. Salmon and trout, including spring Chinook, coho, pink, and steelhead are present in the Greenwater River. The river forms part of the northeasterly boundary between King County and Pierce County. The planning area is from the mouth of the Greenwater River upstream to approximately RM 4.0. Land use consists of forested terrain, recreational and rural residential uses, and the community of Greenwater.

Figure 6.59. Greenwater River Planning Area



6.8.2 Geology and Geomorphology

The lower portion of the Greenwater River travels over a relatively broad, flat valley with steep slopes along the north bank. The Greenwater valley includes a Osceola mudflow (lahar) deposit that flowed from Mount Rainier down the White River over 5,000 years ago.

Osceola Mudflow

was a lahar (mudflow or debris flow that flows down from a volcano) that descended from the summit and northeast slope of Mount Rainer during the period of eruptions about 5,600 years ago.

Anabranching

refers to rivers that have distributary channels that depart from, run parallel or nearly so to, and then reenter the main channel downstream.

Average channel gradient in the project reach is 1.0 to 1.5 percent. Bed materials consist primarily of small gravels to large cobbles (see Figure 6.60). Past logging activities in the watershed destabilized soils both on the hillsides and along the river banks. The resulting instabilities caused landslides, rapid channel migration, natural log jam destabilization (see Figure 6.61), and coarse sediment loading. These changes altered the river from its natural anabranching form to a more single thread channel. The effects of these changes were pronounced during the 1977 flood and led to an increase in sediment supply downstream, rapid channel widening, and severe flooding. A 2017 study of channel migration for the lower Greenwater River (GeoEngineers 2017) was adopted in 2021, with the areas identified at severe risk of erosion now regulated as floodway. The geomorphic study also concluded that the high left bank at Lumpy Lane is a remanent of the Osceola mudflow that is not very susceptible to erosion. The USGS has not completed a sediment transport study of the lower Greenwater River.

Figure 6.60. Greenwater River looking upstream at about RM 4

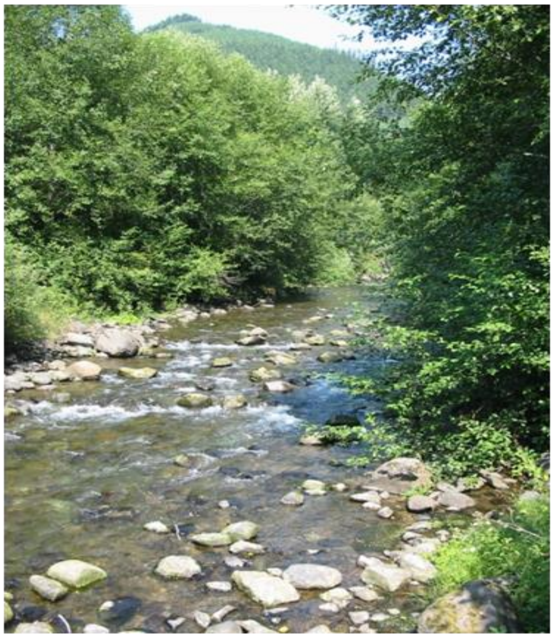


Figure 6.61. Log Jam at RM 3.8, Greenwater River

6.8.3 Hydrology and Hydraulics

The Greenwater River watershed covers about 76 square miles, 60 percent of which is in Pierce County. There is a USGS stream gauge (#12097500) at RM 1.1 on the Greenwater River on the left bank about 0.7 miles east of the community of Greenwater.

The Greenwater sub-basin is approximately 18 percent of the upper White River watershed. The Greenwater River had a disproportionately high peak flow of 10,500 cfs, recorded on December 2, 1977. Subsequent annual peak flows are typically much smaller, including several in the range of 4,500 cfs to 6,000 cfs. Table 6.30 displays estimates of flood frequency flow from the 1987 FEMA Flood Insurance Study. Using data from more recent peak flow events over the past 20 years, Pierce County used regression analysis to estimate revised flood frequency flows (see Table 6.30 and Figure 6.62).

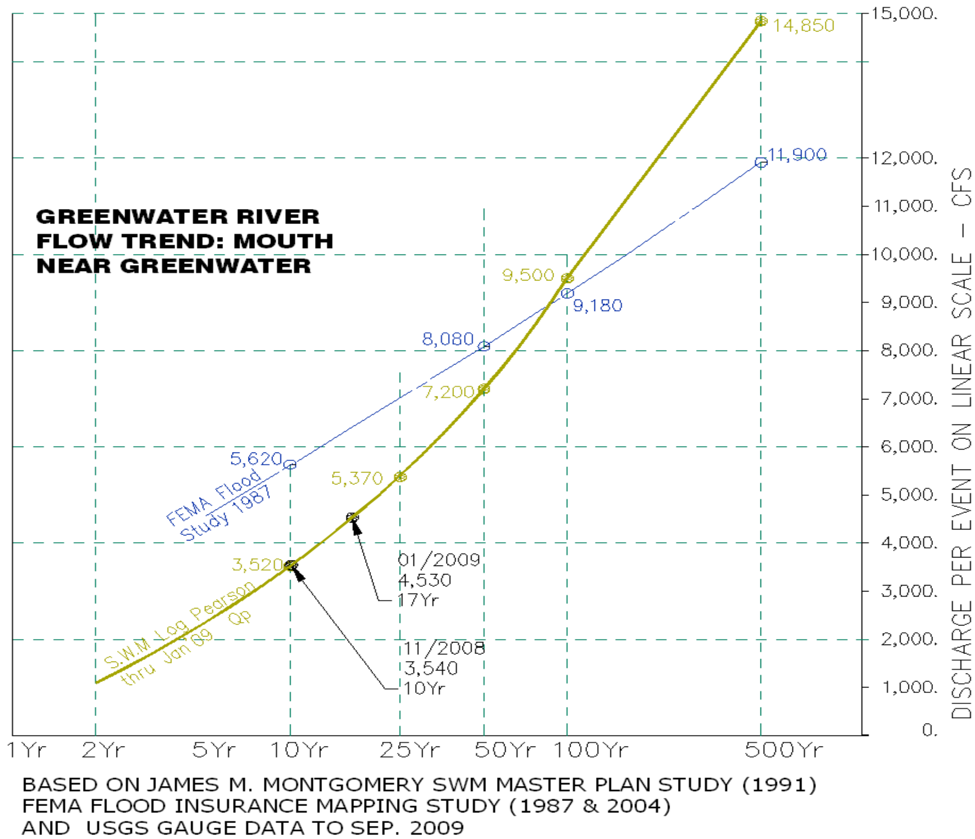
Table 6.30. Greenwater River Flood Frequency Flows at the USGS Greenwater Gauge[a]

Version	Discharge (cfs)				Method
	10-year Event	50-year Event	100-year Event	500-year Event	
FEMA Flood Insurance Study (1987/2017)	5,620	8,080	9,180	11,900	Log Pearson III fit of gauge data with adjustment for precipitation and drainage area based on 1970s data.
Updated Curve Fit with data through 2009[b]	13,500	18,700	20,900	26,400	Log Pearson III Fit of gauge data with adjustment for precipitation and drainage area.

[a] The Greenwater River gauge was not operational from 1978 to 1992.

[b] Pierce County SWM estimated flow and recurrence values are not official nor formally published data and are intended for comparative analysis and reference purposes only.

Figure 6.62. 1987 and 2009 Peak Flow Data at Greenwater Gauge



Incorporating data from the past 20 years results in a curve with a steeper slope than the existing FEMA curve (see Figure 6.62), and a forecast for higher peak flows. This is due to the December 1977 flow peak that far exceeded other recorded flow peaks. The floods of November 2006 and January 2009, significant in many other rivers of the study area, were only 10-year and 5-year events, respectively, in the Greenwater River (see Table 6.31).

Table 6.31. Historical Flooding in Greenwater River

Date	Greenwater River Flows (#12097500) (cfs)
December 1946	5,000
November 1959	5,360
January 1965	5,090

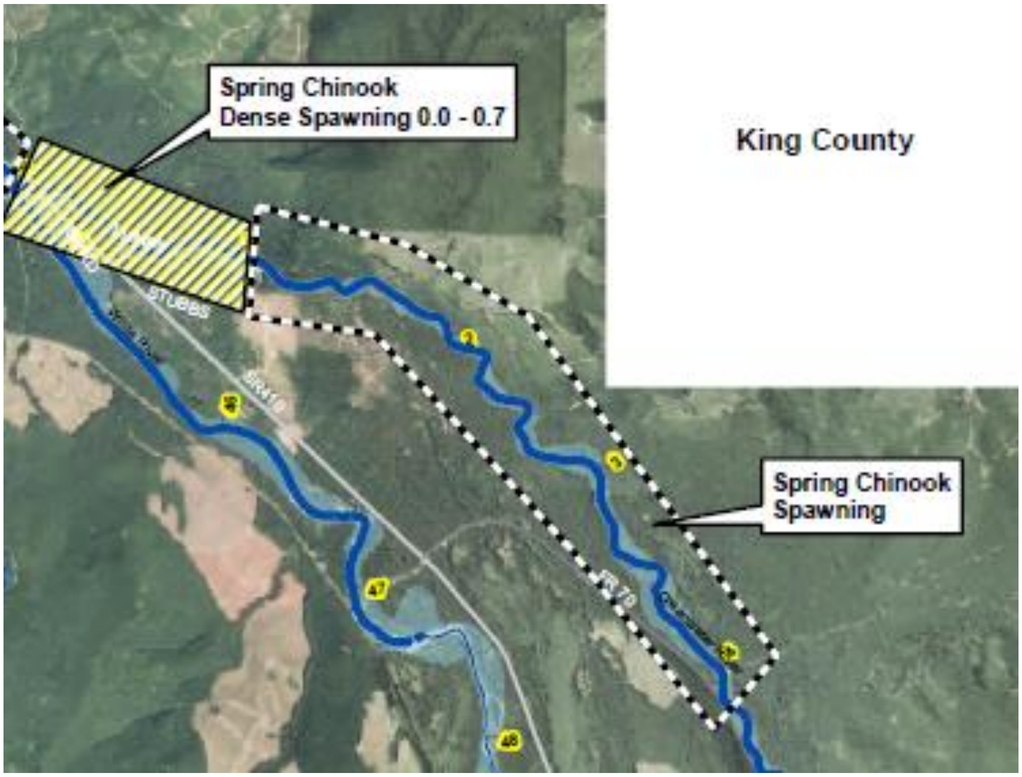
Date	Greenwater River Flows (#12097500) (cfs)
December 1977	10,500
February 1996	5,900
January 2009	4,530
January 2011	5,590
December 2015	4,620
February 2020	6,790
Source: USGS data records	

6.8.4 Ecological Context and Salmonid Use

The Greenwater River is the principal tributary stream for spawning spring Chinook in the Puyallup River watershed. The Greenwater River flows through a steep channel with a narrow floodplain until it enters the study area reach. At about RM 4.0, the river enters a relatively broad floodplain, and the stream gradient diminishes to about one percent. The channel then takes a mild meander in primarily a single thread channel to the White River. This area is the prime spawning and rearing reach of the river, as it contains abundant high-quality spawning gravel and a pool-riffle configuration (Marks et al. 2009). Figures 6.63 and 6.64 shows spawning and redd locations in the Greenwater river. In addition to the existing habitat, a spring Chinook acclimation pond near RM 11 was constructed in 2007 that can hold over 500,000 juveniles as part of a brood stock program organized by the Puyallup Tribe.

Past logging practices and the removal of trees from the channel to protect the community of Greenwater and the SR 410 bridge from flooding has created a deficit in large woody material to supply rearing and adult holding habitat. Replacing large wood has become a recent focus of local watershed recovery groups.

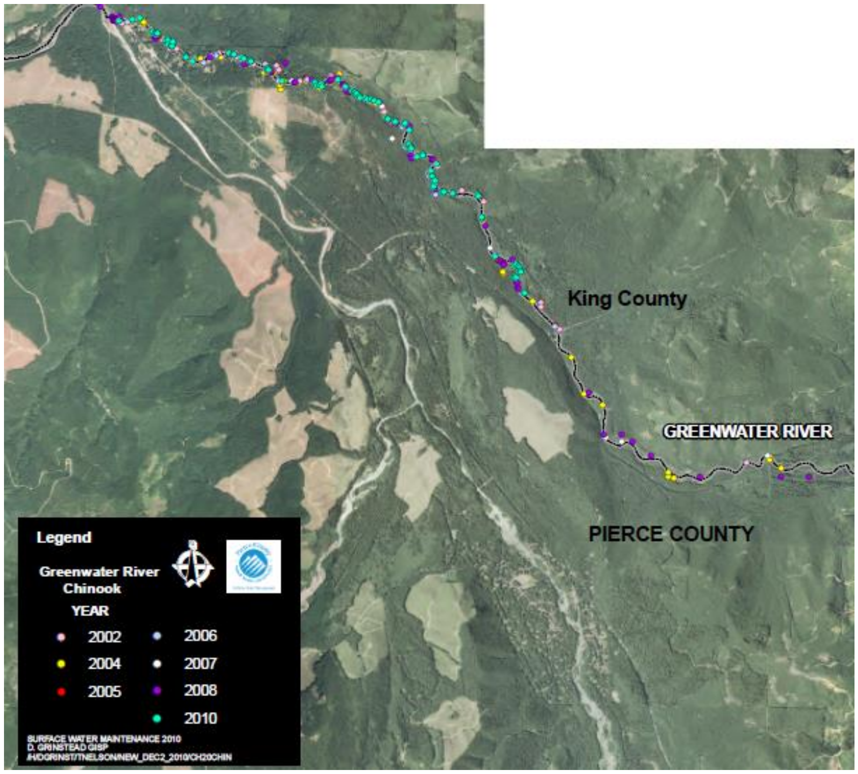
Figure 6.63. White River Spring Chinook Spawning Areas in the Lower Four miles of the Greenwater River



6.8.5 River Management Facilities, Flooding, and Flood Damage

Pierce County has no flood risk reduction facilities along the Greenwater River. King County maintains a series of intermittent revetments along the right bank of the river along the study reach. There is a private revetment on the left bank between RM 0.6 to RM 0.7. Bank armoring has been identified at the SR 410 bridge crossing of the Greenwater River near RM 0.1. The bridge crossing is maintained by WSDOT.

Figure 6.64. Chinook Redd Locations in Greenwater River



Currently, there is no flood warning system used by the National Weather Service for this river reach. Throughout the life of this plan, Pierce County would like to work with King County to develop a flood warning system for this area.

Historical Flooding

In December 1977, the Greenwater River experienced its most severe flooding, with a peak flow of 10,500 cfs. Other large floods occurred in 1946, 1959, 1965, 1996, and 2009 (see Table 6.31). The 1977 event caused the most extensive damage. A large log jam at the SR 410 river crossing contributed to extensive flooding and damage in the community of Greenwater.

Flood Damage to Facilities

As noted above, there are currently no actively maintained Pierce County flood risk reduction facilities on the Greenwater River. The most significant damage occurred during the 1977 peak flood event that affected the SR 410 Bridge and approaches. Some toe and facing rock protecting the bridge banks and approaches probably have been damaged by the peak flows since 1977. The condition and status of the private revetment is not known. There has been loss of private property. In 1990, Pierce County purchased a home on Lumpy Lane that was falling in the river due to channel migration. The county is currently working with an adjacent property owner whose home is being threatened by channel migration, which poses a greater risk than flooding along the study reach.

6.8.6 Key Accomplishments since the 2018 Flood Plan Update

Pierce County is committed to practices (such as CMZ studies) that reduce risks to residents, businesses, and infrastructure, while protecting and improving fish and wildlife habitat that rely on our river systems. The Greenwater River Channel Migration Zone Study (between river miles 0.1 and 1.2) was completed in 2017. This is another important CMZ study needed to enable Pierce County to develop zoning maps based on science within the study to guide development away from high-risk areas. Pierce County Council formally adopted the study in 2022. The CMZ study can be found online at the Channel Migration Zone (CMZ) web page of the Pierce County website.

Recently, a project started (preliminary design) in the fall of 2021 will implement reach-scale restoration actions in the Greenwater River between RM 3.8 and RM 4.0 to restore instream complexity and floodplain connectivity. The overall goal of the project is to rehabilitate lost processes provided by large in-stream wood accumulations of benefit to adult spawning and juvenile rearing salmon populations on the Greenwater River. The objective of this project phase is to remove fill and armor associated with former roads and bridge crossings, which is restricting floodplain processes, and install six mid-channel wood structures. This work would implement restoration treatments developed through reach-scale assessment efforts to inventory existing wood loading rates, assess habitat quantity and quality, map existing geomorphic features, and assess existing hydraulic conditions. This proposed project builds upon work completed in 2010, 2011, and 2014 on upper sections of the Greenwater River between RM 7 and RM 8.

6.8.7 Land Acquisitions

There have been no property acquisitions along the Greenwater River from 2018 to 2021.

6.8.8 Flood and Channel Migration Hazard Mapping

Flood hazard mapping in the Greenwater River has not been updated since the original flood study of the 1970s. The new countywide DFIRM continues to show the old, detailed study on the lower Greenwater River. The entire floodplain is mapped as a FEMA-defined floodway because a floodway encroachment model was not run back in the 1970s. Flood-prone areas along the Greenwater River include the SR 410 crossing and Pierce County residential areas on the left bank, mostly between RM 0 and RM 1.0. King County also has a low residential area on the right bank that is at risk of flooding and channel migration. The DFIRMs for the Greenwater River show 129 acres within the special flood hazard area or 100-year floodplain. A new detailed flood study of this lower reach is needed and would include a DFF floodway analysis.

6.8.9 Problem Identification

Table 6.32 identifies the flooding and channel migration problems in the Greenwater River floodplain.

Table 6.32. Priority Problems Identified in Greenwater River

Location	Problem Description	Source
Channel Migration Problem Areas		
RM 0.4 - RM 0.7 LB	Channel migration north of Lumpy Lane East threatens three to five homes along this reach.	Pierce County

Source: Pierce County SWM records

6.8.10 River Reach Management Strategies

6.8.10.1 Conditions and Constraints of the Greenwater River

The recommended river reach management strategies take into account numerous conditions summarized as follows:

- Development and land use in adjacent floodplain – The Greenwater River floodplain has light residential development along the left bank of the river between RM 0.1 and RM 1.3, and a bridge crossing of SR 410 at RM 0.1.
- River management facilities – There are several private revetments along the left bank between RM 0.1 to RM 1.3. Bank armoring also exists at the SR 410 bridge crossing.
- River channel gradient and width – Channel gradient ranges from 1 and 1.5 percent. The river channel varies in width from approximately 50 feet to 200 feet.
- Presence of salmon spawning and rearing habitat – Species of salmon found in the Greenwater River include Chinook, pink, and coho salmon and steelhead trout. Extensive spawning of spring Chinook occurs in the lower four miles.
- Sediment transport accumulation and incision – The riverbed sediment is a mix of sand, gravel, cobble, and boulders. Sediments have become coarser over time due to the extensive removal of large wood following the 1977 flood. The extent of sediment accumulation or decrease has not been determined.

6.8.10.2 Greenwater River Reach Management Strategies

Recommended river reach management strategies for the Greenwater River are listed below:

Structural Management Strategies:

There are no Pierce County flood risk reduction facilities along the Greenwater River study reach.

Non-structural Management Strategies:

- Floodplain development regulations should be implemented by Pierce County in unincorporated areas of the county.

- Property acquisition or purchase of development rights should be considered on a case-by-case basis.
- Relocation of homes to outside of known channel migration hazards should be considered where appropriate.
- Be responsive to flood and channel migration risk-related calls from property owners and the public along the Greenwater River.

6.8.10.3 Interim Risk Reduction Measures

- HESCO barriers have been installed by King County and the USACE at RM 5.7 to 6.0 in the city of Pacific.

6.8.11 Recommended Capital Projects

There are no capital projects proposed for the Greenwater River.

6.9 Carbon River

6.9.1 Overview

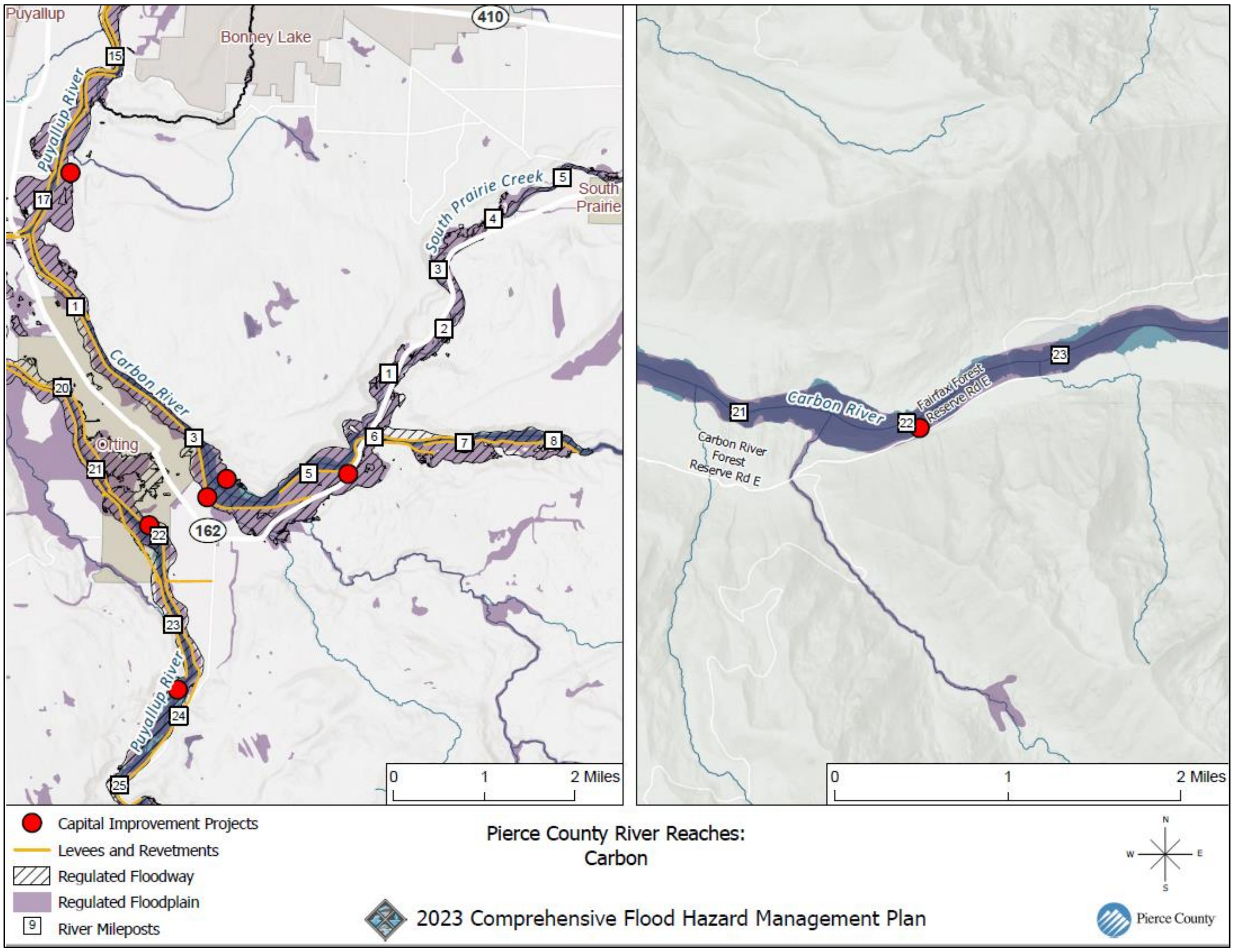
The Carbon River drains an area of 142 square miles that originates on the north face of Mount Rainier at the Carbon Glacier (see Figure 6.65). The river flows 33 miles downstream and then joins the Puyallup River downstream of Orting at RM 17.4. This 2023 Flood Plan concentrates on the lower 8.4 miles, from the eastern end of Alward Road (177th Street East) to the confluence with the Puyallup River, and a short segment in the upper Carbon River between RM 20.9 and RM 22.9.

The need for flood protection along the Carbon River along the lower 8.4 miles was first identified in the 1939 Flood Control Plan (Pierce County 1939). Construction of the levees and revetment were completed in the 1960s. Most of the lower 8.4 miles lies within unincorporated Pierce County, but the left bank between RM 0.75 and RM 3.40 lies along the easterly border of Orting. Above RM 11.0, the river is contained within steep canyon walls up to the community of Fairfax at RM 17.5 (WRIA 10 Stream Catalogue 1977). From RM 8.5 to RM 11.0, the river is confined within a deep and narrow ravine, below which it broadens into a wider valley with channel splitting and formation of large gravel bars. Between RM 0.0 and RM 8.3, the channel corridor lies in a relatively narrow trough-like valley.

The right bank is largely forested from RM 0.8 to RM 8.4. Below RM 0.8, the right bank is largely agricultural land. The left bank of the river from RM 0.75 to RM 3.4 is within the Orting city limits and contains the Orting Wastewater Treatment Plant and single-family residential development. Between RM 3.4 and RM 8.3, the left bank land use consists mostly of agricultural and rural residential land. The left bank has levees from RM 0.0 to RM 3.69 and RM 4.19 to RM 8.26, with a short segment of revetment between RM 3.69 and RM 4.01. The right bank has a levee from RM 0.0 to RM 1.2 and RM 5.95 to RM 7.0.

Two major tributaries enter the Carbon River in this reach—Voight Creek near RM 4.0 and South Prairie Creek near RM 5.8. South Prairie Creek is described in Chapter 6.10. Voight Creek, a smaller tributary, collects runoff from the foothills to the south and west and flows across the valley floor before entering the Carbon River (GeoEngineers 2003). The Carbon River contains the most productive mainstem spawning habitat remaining in the Puyallup River watershed for all species of salmon. Chinook, steelhead, chum, and pink salmon are found in relative abundance. Bull trout are also found in the Carbon River as well.

Figure 6.65. Planning Area for Carbon River



6.9.2 Geology and Geomorphology

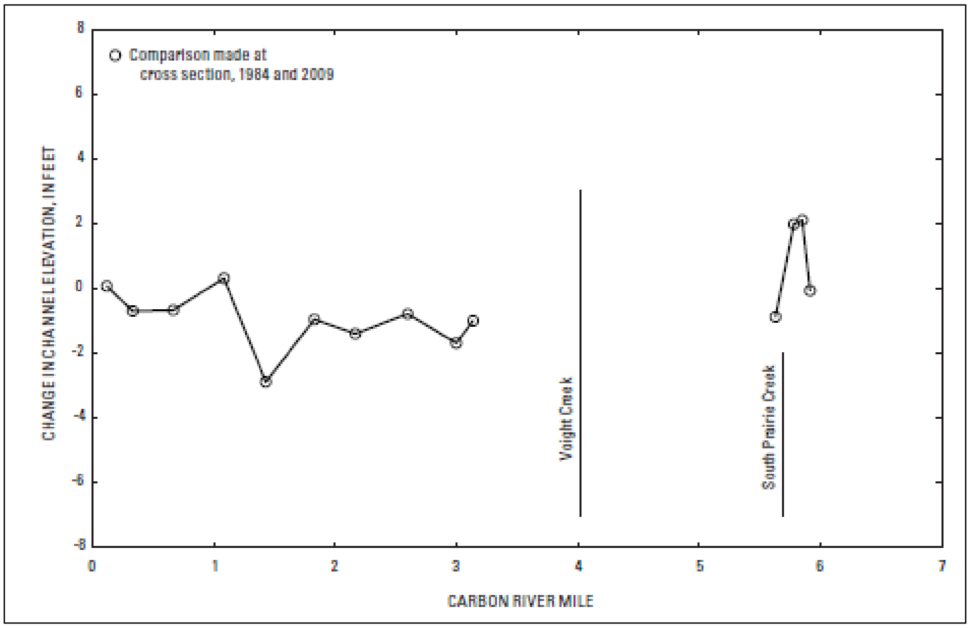
From the confluence with the Puyallup River to just upstream of Orting at RM 4.0, the Carbon River flows next to the Cascadia plateau. In the 1500s, the Electron mudflow deposited more than 15 feet of dense clay-rich mud across the Orting Valley. Prior to land development in the valley, the entire length of the Carbon River reach was a continuous complex of braided and multi-threaded meandering channels. As the river reach developed, growing gravel bars within the braided river system forced the river to the sides of the valley walls, leading to erosion of large, scalloped cut banks in the mudflow deposits and steep side walls. Early flood control policies focused on the construction of levee and revetments along the Carbon River to straighten the river, increase sediment transport downstream, and prevent valley wall sediment from eroding into the river (GeoEngineers 2003). Since the levees were constructed, residential homes and the Orting Wastewater Treatment Plant have been built near the river in areas historically occupied by the river. The levees changed the river from a complex braided and multi-threaded meandering channel to an essentially straight, single-thread stream from RM 0.0 to RM 3.0.

From RM 0.0 to RM 8.3, the gravel and cobble bedload is currently depositing as side bars that build out from channel edges. These lateral bars aggrade into terraces alongside the levees and revetments, thereby reducing channel conveyance (GeoEngineers 2003). The channel gradient from RM 0.0 to RM 4.2 is 0.46 to 0.60 percent, and from RM 4.2 to RM 8.3 the channel gradient varies from 0.72 to 1.15 percent. Typical bed conditions in the upper portion of this reach are shown in Figure 6.66.

Figure 6.66. Carbon River, Looking Upstream near RM 7.0

Analysis by the USGS (2010) as part of the Sediment Transport Study indicates an average river bed elevation change between RM 0.0 and RM 3.2 of -2.9 feet to +0.3 feet between 1984 and 2009 (see Figure 6.67). From RM 5.6 to RM 6.0, the average bed elevation change is between -1.5 to +2.1 feet. There are no data above RM 6.0 from 1984 due to a problem with the 1984 survey.

Figure 6.67. Change in Average Riverbed Elevation between 1984 and 2009, Carbon River



6.9.3 Hydrology and Hydraulics

Hydrologic analyses established peak discharge-frequency relationships for the Carbon River. Flood frequency flows were estimated for the 10-, 50-, 100-, and 500-year floods using Bulletin #17B procedures (USGS 1981). The USGS-operated stream gauging station, Carbon River near Fairfax, Washington (#12094000), has recorded peak discharges from water years 1930 to 2021. The gauge is located approximately 15 miles upstream of the Carbon River mouth near Fairfax.

For purposes of the hydrologic analysis, the Carbon River was divided into three segments, as follows:

- Downstream segment from the Puyallup River to Voight Creek
- Middle segment, from Voight Creek to South Prairie Creek
- Upper segment, from South Prairie Creek to RM 8.3

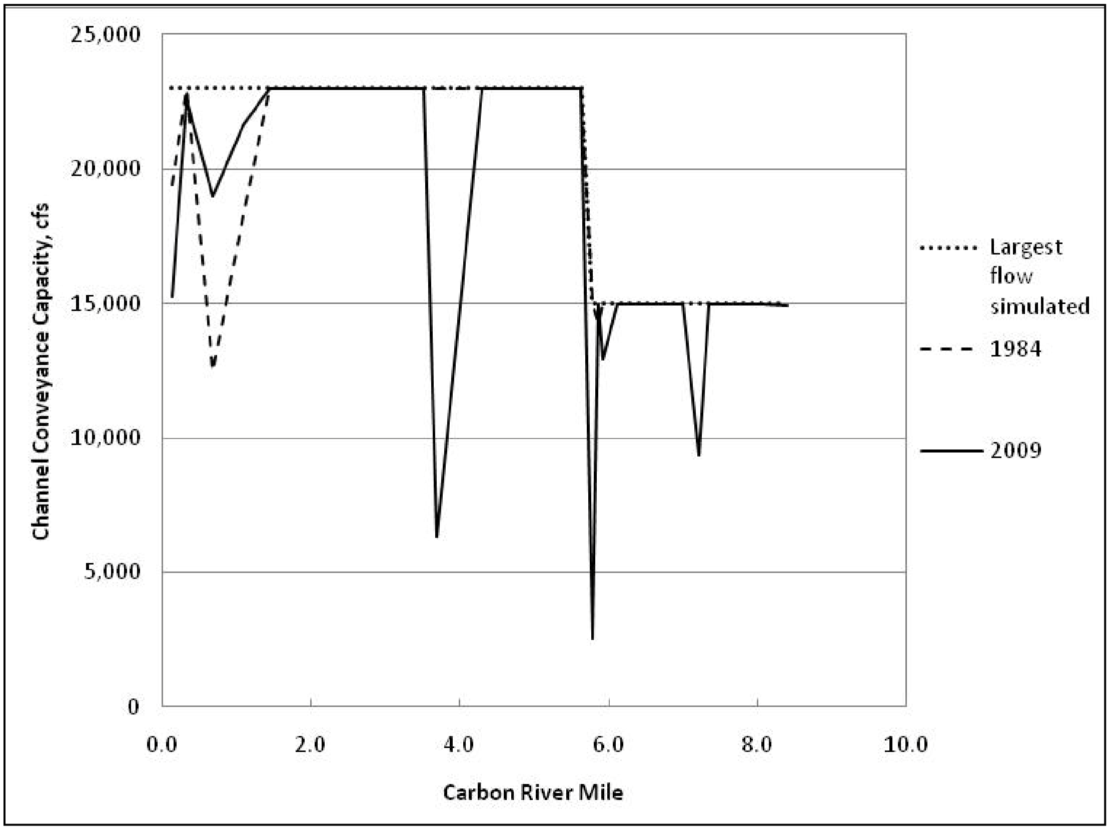
Flow estimates for the middle segment were determined by accounting for flows from South Prairie Creek sub-basin drainage area and precipitation. Regression analysis methods were used to compute the peak flow values. The resultant flood frequency flows are summarized in Table 6.33. The USGS study of conveyance capacity (USGS 2010) indicates that the Carbon River channel can convey between 15,200 to 23,000 cfs before overtopping either the left or right bank between the mouth and RM 5.6, with one exception at RM 3.7, where the right bank capacity is 6,300 cfs (see Figure 6.68). Above RM 5.8, the conveyance capacity is generally 15,000 or greater cfs, with the exception of the right bank at RM 5.8 (2,500 cfs) and right bank at RM 7.2 (9,300 cfs).

Table 6.33. Carbon River Flood Frequency Flows

Location	Discharge (cfs) 10-year Event	50-year Event	100-year Event	500-year Event	Method
Mouth to Voight Creek Confluence	13,100 18,600	17,600 26,800	19,500 30,400	24,200 39,100	1987 FEMA Flood Insurance Study 2009 FEMA Flood Insurance Study (and NHC 2006) and 2004 Log Pearson Type 3 fit gauge data.
Voight Creek Confluence to South Prairie Creek Confluence	11,300 15,300	15,300 22,100	17,000 25,000	21,200 32,200	1987 FEMA Flood Insurance Study 2009 FEMA Flood Insurance Study (and NHC 2006) and 2004 Log Pearson Type 3 fit gauge data.
South Prairie Creek Confluence to Upstream Study Reach Boundary	6,650 8,700	9,350 12,700	10,500 14,500	13,500 19,100	1987 FEMA Flood Insurance Study 2009 FEMA Flood Insurance Study (and NHC 2006) and 2004 Log Pearson Type 3 fit gauge data.

Source: FEMA (1987, 2009) and USGS data records

Figure 6.68. Channel Conveyance Capacity for the Carbon River
Source: USGS 2010

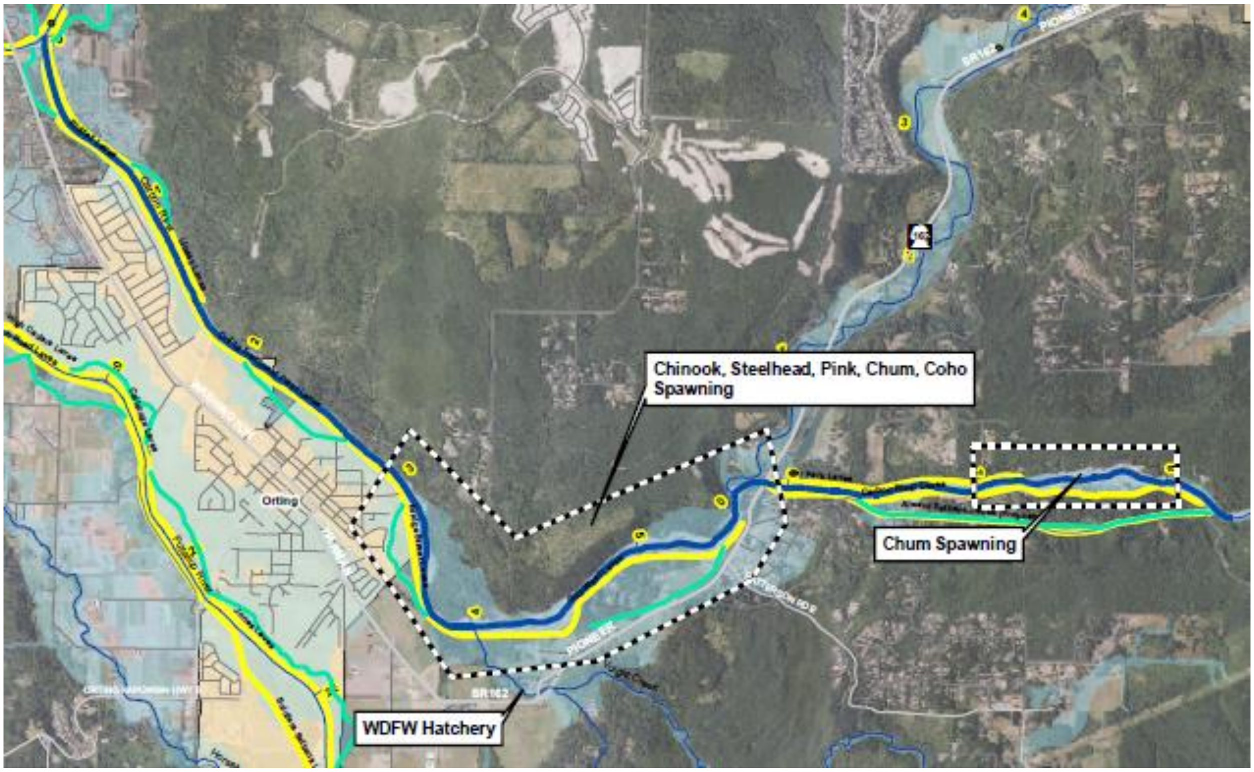


6.9.4 Ecological Context and Salmonid Use

The Carbon River contains some of the most concentrated areas of productive spawning habitat remaining in the Puyallup River watershed for multiple species of salmon, especially from RM 3.0 to RM 5.8 (Frissel 2000). Figure 6.69 shows the spawning areas within the Carbon River. Spawning Chinook, steelhead, chum, and pink salmon are found in relative abundance. The most productive areas in this reach exist where the unconfined right bank allows for meandering and creation of side channel habitat. The right bank in between RM 3.0 and RM 5.8 also offers some excellent summer juvenile rearing habitat where the cool spring water from the base of the valley wall intersects the river. Abundant numbers of fish may result from the proximity to the WDFW Voight Creek hatchery and the productive South Prairie Creek.

Both preservation and restoration action along the Carbon River will benefit fish. The unconfined right bank from RM 3.0 to RM 5.8 should be preserved. Projects such as a setback levee along the left bank of Alward Road near RM 7.0 are a high priority for salmon recovery. Potential also exists along the right bank in the lowest two miles of the river.

Figure 6.69. Salmon and Steelhead Spawning Locations, Carbon River and Voight Creek WDFW Hatchery



6.9.5 River Risk Reduction Facilities, Flooding, and Flood Damage

Current levees along the Carbon River were primarily built in the 1960s. From 1939 to the 1970s, Pierce County followed a plan to establish a single channel on the Carbon River and Puyallup River (upstream of the White River confluence) by excavating gravel and river sediments and side casting them to form levees that were armored with rock riprap. The once meandering river channel was straightened and confined to an average width of 250 feet. The levee system was designed to prevent sediment sources from the banks and cliffs adjacent to the river from entering the channel and contributing to increased sediment transport. It was believed that by constricting the channel width, there would be increased flow velocities to continue sediment transport downstream.

Pierce County currently owns and maintains approximately 11.36 miles of flood risk reduction facilities along the Carbon River in a combination of levees and revetments (see Table 6.34).

Table 6.34. Levees and Revetments along the Carbon River

Name	Location [a]	Ownership
Right Bank		
Lindsay Levee [a]	RM 16.89 (PR) – RM 1.20 (CR)	Pierce County
Ski Park Levee [a]	RM 5.95 – RM 7.00	Pierce County

Left Bank		
Riddell Levee [a]	RM 0.00 – RM 1.71	Pierce County
Orting Treatment Plant Levee [a]	RM 1.71 – RM 3.06	Pierce County
Bridge Street Levee [a]	RM 3.06 – RM 3.69	Pierce County
Voight Downstream Revetment	RM 3.69 – RM 3.98	Pierce County
Voight Upstream Levee	RM 4.01 – RM 4.85	Pierce County
Guy West Levee [a]	RM 4.60 – RM 5.40	Pierce County
Charles Crocker Levee	RM 5.38 – RM 5.90	Pierce County
Alward Segment No 2 Levee [a]	RM 5.93 - RM 6.36	Pierce County
Fish Ladder Levee	RM 6.36 – RM 6.64	Pierce County
Alward Segment No 1 Levee [a]	RM 6.54 – RM 8.27	Pierce County
Alward Revetment	RM 8.27 – RM 8.31	Pierce County

[a] PL 84-99 = USACE Flood Control and Coastal Emergency Act.

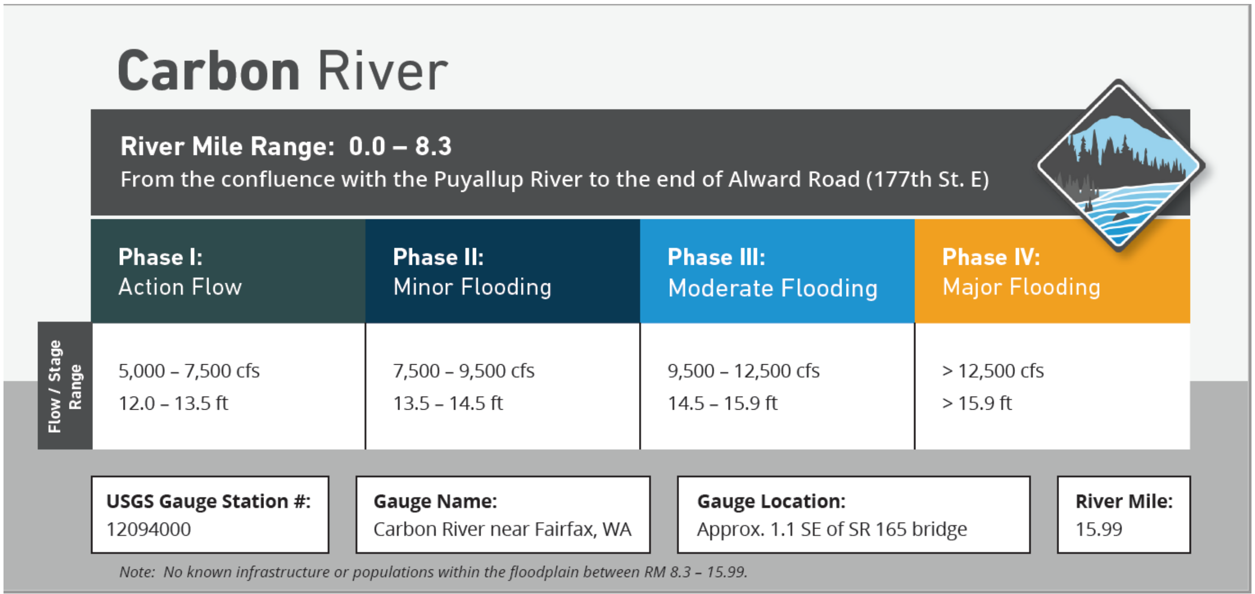
RM = river mile.

Source: Pierce County Surface Water Management records.

6.9.6 Carbon River Flow Warning Matrix

The Carbon River has four flow categories: Phase I, Action Flow; Phase II, Minor flooding; Phase III, Moderate flooding; and Phase IV, Severe flooding. These categories describe the observed or expected severity of the flood impacts in that area. However, the severity of flooding at a given stage is not necessarily the same at all river locations. Most river reaches in Pierce County have a defined flow warning matrix that is used during flood events. Figure 6.70 shows the flow warning matrix table for the Carbon River.

Figure 6.70. Carbon River Flow Warning Matrix



Historical Flooding

Historical flooding of the Carbon River has been recorded in 1933, 1959, 1977, 1990, 1996, 2006, 2008, and 2009 (see Table 6.35). The November 2006 flood is the largest on record, with a measured flow of 14,500 cfs. The categorization of major flooding is based on a threshold of discharges in excess of approximately 10,000 cfs at the Fairfax gauge.

Table 6.35. Historical Flooding on Carbon River

Date	Carbon River Flows at Fairfax Gauge (cfs) – USGS #12094000[a]
December 1933	11,000
November 1959	9,970
December 1977	10,000
November 1990	13,000
February 1996	12,000
December 1996	13,600
November 2006	14,500
November 2008	11,700
January 2009	11,600
December 2015	10,200

[a] Source: Pierce County SWM and USGS records.

Note: There is a gap in the USGS record from 1977 to 1989.

Flood Damage to Facilities

Flood damages to Carbon River flood risk reduction facilities have been extensive in the past three decades. Seven significant flood events have occurred along the study reach since 1990. Damages sustained ranged from full washout of the flood risk reduction structure over several hundred lineal feet to localized scour and erosion. Table 6.36 summarizes recorded levee and revetment damages. The upper portion of this Carbon River reach between RM 6.0 and RM 8.3 has historically been the most vulnerable to repetitive damages that required extensive repairs.

Table 6.36. Damage to Facilities along the Carbon River 1990 – 2021

Storm Season/ Segment Name	Bank	River Mile	Damage Lineal Feet	Damage and /or Repair Made
1990				
Alward 1	Left	6.8	750	Reconstruction.
Alward 1	Left	7.2	1,300	Reconstruction.
Bridge Street	Left	3.2	175	Washout.
Guy West	Left	5.9	400	Reconstruction.
Lindsay	Right	0.4	250	Levee slope protection damage.
Lindsay	Right	0.8	400	Reslope and replace levee washed out by flood.
Riddell	Left	0.4	400	Reslope and replace levee washed out by flood.
Riddell	Both	0.9	400	Reslope and replace levee washed out by flood.
Riddell	Left	0.9	150	Levee slope protection damage.
Ski Park	Right	6.0	770	Flood damage repair.
Ski Park	Right	6.4	300	Washout.
Ski Park	Right	6.4	500	Reconstruction.
Ski Park	Right	6.5	300	Reshape and replace riprap and toe rock.
Ski Park	Right	6.8 & 7.6	1,550	Flood damage repair.
Ski Park	Right	6.1	900	Reconstruction.
South Prairie Confluence	Right	5.9	100	Reconstruction.
1995				
Alward 1	Left	6.7	350	Partial washout.
Alward 1	Left	6.9	150	Full levee washout.
Alward 1	Left	7.1	700	Full levee washout.
Alward 1	Left	7.3	100	Partial washout.
Alward 2	Left	6.2	255	Repair partially failed embankment.
Alward 2	Left	6.3	250	Partial washout.
Guy West	Left	4.6	100	Full levee washout.
Guy West	Left	4.9	100	Partial washout.

Storm Season/ Segment Name	Bank	River Mile	Damage Lineal Feet	Damage and /or Repair Made
1995 (continued)				
Lindsay	Right	0.8	379	Toe/slope failure.
Ski Park	Right	6.9	200	Partial washout.
Ski Park/Alward 1	Both	6.9, 7.3, & 7.4	730	Rebuild fully washed out levee.
Alward 2	Left	6.2	255	Repair partially failed embankment.
Alward 2	Left	6.3	250	Partial washout.
1996				
Alward 1	Left	6.6	400	Toe failure.
Alward 1	Left	6.9	200	Toe failure.
Alward 1	Left	7.2	400	Total levee failure.
Alward 1	Left	7.2	850	Total levee failure.
Alward 2	Left	6.05	250	Toe/slope failure.
Alward 2	Left	6.25	250	Toe/slope failure.
Alward 2	Left	6.3	100	Toe/slope failure.
Bridge Street	Left	3.2	50	Toe/slope failure.
Bridge Street	Left	3.6	350	Total levee failure.
Fish Ladder	Left	6.4	50	Toe/slope failure.
Guy West	Left	4.6	100	Total levee failure.
Guy West	Left	4.9	100	Toe/slope failure.
Lindsay	Right	0.2	450	Toe/slope failure.
Lindsay	Right	0.5	50	Toe/slope failure.
Lindsay	Right	0.6	80	Toe/slope failure.
Lindsay	Right	0.95	50	Toe/slope failure.
Lindsay	Right	1.0	30	Toe failure.
Lindsay	Right	1.1	40	Toe failure.
Lindsay	Right	1.2	125	Toe/slope failure.
Orting Wastewater Treatment Plant	Left	2.7	20	Toe/slope failure.
Riddell	Left	0.4	100	Toe/slope failure.
Riddell	Left	0.8	30	Toe/slope failure.
Riddell	Left	1.05	20	Toe/slope failure.
Ski Park	Right	7.1	800	Total levee failure.
Ski Park	Right	6.18	40	Toe/slope failure.

Storm Season/ Segment Name	Bank	River Mile	Damage Lineal Feet	Damage and /or Repair Made
Ski Park	Right	6.9	320	Total levee failure.
1998				
Alward 1	Left	6.9	150	Repair levee.
Alward 1	Left	7.6	150	Repair levee.
Alward 1	Left	8.0	200	Repair levee.
2003				
Guy West	Left	5.4	260	Partial washout of the toe and levee facing.
Ski Park	Right	6.6	450	Partial washout of the toe and levee facing.
2005				
Alward 1	Left	6.6	450	Replace/ reconstruct/repair.
Alward 1	Left	7.6	750	Replace/ reconstruct/repair.
2006				
Alward	Left	8.3	100	Face erosion.
Alward	Left	8.3	300	Face erosion.
Alward 1	Left	7.2 – 7.4	750	Washout
Alward 1	Left	7.5	1,200	Washout
Alward 1	Left	7.6	700	Washout
Alward 1	Left	8.2	150	Face erosion.
Alward 2	Left	6.0 – 6.1	600	Face erosion.
Alward 2	Left	6.3	600	Washout.
Bridge Street	Left	3.2	50	Washout.
Bridge Street	Left	3.6	120	Washout.
Bridge Street	Left	3.6	200	Face erosion.
Guy West	Left	4.6 – 4.9	1700	Toe erosion/undercut bank.
Guy West	Left	4.8	150	Washout.
Guy West	Left	4.8	100	Washout.
Guy West	Left	4.8	140	Washout.
Guy West	Left	5.0	270	Face erosion.
Guy West	Left	5.2	150	Face erosion.
Guy West	Left	5.4	30	Washout.
Lindsay	Right	0.8	60	Fracture.
Lindsay	Right	1.2	150	Washout.
Lindsay	Right	17.4	50	Face erosion.
Riddell	Left	0.2	50	Slump.
Riddell	Left	0.4	0	Overtopping.

Storm Season/ Segment Name	Bank	River Mile	Damage Lineal Feet	Damage and /or Repair Made
Riddell	Left	1.2	0	Overtopping.
2006 (continued)				
Ski Park	Right	6.0	500	Washout.
Ski Park	Right	6.0	300	Washout.
Ski Park	Right	6.3	100	Face erosion.
Ski Park	Right	6.4	500	Washout.
Ski Park	Right	6.8	550	Washout.
Voight d.s.	Left	3.8	180	Face erosion.
Voight’s u.s.	Left	4.2	20	Fracture.
Voight u.s.	Left	4.4	110	Restore levee face and toe.
2007				
Alward 1	Left	6.6 – 6.7	810	Reconstruct new levee prism and set new face rock.
Alward 1	Left	6.8 – 7.0	1250	Reconstruct levee prism, set new toe, and face.
Alward 1	Left	7.2 – 7.4	850	Reconstruct new levee prism and set new face rock.
Alward 1	Left	8.1	390	Replaced toe and re-slope and replaced face rock.
Alward 1	Left	8.0	450	Re-establish toe and repair face.
Bridge Street	Left	3.6 – 3.7	0	Overtopping.
Guy West	Left	5.0	500	Set new toe and re-slope face.
Lindsay	Right	0.8	600	Replace/ reconstruct/repair.
Lindsay	Right	1.2	450	Re-establish toe and repair face.
Ski Park	Right	6.0	540	Replace/ reconstruct/repair.
Ski Park	Right	6.8	800	Re-establish toe and repair face.
2008				
Alward 1	Left	7.0	100	Face scour and loss face rock.
Alward 1	Left	7.2 – 7.3	796	Toe scour and loss of face rock. Lower face slumping.
Alward 1	Left	8.0	100	Toe scour and loss of face rock. Lower face slumping.
Alward 1	Left	8.1	100	Toe scour and loss of face rock. Lower face slumping.
Alward 1	Left	8.25	150	Toe scour and loss of face rock. Lower face slumping.
Alward 2	Left	6.0	824	Face rock thin due to scour.

Storm Season/ Segment Name	Bank	River Mile	Damage Lineal Feet	Damage and /or Repair Made
Alward 2	Left	6.25	302	Toe scour and loss face rock.
Alward 2	Left	6.35	136	Toe scour and loss face rock.
2008 (continued)				
Bridge Street	Left	3.5	300	Toe scour and loss face rock
Bridge Street	Left	3.55 – 3.7	325	Routine maintenance to the existing levee structure.
Bridge Street	Left	3.6 – 3.7	380	Toe and face scour.
Fish Ladder	Left	6.4	171	Toe scour and loss face rock.
Guy West	Left	4.7	296	Scalloped washout.
Guy West	Left	4.8	1,200	Re-establish levee core to inhibit lateral piping during high water.
Guy West	Left	5.0	290	Replace undersized face rock.
Guy West	Left	5.2	196	Replace undersized face rock.
Guy West	Left	5.3	253	Toe scour and loss face rock.
Lindsay	Right	1.0	50	Toe rock failure and partial face rock failure.
Orting Treatment Plant	Left	2.0	25	Toe scour and loss face rock.
Riddell	Left	0.4 – 0.5	634	Toe scour and loss face rock.
Riddell	Left	0.9 – 1.10	500	Washout of the toe and levee face.
Ski Park	Right	6.0	336	Toe scour and loss of face rock.
Ski Park	Right	6.25	140	Toe scour and loss of face rock.
Ski Park	Right	6.45 – 6.6	900	Face scour and loss face rock.
Ski Park	Right	7.0	139	Washout.
Voight revetment u.s.	Left	4.2	324	Washout.
Voight revetment u.s.	Left	4.4	123	Toe and face scour.
2009				
Alward 1	Left	7.5	118	Face scour with core exposure. Possibly some toe loss. Bank is undercutting.
Alward 2	Left	6.35	140	Toe scour and loss face rock.
Fish Ladder	Left	6.4	110	Lower face scour.
Lindsay	Right	0.6	30	Facing rock failure.
Lindsay	Right	0.9	75	Facing rock failure.
Lindsay	Right	0.9	180	Re-establish toe and repair face.

Storm Season/ Segment Name	Bank	River Mile	Damage Lineal Feet	Damage and /or Repair Made
Lindsay	Right	16.9 – 16.95	100	Toe and facing rock failure.
2009 (continued)				
Riddell	Left	0.4	0	Overtopping.
Ski Park	Right	5.95	50	Armored spillway
Ski Park	Right	6.2	255	Face scour with loss of most face rock.
Ski Park	Right	6.25	144	Primary lower face scour causing upper face to slough.
Ski Park	Right	6.4	310	Face scour with loss of most face rock.
Ski Park	Right	6.75	200	Lower face scour.
Ski Park	Right	6.45 – 6.6	400	Toe scour and loss of embankment.
2011				
Alward 1	Left	7.1	75	Face and potential toe rock failure.
Alward 1	Left	7.55	90	Toe and face rock failure.
Alward 1	Left	8.05	130	Toe and face rock failure.
Alward 1	Left	8.15	50	Face rock failure.
Bridge Street	Left	3.35	30	Toe and face rock failure.
Bridge Street	Left	3.45	120	Face rock failure.
Guy West	Left	4.8	270	Undermining levee.
Guy West	Left	5.3	70	Toe/face scour.
Orting Wastewater Treatment Plant	Left	2.0	129	Toe and rock failure.
Riddell	Left	1.0	140	Toe is scoured out along with some face rock.
Riddell	Left	1.1	400	Toe is scoured out along with some face rock.
Riddell	Left	1.6	210	Undermined section with prism showing in sections.
Voight d.s.	Left	3.75	90	Partial damage to facing rock.
Voight d.s.	Left	3.8	130	Damage to toe and face rock.
Voight u.s.	Left	4.2	700	Some toe rock failure.
2012				
Alward 1	Left	7.1	250	Face and potential toe rock failure
Alward 1	Left	8.05 – 8.15	350	Toe and face rock failure.
Bridge Street	Left	3.35	60	Face and toe scour.
Bridge Street	Left	3.4	45	Facing and toe scour.

Storm Season/ Segment Name	Bank	River Mile	Damage Lineal Feet	Damage and /or Repair Made
Bridge Street	Left	3.45	120	Face rock is gone.
Guy West	Left	4.8	270	Levee undermined along toe.
2012 (continued)				
Guy West	Left	5.3	170	Toe & face rock failing.
Orting Treatment Plant	Left	2.0	129	Toe and face rock failure.
Riddell	Left	0.4	634	Toe scour and loss of face rock.
Riddell	Left	1.0	140	Toe is scoured out along with some face rock.
Riddell	Left	1.6	210	Undermined trees are pulling apart face rock.
Voight revetment downstream	Left	3.8	130	Some minor damage to face rock.
Voight revetment upstream	Left	4.2	700	Some toe rock failure.
2013				
Alward 1	Left	7.0 – 7.1	400	Toe and face rock failing.
Alward 1	Left	7.2	150	Minor toe rock repair.
Fish Ladder	Left	6.4	100	Toe and face rock failure.
Guy West	Left	5.5	250	Toe and face rock failing.
Orting Treatment Plant	Left	2.0	150	40 lineal feet of prism core exposed.
Riddell	Left	1.6	250	Missing face and toe rock.
2014				
Guy West	Left	5.75	250	Face rock failure.
Riddell	Left	0.5	500	Toe scour and loss face rock.
Riddell	Left	1.6	260	Toe and face rock failure.
Ski Park	Right	6.0	100	Toe and face erosion.
2015				
Alward 1	Left	6.55	200	Levee rehabilitation
Alward 1	Left	7.1	40	Missing toe rock.
Alward 1	Left	7.2	390	Levee rehabilitation.
Alward 1	Left	7.9	100	Large log jam diverting flows/jet scour into levee.
Alward 1	Left	7.9	20	Log jam is gone that forced flows into levee.
Alward 1	Left	7.9	120	Toe and face rock damaged from large log Jam.

Storm Season/ Segment Name	Bank	River Mile	Damage Lineal Feet	Damage and /or Repair Made
Alward 1	Left	8.1	60	Toe rock missing.
Alward 1	Left	8.2	40	Missing Toe Rock in three locations.
Alward 1	Left	8.2	30	Missing Toe Rock in three locations.
2015 (continued)				
Alward 1	Left	8.2	150	Large scour has formed at the toe of the levee. Toe and face rock has fallen into scour hole.
Alward 2	Left	6.35	100	Levee rehabilitation.
Alward 2	Left	6.2 – 6.3	490	Levee rehabilitation.
Bridge Street	Left	3.35	200	Levee rehabilitation.
Bridge Street	Left	3.4	130	Face rock missing.
Fish Ladder	Left	6.35 – 6.4	200	Rock displaced.
Fish Ladder	Left	6.35	100	Levee rehabilitation.
Fish Ladder	Left	6.4	34	Missing Toe rock.
Fish Ladder	Left	6.4	16	An additional 16 feet of revetment damaged from flood event.
Fish Ladder	Left	6.4	100	Emergency repair.
Fish Ladder	Left	6.45	150	Face and Toe Rock missing.
Guy West	Left	4.65	150	Levee rehabilitation.
Guy West	Left	4.8	360	Levee rehabilitation.
Guy West	Left	5.3 – 5.35	375	Levee rehabilitation.
Guy West	Left	5.2	40	Missing toe and face rock.
Guy West	Left	5.75	150	Missing toe rock.
Lindsay	Right	1.2	150	Toe rock missing.
Lindsay	Right	0.8	30	Missing toe rock and face rock slumping.
Lindsay	Right	0.8	200	Trees were undermined and then pulled out a section of face rock in several locations.
Lindsay	Right	0.8	125	Missing toe rock and face rock.
Riddell	Left	0.55	60	Missing face rock
Ski Park	Right	6.2 - 6.3	735	Levee rehabilitation.
Ski Park	Right	6.20	40	Section of toe rock missing.
Ski Park	Right	6.25	180	Missing toe and face rock.
Ski Park	Right	6.80	200	Vertical face along inside radius of river bend.
Ski Park	Right	6.80	200	Vertical face.
Voight revetment d.s.	Left	3.8	120	Missing toe and face rock.

Storm Season/ Segment Name	Bank	River Mile	Damage Lineal Feet	Damage and /or Repair Made
Voight revetment d.s.	Left	3.8	140	Levee rehabilitation.
2015 (continued)				
Voight revetment d.s.	Left	4.2	40	Partial undermining through two repair sites in trees section.
Voight revetment u.s.	Left	4.2	80	Missing toe and face rock.
Voight revetment u.s.	Left	4.2	90	Missing toe and face rock.
Voight revetment u.s.	Left	4.3	20	Tree pulled out a piece of face and toe rock.
Voight revetment u.s.	Left	4.3	50	Tree pulled out a piece of face and toe rock.
Voight revetment u.s.	Left	4.3	100	Large cedar tree and alder tree pulled a section of levee down.
2017				
Alward 1	Left	7.9	120	Toe and face rock damaged from large log jam.
Alward 1	Left	8.1	100	Toe rock missing. Scalloped along toe.
Alward 2	Left	6.20	478	Reconstruction/preservation.
Alward 2	Left	6.0	150150	Unacceptable PL 84-99 tie in, proposing slightly setback levee alignment to tie into former railroad embankment.
Bridge Street	Left	3.4	130	Face rock failure. Face rock missing.
Bridge Street	Left	3.7	120	Toe and face rock.
Bridge Street	Left	3.4	340	Loss of toe and face rock.
Bridge Street	Left	3.1	200	Loss of toe rock.
Fish Ladder	Left	6.4	200	Loss of bank between 177th and the end of Alward 1 Levee.
Guy West	Left	5.75	150	Toe and face rock failure.
Orting Wastewater Treatment Plant	Left	2.3	20	Portion of face rock missing.
Orting Treatment Plant	Left	2.7	40	Toe rock failure.
Orting Treatment Plant	Left	2.7	140	Partial of face rock missing.
2017 (continued)				

Storm Season/ Segment Name	Bank	River Mile	Damage Lineal Feet	Damage and /or Repair Made
Orting Treatment Plant	Left	2.1	75	Levee face damage.
Riddell	Left	1.2 - 1.3	500	Toe rock failure.
2018				
Bridge Street	Left	3.1	200	Erosion and bank caving.
Bridge Street	Left	3.4	230	Levee rehabilitation.
Alward Segment No. 1	Left	6.5	225	Levee rehabilitation.
Alward Segment No. 1	Left	7.9	120	Erosion of face and toe rock.
Alward Segment No. 1	Left	8.1	100	Missing toe rock.
2020				
Riddell	Left	0.4	410	Levee rehabilitation.
Lindsay	Right	1.0	150	Erosion of face and toe rock.
Orting Treatment Plant	Left	2.0	130	Erosion of face and toe rock.
Orting Treatment Plant	Left	2.6	50	Localized scour repair.
Orting Treatment Plant	Left	2.8	216	Erosion and bank caving.
Charles Crocker	Left	5.6	460	Levee rehabilitation.
2021				
Lindsay	Right	1.0	275	Erosion and bank caving.
Bridge Street	Left	1.5	40	Localized scour repair.
Bridge Street	Left	3.2	405	Levee rehabilitation.
Ski Park	Right	6.2	155	Erosion of face and toe rock.

6.9.7 Key Accomplishments since the 2018 Flood Plan Update

Major Projects

Since 2018, major repairs (generally 750 lineal feet or more in length) have occurred along the Carbon River following large flood events (see Table 6.37). Records maintained by Pierce County SWM show that the most extensive repairs have occurred between RM 6.0 and RM 7.6. Since 1990, no new flood risk reduction facilities have been constructed.

Table 6.37. Major Repairs Completed on Carbon River since 2018 Flood Plan

Segment Name	Approx. Location	Damage	Length	Estimated Cost	Flood Event
Right Bank					
Ski Park	RM 7.1	Full washout.	800	$456,800	Nov. 1995/Feb. 1996
Ski Park	RM 6.8	Toe damage and face scour.	1,075	$357,500	December 2007
Ski Park	RM 6.45 – RM 6.6	Face scour.	900	$279,000	November 2008
Left Bank					
Alward Road Levee	RM 7.2	Full washout.	850	$485,350	February 1996
Alward Road Levee	RM 7.5	Full washout.	1,200	$ 960,000	November 2006
Alward Road Levee	RM 6.6 – RM 6.7	Full washout.	810	$283,500	December 2007
Alward Road Levee	RM 7.2 – RM 7.4	Full washout.	850	$425,000	December 2007
Alward Road Levee	RM 6.0	Face rock scour and core exposure.	824	$288,400	November 2008
Alward Road Levee	RM 7.2 – RM 7.3	Toe scour and loss of face rock. Lower face slumping.	796	$398,000	November 2008

Source: Pierce County SWM records.

Following the January 2009 storms, the Voight Creek Hatchery facilities were relocated to higher ground upstream of SR 162. The hatchery was just one of many facilities that was damaged by record flooding on this reach. This event triggered a presidential disaster declaration, which made funds available to public entities for disaster-related damage. This project was completed with coordination and support from the Puyallup Tribe.

6.9.8 Land Acquisitions

Between 2018 and 2021, 36 acres of property has been acquired along the Carbon River. These property acquisitions supported the Alward Road capital project.

6.9.9 Flood and Channel Migration Hazard Mapping

Flood Hazard Mapping

Secluded

refers to an area at risk of flooding behind a non-accredited levee.

Flood hazard mapping for the Carbon River includes detailed flood studies (FEMA/ NHC 2006) and the creation of DFIRMs, which were adopted in 2017. In order to publish the countywide DFIRM areas that were affected by non-accredited levees were "secluded" from this map update. This means that the Carbon River from the Puyallup River to South Prairie Creek still shows the same flood risk as it was understood in the 1970s. Flood-prone areas in Orting include school, residential, and commercial lands. In unincorporated areas, agricultural and residential properties are in the flood-prone areas. The FEMA/NHC 2006 flood study for the Carbon River show 1,317 acres within the special flood hazard area or 100-year floodplain. The FEMA/NHC 2006 flood study is regulated as best available data by Pierce County and used as guidance by the City of Orting. The mapped DFF area in unincorporated areas is 945 acres.

Channel Migration Hazard Mapping

Severe, moderate, and low CMZs were mapped for the Carbon River (GeoEngineers 2003) and adopted in November 2004. The severe CMZ covers 999 acres in unincorporated area along the Carbon River. The mapped severe CMZ is quite narrow from RM 0.0 to RM 3.1, with a width from 400 to 1,000 feet, and more extensive from RM 3.1 to RM 5.6, with width varying from 800 to 1,800 feet (GeoEngineers 2003). Upstream of RM 6.0 to RM 8.3, the severe CMZ varies from 500 to 1,200 feet. Pierce County regulates severe CMZ mapped areas as floodway in accordance with Chapter 18E.70 of the PCC.

6.9.10 Problem Identification

Table 6.38 lists the flooding and channel migration problems identified in the Carbon River floodplain.

Table 6.38. Priority Problems Identified in Carbon River

Location	Problem Description	Source
Levee and Revetment Overtopping and Breaching		
RM 0.0 – RM 1.2 LB	Levee overtopping observed at or near RM 0.0 (2006) and RM 0.4 (2009). 400 LF of washout at RM 0.8 in 1990. Threatens SR 162 and homes.	Pierce County
RM 0.0 – RM 1.2 RB	Levee washout of 400 LF at RM 0.8 (1990) and 150 LF at RM 1.2 (2006).	Pierce County
RM 3.0 – RM 3.8 LB	Levee overtopping and breaching in 1996, 2006, and 2009 at RM 3.6–RM 3.7; additional washouts between RM 3.0 and RM 3.2 in 1990 and 2006.	City of Orting, Pierce County, WSDOT

Location	Problem Description	Source
Levee and Revetment Overtopping and Breaching (continued)		
RM 3.9 – RM 5.9 LB	Levee has experienced major damages (face and toe scour and undercut banks) in last three major flood events in 2006, 2008, and 2009.	Pierce County
RM 6.0 – RM 6.4 LB	Levee has experienced repetitive damages since 1990, including overtopping at RM 6.0 and RM 6.1 in 2006.	Pierce County
RM 6.0 – RM 6.4 RB	Levee has experienced repetitive damages since 1990. One home washed into river and flooding of SR 162 in 2006.	Pierce County
RM 6.4 – RM 8.3 LB	Levee has experienced repetitive damages since 1990.	Pierce County
RM 6.4 – RM 8.3 RB	Levee has experienced repetitive damages since 1990. Levee/revetment has not been repaired above RM 7.0 since 2006.	Pierce County
Tributary Backwater Flooding		
RM 0.45 – RM 0.8 LB	Orting stormwater outfall near RM 0.8 has no outlet to river; backwater conditions near RM 0.45 over-saturates levee from RM 0.45-0.8	City of Orting, Pierce County
RM 1.7 – RM 3.65 LB	Backwater channel flows downstream behind levee and discharges to river behind Orting wastewater treatment plant at RM 1.7.	Pierce County
RM 3.9 – RM 4.0 LB	Voight Creek and Coplar Creek backwater along riparian zone behind levee, resulting in flooding along Corrin Avenue NW and SR 162; also, some backwater effects upstream to the hatchery.	City of Orting, Pierce County
RM 6.45 LB	Backwater flooding of small creek behind fish ladder (on south side of Alward Road) occurred in 2006 and 2008.	Pierce County
Public Safety/Emergency Rescue		
RM 6.4 – RM 8.4 LB	Levee breach and flooding along Alward Road and failure to evacuate led to emergency rescue in 2006 (helicopter and boat); evacuations also occurred in 1996.	Pierce County
Channel Migration Problem Areas		
RM 7.0 – RM 7.9 RB	Channel migration during 2006 and 2009 events eroded right bank levee/revetment, exposing steep slopes and valley wall to erosion.	Pierce County
RM 6.0 – RM 8.0 LB	This segment highly susceptible to channel migration due to high sediment load affecting left bank levees and revetments.	Pierce County
RM 22.4 – RM 24.0 LB	Channel migration near entrance to Mt. Rainier National Park impacted county access road (Fairfax Forest Reserve Road); washouts in 2006 and 2008.	Mt. Rainier National Park; Pierce County Roads
Flooding of Structures and Infrastructure (Roads/Bridges)		
RM 0.0 – RM 0.5 RB	McCutcheon Road closures caused by Carbon River flooding near the mouth of Carbon River.	Pierce County Roads

Location	Problem Description	Source
RM 4.2 – RM 5.8 LB	SR 162 floods along Carbon River east of Orville Road.	WSDOT
Sediment and Gravel Bar Accumulation		
RM 0.0 – RM 3.0	Gravel deposition reduces channel conveyance capacity and threatens levee/revetments in this segment; Orting has identified 20+ gravel bars.	Pierce County, City of Orting
RM 3.0 – RM 5.9	Gravel accumulation reduces channel conveyance capacity and contributes to overbank flow in this segment (and exacerbate levee damages).	Pierce County
RM 5.9 – RM 8.4	This segment has high bluffs along right bank between RM 7.0 and RM 8.0 that contribute large sediment load to river.	Pierce County
RM 24 – RM 29	Gravel and debris accumulation increases risk of flooding and channel migration.	Public Input (Meeting #1)
Facility Maintenance and Repair Needs		
RM 6.4 LB	Revetment damage resulted in washout of 177th Street E. (Alward Road), exposing water main in 2008.	Pierce County
Fish Habitat Problem Areas		
RM 0.0 – RM 3.0 LB/RB	Levee/revetment construction cut off floodplain from river channel, preventing off-channel rearing and refuge for salmon and flood storage (Carbon confluence, right bank Carbon, High School, Bridge Street (sites 21, 22, 23, 24 in the Pierce County 2008 Levee Setback feasibility report).	Puyallup Tribe
RM 4.5 – RM 5.5 LB	Levee/revetment construction cut off floodplain from river channel, preventing off-channel rearing for salmon and flood storage (West setback – site 25 and Rauch Creek restoration potential).	Puyallup Tribe
RM 6.3 – RM 6.4 LB	Rocks displaced from levees block fish passage at Bradley Creek fish ladder near Alward Road.	Public Input (Meeting #1)
RM 6.4 – RM 8.3 LB	Existing levee constricts channel migration in a high energy segment of Carbon River and results in loss of side-channel habitat for Chinook, steelhead, and other salmon (Alward Road setback – site 26 in feasibility report).	Pierce County, Puyallup Tribe

Source: Pierce County SWM records.

LB = left bank; LF = linear feet; RB = right bank; RM = river mile.

6.9.11 River Reach Management Strategies

6.9.11.1 Conditions and Constraints of the Carbon River

- The recommended river reach management strategies take into account numerous conditions, summarized as follows:

- Development and land use in adjacent floodplain – The Carbon River floodplain has a relatively small portion that is urban along the east edge of Orting. Agricultural and low-density residential lands exist near the mouth, upstream of Orting, and along Alward Road.

- River risk reduction facilities – Both the left and right banks of the Carbon River are constrained by levees and revetments, with the exception of the right bank from RM 1.2 to RM 5.9 and RM 7.0 to RM 8.4 adjacent to steep valley walls.

- River channel gradient and width – Channel gradient varies from 0.46 to 0.60 percent between RM 0.0 to RM 3.9 and 0.6 to 1.15 percent between RM 3.9 and RM 8.4. The river channel width generally varies from 160 feet to 420 feet but is substantially wider at RM 3.5 and from RM 4.0 to RM 6.0, with the width varying from 540 feet to 890 feet.

- Presence of salmon spawning and rearing habitat – Species of salmon found in the Carbon River include Chinook, pink, coho, and chum as well as steelhead and bull trout. The highest concentration of spawning occurs from approximately RM 3.0 to RM 6.0.

- Sediment transport accumulation and incision – Mostly cobbles, gravel, and sand are present in the riverbed in the lower 8.4 miles of the Carbon River, with some boulders above RM 6.0. The average riverbed between the mouth (RM 0) and RM 3.2 changed in elevation from -2.9 feet to +0.3 feet between 1984 and 2009. From RM 5.6 to RM 6.0, the average bed elevation change is between -1.5 to +2.1 feet. Between RM 3.2 and RM 5.6, bed elevation changes are unknown. From observation by Pierce County personnel, the Carbon River segment between RM 6.0 and RM 8.4 appears to be in a cycle of substantial sediment aggradation.

In the near term, the primary objective for the Carbon River is to maintain the structural integrity of the levee and revetment system so the facilities continue to reduce risks to public health and safety and reduce damage to property and infrastructure. Another objective is to construct setback levees to further reduce flood risk . An additional management strategy objective is to realize capital projects that enhance and create aquatic habitat through levee or revetment setbacks, riparian re-vegetation, and strategic placement of large woody material in addition to providing flood protection.

6.9.11.2 Carbon River Reach Management Strategies

The recommended river reach management strategies for the lower Carbon River are described below:

Structural Management Strategies:

- RM 0.8 to RM 3.9 left bank – The goal for levees and flow conveyance should be the 100-year design in Orting.

- RM 0.0 to RM 0.8 left bank; RM 3.9 to RM 8.4 left bank; RM 0.0 to RM 1.2 right bank; and RM 5.9 to RM 7.0 right bank – The goal for levees should be to maintain the existing infrastructure.

Non-structural Management Strategies:

- Floodplain development regulation consistent with Pierce County critical area regulations for flood hazard areas should be administered by the City of Orting.
- Acquire repetitive loss properties, and enable capital project construction, or purchase, of development rights to prevent new floodplain development. A particular area of focus is the left bank from RM 6.0 to RM 8.4.
- Investigate new technologies to add a flow gauge lower in the Carbon River system. Proposed location near RM 3.06 along Bridge Street. Attach a potential gauge to the old bridge pier.

6.9.11.3 Interim Risk Reduction Measures.

- There are no IRRMs on the Carbon River reach.

6.9.12 Recommended Capital Projects

The following capital improvement projects are recommended to address the priority problem areas identified in Table 6.38.

Riverine Flood Project **Project Score: 55**

Project Name: Alward Road Floodplain Acquisition and Setback Levee

Project webpage location:
www.piercecountywa.gov/3578/177th-Street-EAlward-Road-Property-Acqui

Project location: Carbon River along 177th Street East, RM 6.4 to 8.4, left bank (see Figure 6.71)

Estimated project cost over a 10-year period: $20.2 million

Total project cost: $26.9 million

What is at risk?

The Carbon River transports significant amounts of sediment and woody material from Mount Rainier and the upper watershed river banks. During normal flows, this segment of the river is unable to transport the large quantities of material moving through the system. This causes the excess material to deposit within the channel. The excess material remains in place until flood events provide enough energy and velocity to suspend the material and move it downstream. As flows increase and water levels rise, excess gravel material reduces channel conveyance capacity, thereby contributing to flooding within this segment. Additionally, this segment of the river is within the mapped severe CMZ hazard area.

Repeated damages in this area from the November 2006 and January 2009 flood events has caused over $3.5 million in damages to the existing levee system and over $2 million in damages to adjacent private properties. During the same time frame, substantial damages of several private residences (see Figure 6.72) resulted in complete losses of structures. In November 2006, an emergency rescue of a family by helicopter was necessary.

What is the recommended solution?

Acquisition of approximately 20 properties located north of Alward Road is recommended. As of March 2021, Pierce County currently owns 61 parcels within this area. Existing flood protection facilities will be maintained as the acquisitions proceed. If a major flood severely damages these facilities, the county will assess the damage and decide how to proceed. In the future, a new setback levee approximately 9,800 lineal feet would be constructed along Alward Road, which would include removal of the existing levee. To increase roughness along the levee, 25 engineered log jams would be installed along the left and right bank of the river. These engineered log jams would provide protection against erosion, scour, and undercutting of the levee and river banks. A new fish passage culvert will need to be incorporated within the setback levee for the unnamed tributary that enters on the left bank at RM 7.4.

Who will Pierce County coordinate with on this project?

Pierce County will coordinate with the Puyallup Tribe, WDFW, USFWS, NMFS, USACE, and Puget Sound Clean Air Agency on this project.

Figure 6.71. Location of the Alward Road Floodplain Acquisition and Setback Levee Project

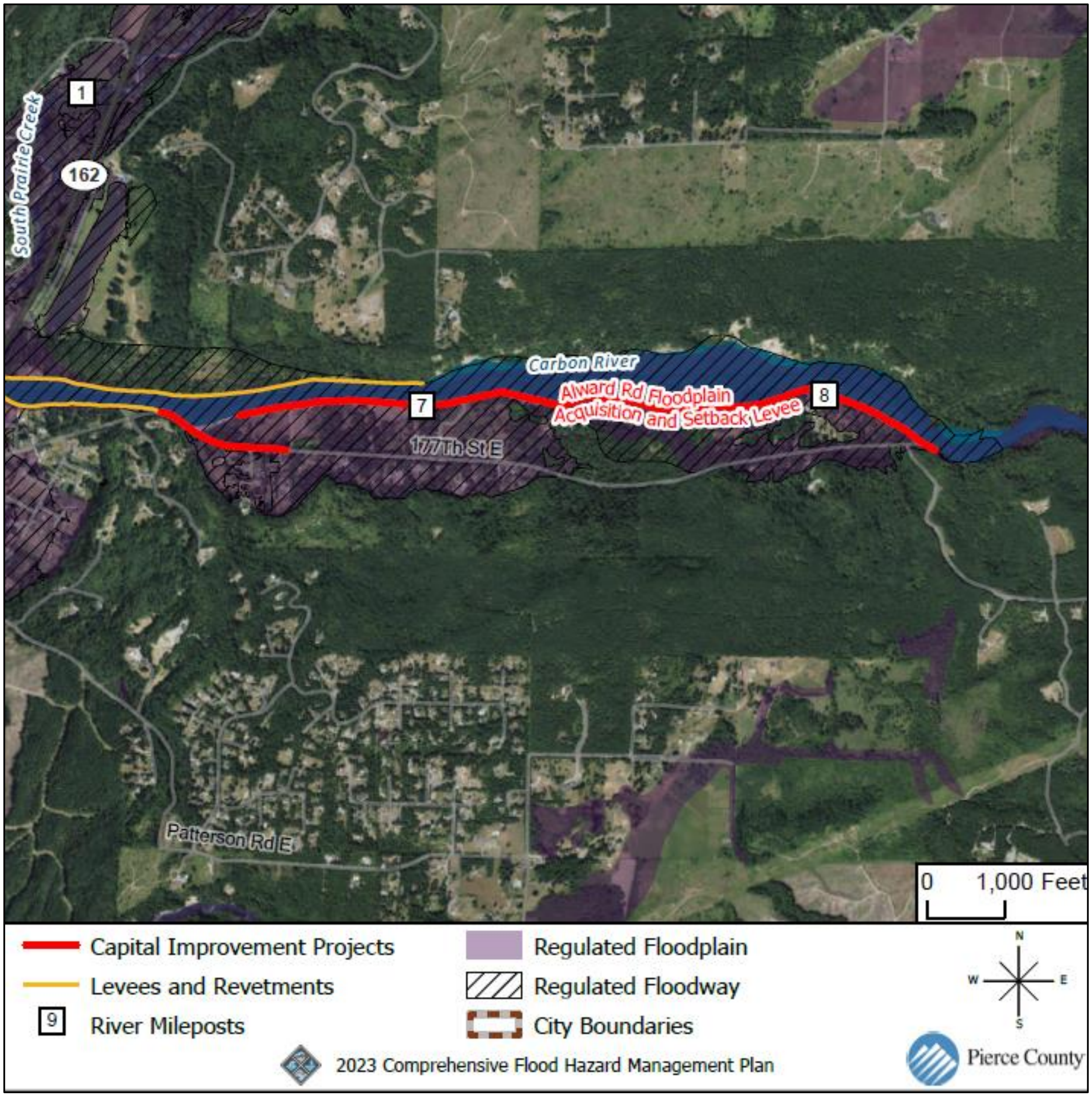


Figure 6.72. Carbon River Flooding of Residential Areas along Alward Road and 177th Street

What are the environmental considerations?

This project is located in an area used by ESA-listed Chinook salmon, bull trout, and winter steelhead. Coho salmon are also known to be present. Some spawning occurs in this segment. Coho salmon and cutthroat trout have been identified within the un-named stream that enters at RM 7.4 left bank.

What is the current status of the project?

A feasibility study is being conducted as well as the property acquisition phase.

What tasks will take place with this project from 2023–2033?

Property acquisition will continue as needed for the selected project alternative. Project scoping and preliminary engineering will also be conducted during this timeframe.

What are the Project Benefits/Drivers?

Habitat

Habitat Conservation Plan

Riverine Flood Project **Project Score: 49**

Project Name: Carbon River Setback Levee, left bank near Bridge Street to upstream of Voight Creek

Project webpage location: https://www.piercecountywa.gov/7931/Projects-in-Planning

Project location: Carbon River left bank, between RM 3.0 and 4.5 (see Figure 6.73)

Estimated project cost over a 10-year period: $17.5 million

Total project cost: $19.6 million

What is at risk?

In the 1990s, the Carbon River moved its channel from the right bank to the left bank between RM 3.6 and RM 4.2, which pushed the river up against the levee. During periods of high flows in the Carbon River (see Figure 6.74), Voight Creek, which enters the river at RM 3.98, and its tributary Coplar Creek are unable to discharge and therefore backwater behind the levee. Depending on the volume of water, the Voight and Coplar creek flows will split, with a portion continuing north into Orting and the remainder flowing under the Foothills Trail and flooding adjacent property. The existing levee currently does not provide a 100-year level of service.

What is the recommended solution?

The first phase will primarily focus on property acquisition from willing landowners. Depending upon property acquisition results and progress, a second phase would then focus on preliminary design for the downstream segment, between RM 3.0 and RM 3.9 (left bank side). A third phase would then focus on the remainder segment of the setback levee between RM 3.9 and RM 4.5. Major issues and challenges respective to trail relocation and agricultural impacts will need to be further addressed and resolved as part of the third phase, as well as property owner interest and willingness to sell their property.

Other Information

A second phase of the Carbon River Setback Levee Feasibility Study will also be performed concurrently with the first phase of the setback levee project. This study will focus on setback levee alternatives and opportunities for the Carbon River left bank side, essentially between Voight Creek and the SR 162 bridge (RM 4.4 and RM 5.8). This study may possibly identify greater options for potential opportunities for a setback levee feature in the upstream reach that could affect and influence a setback levee design and alignment along the south side of the Carbon River (Voight Creek area) in the current study area. A setback levee feature in the upstream reach may provide more options in the Voight Creek area that may not need to encumber as much land area as the current Alternatives 1 through 3 shown in the completed feasibility study. This could thereby allow for a setback alignment that is more conducive and compatible with existing improved property and land uses.

Figure 6.73. Location of the Carbon River Setback Levee Left Bank near Bridge Street to Upstream of Voight Creek

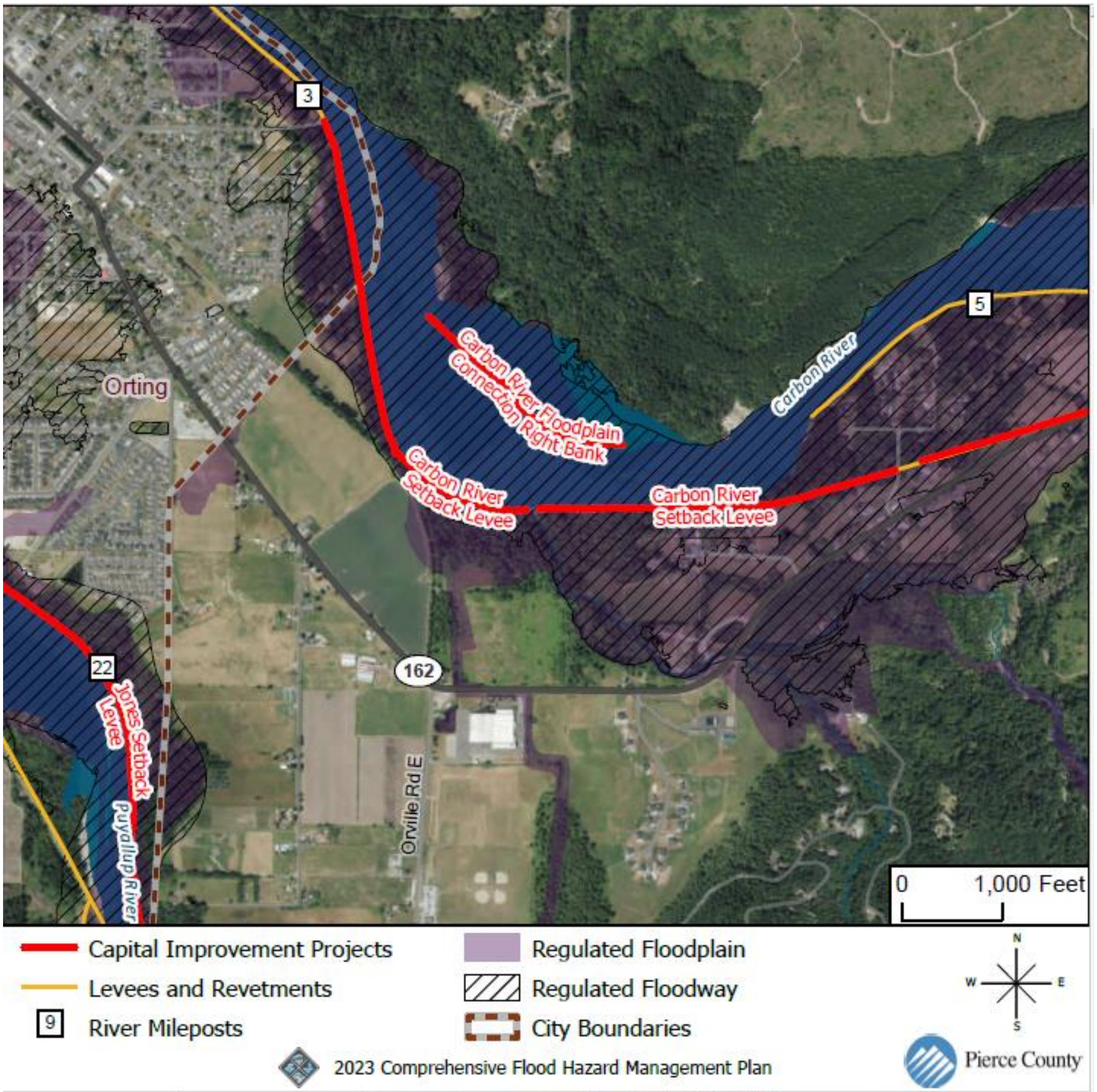


Figure 6.74. Aerial Photograph of the Carbon River at Flood Stage Upstream of Orting

Who will Pierce County coordinate with on this project?

Pierce County will coordinate with the Puyallup Tribe, City of Orting, WDFW, USFWS, NMFS, and USACE on this project.

What are the environmental considerations?

This project is located in an area used by ESA-listed Chinook salmon, bull trout, and winter steelhead. Chinook and winter steelhead spawn in this section of the river. Coho salmon are also known to be present.

What is the current status of the project?

The project is in the property acquisition phase. Acquisitions will occur as property owner interest and funding arise.

What will take place with this project from 2023–2033?

Listed below are tasks to be completed and initiated on the project between now and 2033.

- Property acquisition from willing sellers.
- Design of Phase 1 downstream segment of the setback levee feature, depending on property owner interest.
- Conduct second part of a setback levee feasibility study for the upstream reach of the Carbon River between Voight Creek and the SR 162 bridge.

- Continued outreach and collaboration with affected property owners for all phases of a setback levee project.
- Continued coordination and collaboration with the City of Orting to try and resolve trail relocation issues, concerns, and impacts.

What are the Project Benefits/Drivers?

Agriculture Flood Risk Habitat Water Quality

Riverine Flood Project **Project Score: 33**

Project Name: Carbon River Right Bank Floodplain Connection

Project webpage location:
www.piercecountywa.gov/7082/Carbon-River-Right-Bank-Floodplain-Conne

Project location: North side of Carbon River (right bank side) and north of SR 162 between RM 3.2 and RM 4.2 (see Figure 6.75)

Estimated project cost over a 10-year period: $3.4 million

Total project cost: $4.1 million

What is at risk?

Fish habitat (see Figure 6.76) and existing left bank Carbon River Levee are at risk; however, the project is not for flood reduction benefit-specific purposes. Also at risk is not achieving sufficient mitigation credit for levee maintenance and operations along rivers.

What is the recommended solution?

Construct and place at least six engineered log jams in the main stem close to the Carbon River active channel (three apex jams and three deflector jams). The size of these log jams will vary from large size apex jams (approximately 15 feet by 25 feet) to smaller size deflector jams (approximately 8 feet by 10 feet).

Who will Pierce County coordinate with on this project?

Pierce County will coordinate with the Puyallup Tribe, City of Orting, WDFW, USFWS, NMFS, and USACE on this project.

What are the environmental considerations?

This project site is located in an area used by ESA-listed Chinook salmon, bull trout, and winter steelhead. Chinook and winter steelhead spawn in this section of the river. Coho salmon are also known to be present.

Other considerations

This project is identified and listed as part of the draft Pierce County Habitat Conservation Plan (HCP) The project will provide fish habitat mitigation credits under the plan and is located in a reach of the Carbon River that is known to be of high quality habitat and productive for salmonid spawning use.

What is the current status of the project?

As of winter 2023, the 30 percent design plans were completed. The 60 percent and final design plans are pending along with permit application preparation and submittal. The 60 percent design plans are pending until resolution of the review comments respective to the draft Habitat

Conservation Plan; some comments apply to the Carbon River Right Bank Floodplain Connection project.

Figure 6.75. Location of the Carbon River Right Bank Floodplain Connection

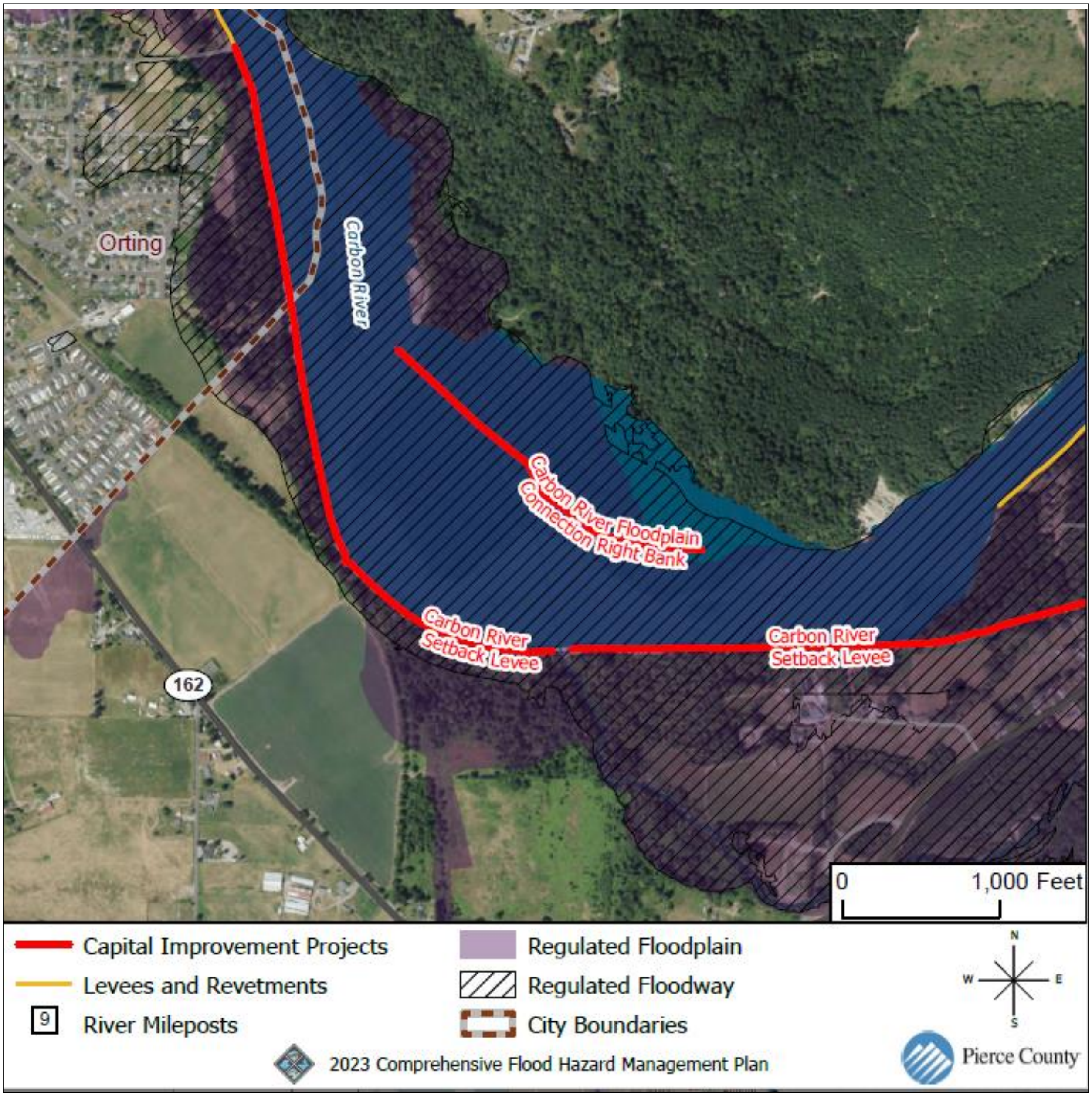


Figure 6.76. 2006 flooding on the Carbon River Left Bank, Water Nearly Overtopping with the Voight Creek Hatchery flooding in the distance.

Upon resolution, this project will proceed to 60 percent and final design phase and property/easement acquisition phase. Completion of permit applications and submittal will also follow upon completion of the 60 percent design plans.

What will take place with this project from 2023–2033?

During this timeframe, the 60 percent design will be completed to final design. Required environmental permits will also be obtained along with acquisition of the associated and needed easements and/or affected properties.

What are the Project Benefits/Drivers?

Habitat

Habitat Conservation Plan

Water Quality

Riverine Flood Project **Project Score: 45**

Project Name: Upper Carbon/Fairfax Road Bank Stabilization

Project webpage location: (to be provided at a later date)

Project location: End of road at Mount Rainier National Park boundary, RM 22.4 – RM 24.0 (see Figure 6.77)

Estimated project cost over a 10-year period: $4 million

Total project cost: $5 million

What is at risk?

Channel migration along the left bank of the Carbon River near the Carbon River entrance to Mount Rainier National Park is impacting the access road (see Figures 6.78 and 6.79), Fairfax Forest Reserve Road, and the park entrance. The park entrance road within the park boundary has been washed out three times, in 2006, 2008, and 2021.

What is the recommended solution?

To protect the two miles of Fairfax Forest Reserve Road, three engineered log jams with large rock and wood matrix would be installed along the left bank of the Carbon River. In addition, six engineered log jams would be installed at two locations, RM 23 and RM 23.7. Installation would stabilize the river bank and direct the river away from the bank.

Who will Pierce County coordinate with on this project?

Pierce County will coordinate on this project with the Puyallup Tribe, Mount Rainier National Park, WDFW, USFWS, NMFS, and USACE.

What are the environmental considerations?

This project is located in an area likely used by ESA-listed bull trout and winter steelhead.

What is the current status of the project?

This project is currently not an active project. Maintenance work may eliminate the need for this project.

What will take place with this project from 2023–2033?

The effectiveness of maintenance activity will be monitored. An additional feasibility analysis may be needed.

What are the Project Benefits/Drivers?

Flood Risk

Figure 6.77. Location of the Upper Carbon/Fairfax Road Bank Stabilization Project

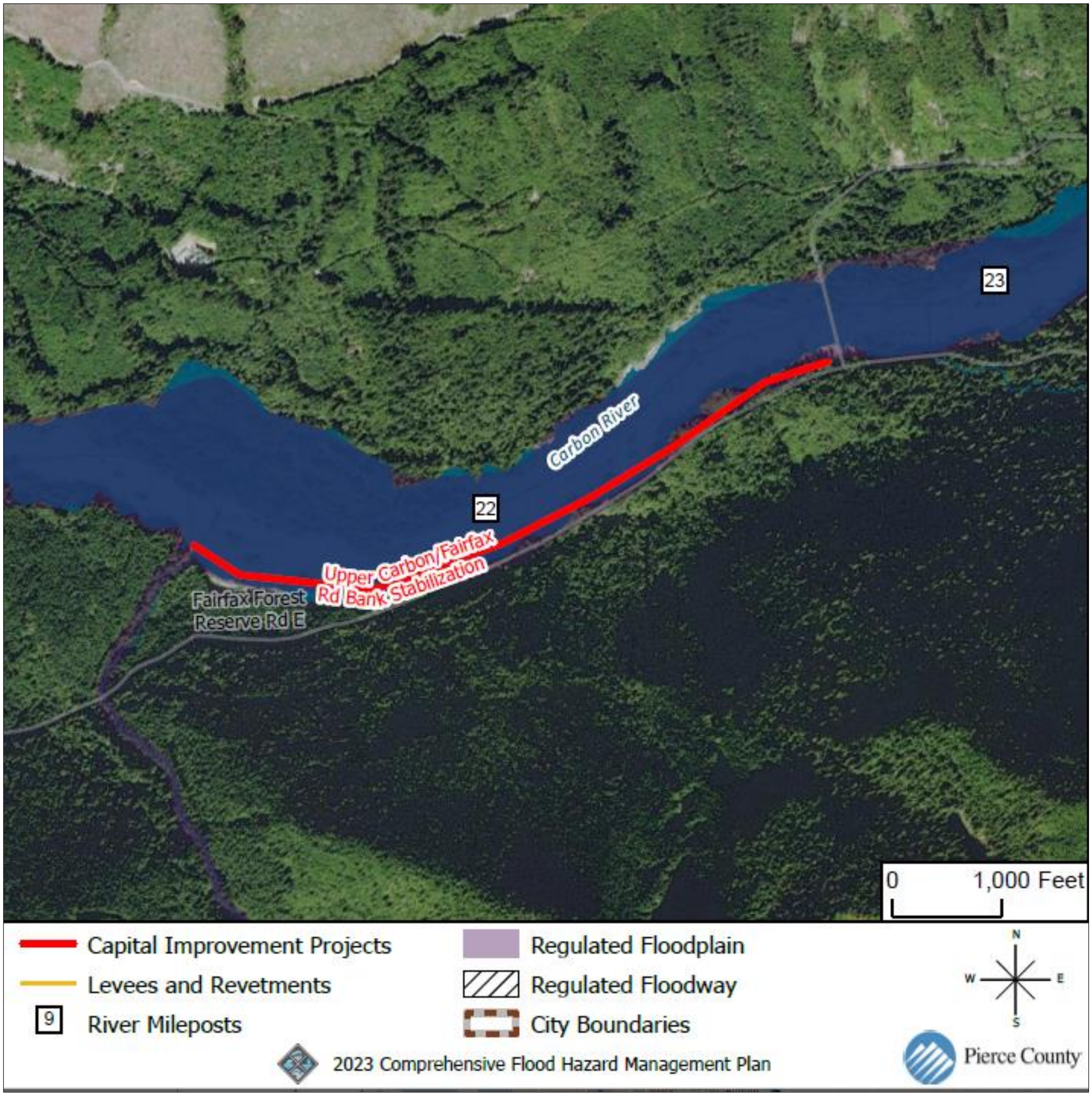


Figure 6.78. Looking Upstream at the Upper Carbon River Washout Area

Figure 6.79. Looking Downstream at Lower Carbon River Washout Area

Riverine Flood Project **Project Score: 37**

Project Name: Carbon River Left Bank Voight Creek to SR 162 to Bridge, RM 4.5 – RM 5.9 Feasibility Study

Project webpage location: www.piercecountywa.gov/6340/Carbon-River-Levee

Project location: Carbon River left bank side from Voight Creek (RM 4.5 to SR 162 bridge crossing (RM 5.9) (see Figure 6.80)

Estimated project cost over a 10-year period: $6 million

Total project cost: $25 million

What is at risk?

Flooding of Existing houses, SR 162, the existing levee structure, Voight Creek hatchery, and the Foothills Trail are at risk (see Figures 6.81 and 6.82).

What is the recommended solution?

Identify alternatives and select a preferred alternative for a setback levee feature within the study area. This includes property acquisition and removal of house structures from the floodplain and potential re-alignment of a portion of the Foothills Trail.

What is the current status of the project?

A feasibility study is in preliminary scoping. Preliminary scoping for a setback levee feasibility study is being conducted.

What will take place with this project from 2023–2033?

A setback levee feasibility study will be completed. Depending on feasibility study results, property acquisitions and possibly preliminary design (after completion of the feasibility study) will begin over time, followed by final design and permitting (depending on property acquisition progress).

What are the Project Benefits/Drivers?

Flood Risk

Habitat

Figure 6.80. Location of the Carbon River Left Bank Voight Creek to SR 162 Bridge Project

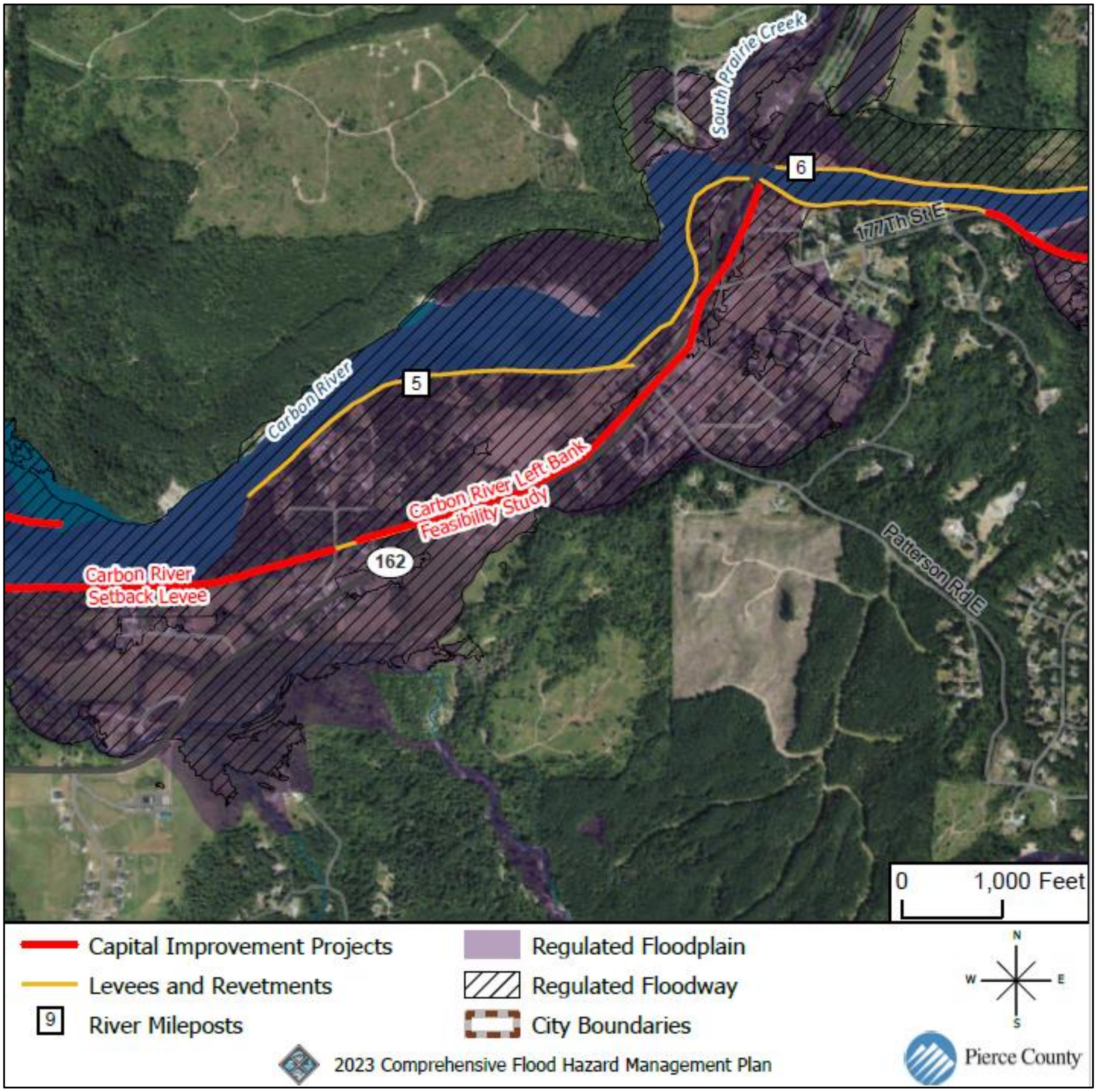


Figure 6.81. Right Bank of Carbon River near RM 5.1

Figure 6.82. Carbon River near RM 4.9.

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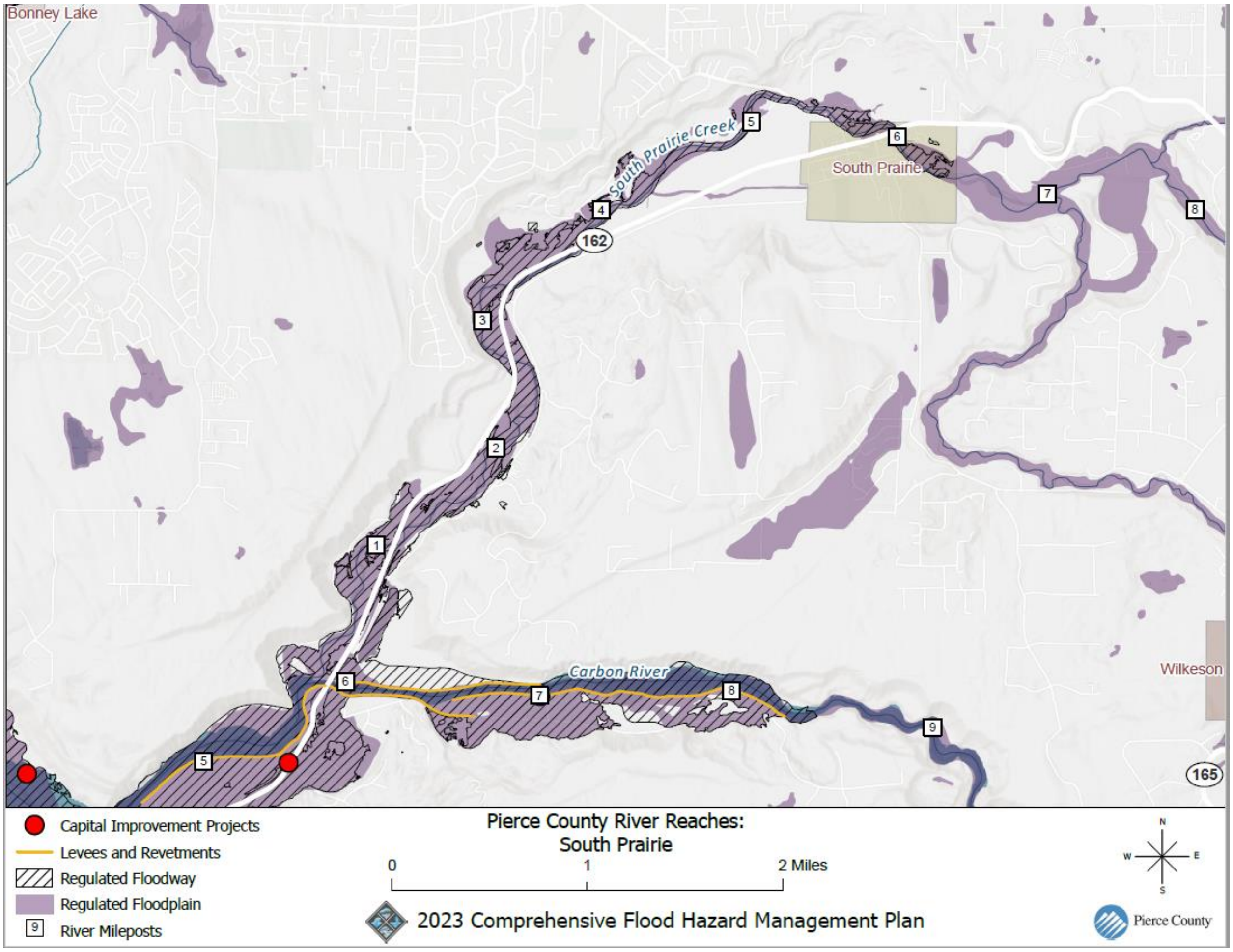
6.10 South Prairie Creek

6.10.1 Overview

South Prairie Creek lies within the center of the Puyallup River watershed, east of Orting, as shown in Figure 6.83. South Prairie Creek has a 90-square-mile drainage basin ranges from an elevation of 285 feet to the summit of Pitcher Mountain with an elevation of 5,933 feet (USGS 1998). The focus of this reach study area is the lower floodplain area of South Prairie Creek between RM 0.0 and RM 6.4 that extends from the confluence with the Carbon River (RM 5.8) to the upstream end of the town of South Prairie.

From 1950 to 2022, South Prairie Creek experienced seven flood events over 6,500 cfs. The largest peak flow was in 2009 at 9,480 cfs, and five of the top seven have occurred after since the current FEMA flood study was writen. Tributaries to South Prairie Creek include Wilkeson Creek, Spiketon Creek, and Beaver Creek. Land use consists of agricultural and rural residential, and South Prairie. There are no Pierce County levees along lower South Prairie Creek, but there are isolated rock riprap revetments and earthen berms that have been constructed by agricultural and residential landowners and near SR 162 bridge crossings of the creek. Salmon and trout, including fall Chinook, coho, pink, chum, and steelhead, use South Prairie Creek. Bull trout use South Prairie Creek for overwintering and foraging habitat. South Prairie Creek is one of the most productive salmon and steelhead tributaries in the entire Puyallup River watershed.

Figure 6.83. Planning Area for South Prairie Creek



6.10.2 Geology and Geomorphology

> **Alluvium**
>
> **is a general term for all deposits laid down by present-day rivers, especially during flooding.**

The subsurface geology in the South Prairie Creek reach study area consists mostly of sedimentary and volcanic rock. Surface geology consists primarily of unconsolidated Pleistocene glacial-drift deposits, known as Vashon Drift, with small areas of mudflow deposits (USGS 1998). About 5,600 years ago after volcanic eruptions on Mount Rainier, the Osceola mudflow flowed down the White River, and a sizable lobe flowed down the South Prairie Creek valley. Prior to this event, the White River flowed through a narrow gorge at the south end of Mud Mountain and occupied the present-day South Prairie Creek valley. The massive lahar diverted the White River into its historic course and created the much smaller South Prairie Creek watershed, a stream lacking the power to mobilize the large amount of alluvium on the valley floor deposited by the historical White River and the lahar. Much of the mudflow material remains exposed on the surface of the lower valley. The remainder has been eroded and replaced with recently deposited gravel and cobble alluvium in the stream channel and silt and sand in the adjacent floodplain (USGS 1998, Crandell 1963).

The South Prairie Creek valley is about 1,000 feet wide, with steep valley walls that range from 100 to 250 feet in height (GeoEngineers 2005). The presence of the Osceola mudflow and the abrupt decrease in basin size has had significant effects on the fluvial and geomorphic character of South Prairie Creek. Many segments of South Prairie Creek show evidence of incision and vertical channel migration, as demonstrated by riprap stranded high on channel banks and undercut root systems of riparian trees.

The average channel gradient varies from 0.27 to 0.46 percent between RM 0.0 and RM 3.5 and from 0.60 to 0.80 percent between RM 3.5 and RM 5.8. Channel migration in South Prairie Creek is limited by insufficient energy to mobilize the floodplain alluvium laid down from the historical White River and the Osceola mudflow. South Prairie Creek was not included in the 2010 USGS sediment transport study.

6.10.3 Hydrology and Hydraulics

The South Prairie Creek USGS Gauge Station (#12095000) has a 64-year record (1950 to 2022, with a gap from 1979-1987). The gauge measures 87 percent of the 90-square-mile basin area. Flood concerns and problems in recent years have involved flood damage to private property, including house structures and driveway access, as well as public utilities and roadway infrastructure. In addition, South Prairie Creek is incised along several segments.

The hydraulic model and Flood Insurance Mapping Study for South Prairie Creek was completed for FEMA in 2006 (NHC 2006). However, peak flows from 2006, 2009, 2020, 2021, and 2022 warrant further analysis to see how much the additional flows will affect flood flow frequencies. The NHC (2006) and SWM (2009) flood frequency flows are shown in Table 6.39 for the 10-, 50-, 100-, and 500-year floods.

Table 6.39. South Prairie Creek Flood Frequency Flows at USGS South Prairie Creek Gauge

	Discharge (cfs)				
Version	10-year	50-year	100-year	500-year	Method
South Prairie Creek at USGS gauge	5,030	6,640	7,330	8,950	1987 FEMA Flood Insurance Study (Log Pearson III fit of gauge data)
South Prairie Creek at USGS gauge	6,200	8,600	9,700	12,100	2009 FEMA Flood Insurance Study (and NHC 2006) (Log Pearson III fit of gauge data)
South Prairie Creek at USGS gauge with Updated Curve Fit with data through 2009[a]	6,350	9,100	10,250	13,000	Log Pearson III fit of gauge data based on SWM regression analysis with data through 2009

Source: FEMA (1987, 2009), Pierce County SWM and USGS records.

[a] SWM regression analysis (not official or formal published data).

6.10.4 Ecological Context and Salmonid Use

South Prairie Creek is the most productive tributary stream for salmonids in the Puyallup River watershed. Without the productivity of this stream, Chinook and steelhead populations in the Puyallup River watershed may not be sustainable. Chinook, coho, chum, and pink salmon and steelhead and cutthroat trout all spawn and rear in the study reach in significant numbers. Bull trout and sockeye salmon have also been documented using the stream.

The stream has a gentle gradient and abundant high-quality spawning gravel within the study reach. The reach also contains numerous deep pools, but large wood that adds quality habitat to the pools is sparse. Logging practices and the conversion of the flood plain to agriculture removed most of the wood from the stream. Prior to development, the stream was lined by a cedar, fir, and spruce forest. Small streams enter South Prairie Creek and often provide a corridor to excellent spring water rearing habitat at the base of the valley walls. Many of these small streams and wall-based channels have been ditched or drained to facilitate agriculture and residential development.

The South Silver Springs, which was constructed in 2010 by Pierce County SWM, provides excellent summer habitat for juvenile coho and cutthroat trout. Temperatures in this area are moderated due to cold water springs emanating from the base of the hill slope. Recent juvenile sampling and passive integrated transporter tagging as a part of a larger basin-wide study found large numbers of juvenile coho in South Silver Springs during the hottest part of the summer. There are few fish rearing in South Prairie Creek, likely due to high temperatures.

Local efforts are underway to preserve extensive portions of riparian and stream habitat in the study area, and significant land is currently in Pierce County and Pierce Conservation District ownership. Several salmon recovery grant-funded projects are currently underway to preserve and restore the stream and riparian area within this reach.

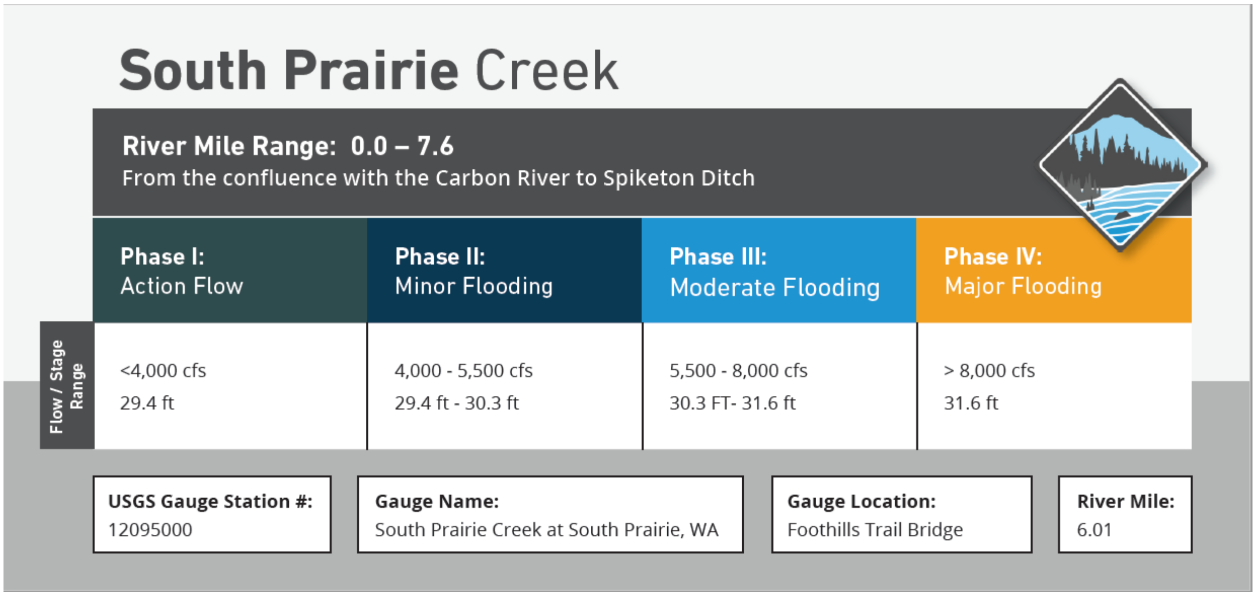
6.10.5 River Management Facilities, Flooding, and Flood Damage

No flood risk reduction facilities are owned and maintained by Pierce County SWM along South Prairie Creek. However, there are some riprap revetments and armoring maintained by WSDOT along SR 162 crossings and by Pierce County Roads along South Prairie Road East.

6.10.6 South Prairie Flow Warning Matrix

South Prairie Creek has four flow categories: Phase I, Action Flow; Phase II, Minor flooding; Phase III, Moderate flooding; and Phase IV, Severe flooding. These categories describe the observed or expected severity of the flood impacts in that area. However, the severity of flooding at a given stage is not necessarily the same at all river locations. Most river reaches in Pierce County have a defined flow warning matrix that is used during flood events. Figure 6.84 shows the flow warning matrix table for South Prairie Creek.

Figure 6.84. South Prairie Creek Flow Warning Matrix



Historical Flooding

Major flood events in South Prairie Creek have damaged infrastructure as well as residential, agricultural, and recreational properties. In most large floods, there is widespread flooding of roads, residential, and agricultural properties as well as damage at the Veteran of Foreign Wars campground. In January 2009, the Town of South Prairie Fire Station was flooded and sustained $36,000 in damage. State Route 162 and other local roads have been regularly closed during flooding due to water and debris over the roadway. This can limit access to SR 165 or Mundy Loss Road toward Buckley.

Major flooding occurred in South Prairie Creek in 1955, 1996, 2006, 2009, 2020, 2021, and 2022 (see Table 6.40). The January 2009 flood is the largest on record, with a measured flow of 9,480 cfs, which exceeded the 100-year flood flow of 9,700 cfs estimated by FEMA (FEMA / NHC 2006). Since the 2013 Flood Plan was adopted, there have been three additional major flooding events in this reach.

Table 6.40. Historical Major Flooding on South Prairie Creek

Date	South Prairie Creek Flows at South Prairie Gauge (cfs)
December 1955	6,850
February 1996	8,170
November 2006	6,540
January 2009	9,480
February 2020	6,710
November 2021	6,770
January 2022	7,330

Flood Damage to Facilities

WSDOT reported scour of bridge piers and large woody material buildup on bridges as problems on several bridges crossing South Prairie Creek. Water and debris on roadways is a common problem for Pierce County roads, but damage to roadways is not widespread. Typically, some repair and maintenance of toe and facing rock follows large flood events. In 1996, South Prairie Creek jumped the right bank and washed-out South Prairie Road near 246th Avenue East and did the same farther downstream at Spring Site Road. Road reconstruction, bank stabilization, and an armored overflow flood re-entry channel repaired the flood damage. In 2020, the same event occurred just upstream of the 1996 event, and repair work was required to rebuild the road embankment and stabilize the channel. In 2022, South Prairie Creek's Wastewater Treatment Plant outfall was threatened due to channel migration along the creek, as seen in Figure 6.85.

Figure 6.85. Bank Erosion Impacting South Prairie Wastewater Treatment Plant Outfall, 2022

6.10.7 Key Accomplishments since the 2018 Flood Plan Update

Major Projects

Since the 2018 Flood Plan Update was completed, Pierce County has carried out an annual program that includes maintenance and repair of facilities. Specific capital projects are described below.

In early 2021, Floodplains for the Future supported the formation of the South Prairie Creek Implementation team, a partnership focused on coordinating efforts and increasing collaboration for fish habitat improvement projects, acquisitions for flood risk reduction, and supporting agricultural viability in South Prairie Creek. Projects have been ongoing in this reach for many years, and the Implementation Team streamlines communication, increases collaboration and partnership, and creates an efficient model for the continued advancement of partnership project implementation. Regular participants are Pierce County SWM, Pierce County Parks, Pierce County Agricultural Resources, South Puget Sound Salmon Enhancement Group, Pierce Conservation District, Puyallup Tribe Fisheries, and Forterra. Additional information on this project can be found online at South Prairie Creek: Bringing Fish Home and Planning for More – Floodplains for the Future.

In late 2021, Pierce County met with representatives and residents from the town of South Prairie to develop a pathway to address flooding problems within the town. Pierce County recognized that the town was understaffed and needed additional support to develop a pathway for inclusion within the 2023 Flood Plan. Over the course of three workshops, the participants identified flooding problems within the community, potential solutions to those problems, and a complex pathway to identify near- and long-term actions for implementing the solutions. Participants included town council members, the town mayor, planning staff, fire and rescue, and residents affected by flooding. The final draft pathway is included in Appendix E

6.10.8 Land Acquisitions

In 2021, the Pierce Conservation District acquired the 73-acre Soler Farm just outside the town limits of South Prairie. This property acquisition was done in partnership with the Pierce County Flood Control Zone District, the Puyallup Tribe Fisheries Department, South Puget Sound Salmon Enhancement Group, Forterra, and Pierce County SWM.

6.10.9 Flood and Channel Migration Hazard Mapping

Flood Hazard Mapping

Hazard mapping along South Prairie Creek includes detailed flood studies (FEMA 2009, NHC 2006) that was incorporated into the DFIRMs (FEMA 2017). Flood-prone areas along South Prairie Creek include rural residential, agricultural, and recreational land, and limited areas in South Prairie. The DFIRMs for South Prairie Creek within the study area show 469 acres within the special flood hazard area, or 100-year floodplain. The mapped DFF area is 247 acres.

Channel Migration Hazard Mapping

Channel migration in South Prairie Creek is naturally limited by the coarse substrate of boulders and large cobbles deposited by the ancestral White River and the Osceola mudflow. The creek has carved out a channel into the mudflow depositions but is essentially entrenched within these deposits in many locations (GeoEngineers 2005). Only during large floods in 1964 and 1996 have there been significant channel adjustments and erosion. Channel migration has been further limited or stopped altogether by bank revetments.

Severe, moderate, and low channel migration potential areas were delineated for South Prairie Creek (GeoEngineers 2005). The severe CMZ covers an area of 183 acres along South Prairie Creek. Pierce County regulates severe CMZ mapped areas as floodway in accordance with Pierce County Code Chapter 18E and adopted the South Prairie Creek CMZ in 2017.

6.10.10 Problem Identification

Table 6.41 includes the flooding and channel migration problems identified in the South Prairie Creek floodplain.

Table 6.41. Priority Problems Identified in South Prairie Creek

Location	Problem Description	Source
Bank and Revetment Overtopping and Breaching		
RM 0.0 – RM 1.24 LB/RB	Overtopping and severe flooding; SR 162 flooded in 2006 and several homes cut off from highway.	Pierce County
RM 2.0 – RM 2.4 LB/RB	Flooding between SR 162 and South Prairie Carbon River Road (homes and properties); flooded near wood pallet business (2006, 2008); bank overtopping near RM 2.0 and RM 2.4.	Pierce County
RM 2.8 – RM 3.8 LB	SR 162 (between Spring Site Road and Kaperak Road) in 2006, 2009; bank overtopping near RM 2.8; overtopping of Kaperak Road in 2008, 2009.	Pierce County
RM 4.9 LB/RB	Both banks overtopped with property and homes flooded (2006).	Pierce County
RM 5.6 RB	S. Prairie flooded near 246th Avenue E., several properties affected, 2006.	Pierce County
Public Safety/Emergency Rescue		
RM 3.5 – RM 3.5 RB	Several homes evacuated by boat during 2006 flood in vicinity of Kaperak Road and SR 162; one evacuation in 2008.	Pierce County Sheriffs
Channel Migration Problem Areas		
RM 0.4 – RM 0.6 RB	Channel migration threatens private road and access to 3–5 homes.	Pierce County
RM 3.7 – RM 3.7 LB	Channel migration threatens SR 162 at Spring Site Road.	Pierce County
Flooding of Structures and Infrastructure (Roads/Bridges) [not already noted above]		
RM 0.0 – RM 3.8 LB/RB	SR 162 floods in numerous locations forcing closure of road from Carbon River bridge to Soler Farm or South Prairie; three bridges between RM 2.7 and 3.8 are a problem from LWM buildup on piers (#162/016, 017, and 018).	WSDOT
RM 0 – RM 6.2 LB/RB	Flooding damaged multipurpose trail along S. Prairie Creek, repair needed.	South Prairie Creek Advisory Committee member

Location	Problem Description	Source
RM 1.7 – RM 2.5 LB	South Prairie Carbon River Road E., flooding water over roadway and sediment deposits resulted in closure from SR 162 to 157th Street E.	Pierce County Roads
Flooding of Structures and Infrastructure (Roads/Bridges) [not already noted above] (continued)		
RM 3.3 – RM 3.4 RB	Kaperak Road E. – during flood events, creek overtops flooding road and causing infrastructure damage – off SR 162.	Pierce County Roads
RM 3.7 – RM 3.7 RB	Spring Site Road – during flood events, creek overtops flooding road and causing infrastructure damage 100 feet north of SR 162.	Pierce County Roads
RM 5.4 – RM 5.9 RB	South Prairie Road E. – during flood events, creek overtops flooding road and causing infrastructure damage – from 246th Avenue Court E. to SR 162.	Pierce County Roads
RM 5.4 LB	Outfall from Town of South Prairie WWTP has been covered in sediment from large floods and most recently damaged by channel migration.	Town of South Prairie
RM 6.0 LB	Town of South Prairie Fire Station floods when creek overtops bank upstream of SR 162 crossing; station also used for Emergency Management ($36,000 damage in 2009).	Town of South Prairie
Fish Habitat Problem Areas		
RM 0.0 – RM 0.4 LB/RB	Development at mouth of South Prairie Creek and Carbon River has impacted productive salmonid area at mouth of creek.	Puyallup Tribe
Public Access		
RM 6.0 LB	Lack of access to creek near South Prairie trailhead.	Pierce County Parks

Sources: Pierce County Surface Water Management records.

LB = left bank: LWM = large woody material; RB = right bank; RM = river mile.

6.10.11 River Reach Management Strategies

6.10.11.1 Conditions and Constraints of South Prairie Creek

The recommended river reach management strategies for South Prairie Creek take into account numerous conditions summarized below:

- Development and land use in adjacent floodplain – The South Prairie Creek floodplain is primarily rural and includes both low-density residential and agricultural land uses, and the Town of South Prairie upstream of RM 5.6. SR 162 is adjacent to the creek along the lower four miles.
- River management facilities – Revetments along short stretches of roads and near bridges is the extent of public river management facilities along the creek. Private revetments exist along the creek but are not maintained by the county.

- River channel gradient and width – Channel gradient varies from 0.27 to 0.46 percent between RM 0.0 to RM 3.5 and from 0.60 to 0.80 percent between RM 3.5 and RM 5.8. The river channel width generally varies from approximately 40 feet to 160 feet.
- Presence of salmon spawning and rearing habitat – Chinook, coho, chum, and pink salmon and steelhead and cutthroat trout all spawn and rear in South Prairie Creek.
- Sediment transport accumulation and incision – Streambed sediment is composed of sand, gravel, cobble, and some boulders (GeoEngineers 2005). Little information is available about sediment transport conditions in South Prairie Creek, though some segments are incising. The creek was not included in the 2010 USGS sediment transport study.

The primary objective for South Prairie Creek is to protect the public infrastructure (roads, bridges, and public trail system). Another objective is to improve aquatic habitat through riparian revegetation, and strategic placement of large woody material.

6.10.11.2 South Prairie Creek Management Strategies

The recommended river reach management strategies for South Prairie Creek are listed below:

Structural Management Strategies:

- The level of erosion protection for revetments should be the channel migration resistance design in areas near bridges and where the creek is adjacent to public roads.

Non-structural Management Strategies:

- Floodplain development regulations should be implemented by the Town of South Prairie consistent with Pierce County critical area regulations for flood hazard areas.
- Property acquisition or purchase of development rights should be considered on a case-by-case basis to remove the most flood-prone structures and people out of the most hazardous areas. Encourage the property owners within the flood hazard area to purchase flood insurance.
- Create side channels and riparian wetlands to store flood water.
- South Prairie Creek implementation team is actively scoping projects and building projects.

6.10.11.3 Interim Risk Reduction Measures

- There are no IRRMs on this South Creek Prairie reach.

6.10.12 Recommended Capital Projects

There are no capital projects proposed for South Prairie Creek.

6.11 Middle Nisqually River – McKenna Area

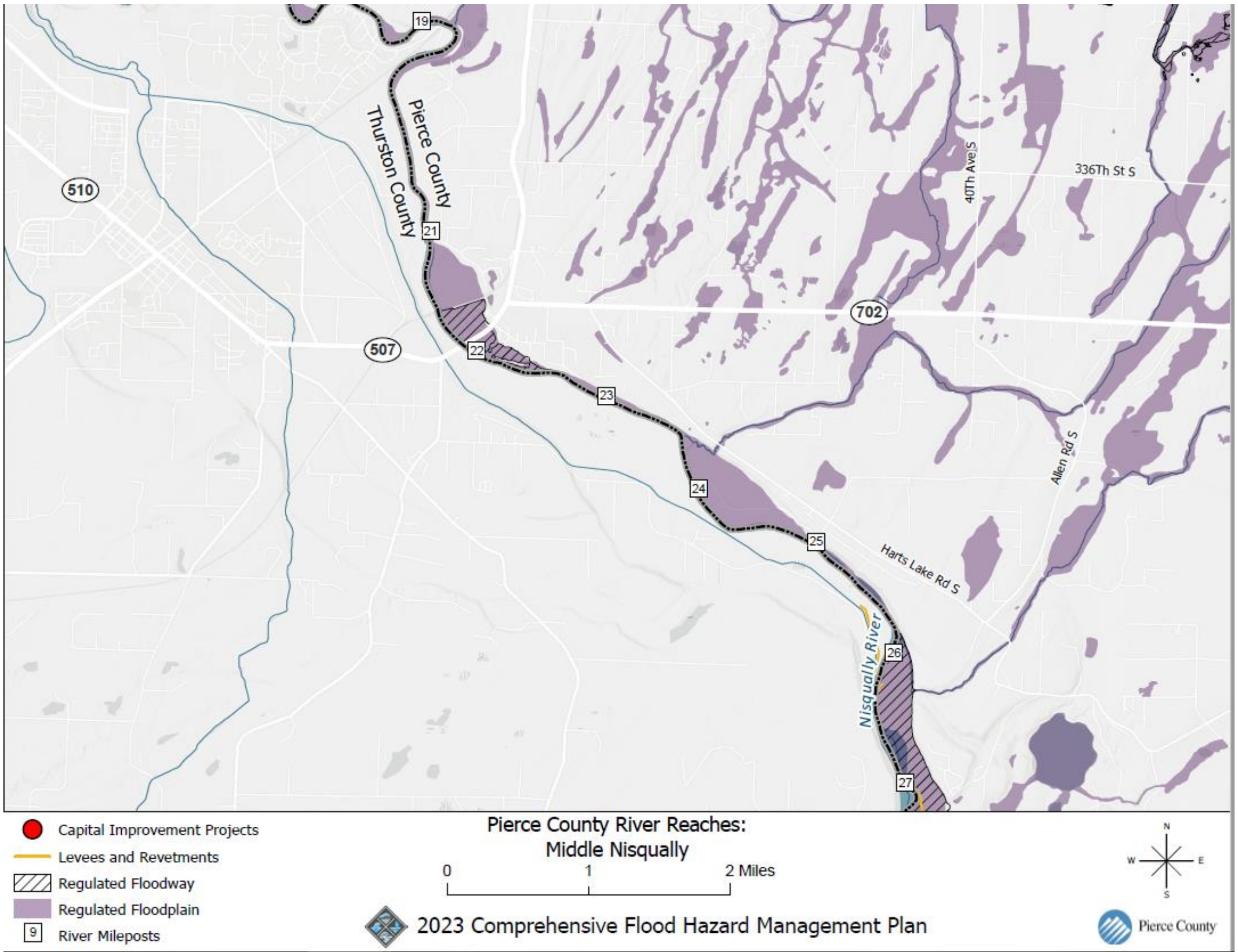
6.11.1 Overview

The middle Nisqually River drains a watershed of approximately 760 square miles. The river originates from the Nisqually Glacier on the south slope of Mount Rainier and flows 78 miles to the estuary at the Nisqually National Wildlife Refuge before flowing into Puget Sound. Nearly 58 percent of the Nisqually River watershed lies in Pierce County, with the remainder in Thurston County (as shown in Figure 6.86) (about 16 percent) and Lewis County (about 26 percent).

The drainage area to the USGS gauge on the Nisqually River at McKenna is 517 square miles. The middle Nisqually River at McKenna forms the boundary between Pierce County and Thurston County. Flood risk on this reach is predominately in Thurston and Lewis counties, as most of the Pierce County area is on high bank of the river. The focus of this reach is from approximately RM 21.0 to RM 26.0, where the 100-year floodplain is up to 2,900 feet wide, and where substantial flooding occurred in the McKenna area during the February 1996 flood event.

Land use in the McKenna vicinity consists of medium-density residential, rural residential, and agriculture and pasture lands. There are also extensive lakes and wetlands in the surrounding area. Salmonid use in this reach of the Nisqually River includes fall Chinook, coho, chum, and pink salmon and winter steelhead trout.

Figure 6.86. Planning Area for the Middle Nisqually River



6.11.2 Geology and Geomorphology

The broad valley in this section of the river historically accommodated a wide channel migration zone. As described in the 2014 Nisqually Basin Plan, In the lower half of this reach where the valley is over 2,000 feet wide on average, several remnant historical channels are still visible throughout the historical CMZ (Pierce County 2013). The channel is currently confined and channel migration is limited due to flood-control modifications, mostly on the left bank of the river in Thurston County. The bank protection and levees have mostly been constructed by various private landowners. No CMZ has been mapped for this area. The gradient of the river channel in this reach is 0.1 to 0.2 percent.

6.11.3 Hydrology and Hydraulics

There are two dams on the Nisqually River: La Grande Dam at RM 41.19 and Alder Dam at RM 42.86, which forms the 3,000-acre Alder Lake. The two dams are part of the Nisqually hydroelectric project owned and operated by Tacoma Power, which is part of Tacoma Public Utilities. According to Tacoma Power, the dams provide incidental attenuation of floods, but their

Federal Energy Regulatory Commission operating agreement and license has no flood control requirements (Pierce County 2014).

Table 6.42 shows the latest hydrology report findings included in the 2023 FEMA project map revision for the Nisqually River. The one percent discharge (also known as the 100-year flood) is a statistical calculation that has a range of possible outcomes. According to FEMA procedures, the Flood Insurance Study shows the most likely outcome and new FEMA products are showing a fuller range of possible outcomes. For instance, in the new Nisqually FIS, the "1-Percent Plus Annual Chance" shows a discharge of 85,500 cfs, whereas the published "1-Percent Annual Chance" discharge is 56,700 cfs. The extent of the floodplain is modeled to the 56,700 cfs discharge (68 percent confidence), but if the higher 85,500 cfs flood were to occur, it would still be within the 84 percent confidence of the 1-percent annual chance flood (Strategic Alliance for Risk Reduction [STARR]II 2019).

Table 6.42. Middle Nisqually River Flood Frequency Flows

	Discharge (cfs)				
Location	10-year	50-year	100-year	500-year	Method
Nisqually River at mouth	12,900	16,600	22,500	30,000	1987 FEMA Flood Insurance Study (Log Pearson III fit of gauge data). 2023 FEMA Flood Insurance Study
Nisqually River (near McKenna)	29.900	38,300	52,100	70,500	2009 SWM Estimate at USGS gauge at McKenna. 2023 FEMA Flood Insurance Study

6.11.4 Ecological Context and Salmonid Use

The middle Nisqually River of the study area flows downstream from the Centralia diversion dam at RM 26.2 through McKenna and under the Tacoma Rail and SR 507 bridges to RM 21.3.

Historically, this section of the river was in a broad valley of low gradient (0.1 to 0.2 percent), which allowed wide channel migration. Several remnant historical channels are still evident from the air. Currently the channel is confined, and channel migration is limited due to areas of old flood control levees and revetments, including several apparently installed by private landowners.

This reach serves as a migration corridor for all species of salmon in the Nisqually River and provides spawning habitat for chum, coho, pink, and Chinook salmon and steelhead. There is abundant spawning gravel just downstream of the Centralia diversion dam. Farther downstream, the habitat is characterized by deep pools, boulders, and pockets of spawning gravel. Riparian habitat varies considerably, with long forested stretches of medium-sized hardwood stands. Bank development and forest removal for agriculture, especially on the left bank, limits large woody material recruitment opportunities, as does the diversion dam at the upstream end of the reach. The Nisqually Indian Tribe (Nisqually Tribe) conducts steelhead redds surveys in this reach, and WDFW uses it as an index reach for Chinook spawning.

6.11.5 River Management Facilities, Flooding, and Flood Damage

There is no known flood risk reduction facility infrastructure, past or present, owned or maintained by the Pierce County SWM. WSDOT has limited armoring along the SR 507 bridge crossing. The extent of armoring along the Thurston County (left bank) side of the river is not well known. Centralia Power owns and maintains four levee segments. Table 6.43 lists the known levees in this reach.

Table 6.43. Levees in the Middle Nisqually River

Name	Location	Ownership
Centralia Power Levee, LB	RM 25.55 – RM 26.30	Centralia Power
Centralia Power Levee, RB	RM 26.25 – RM 26.30	Centralia Power
Mid-Nisqually Levee, RB	RM 27.01 – RM 27.37	Centralia Power
Mid-Nisqually Levee, RB	RM 27.67 – RM 28.12	Centralia Power

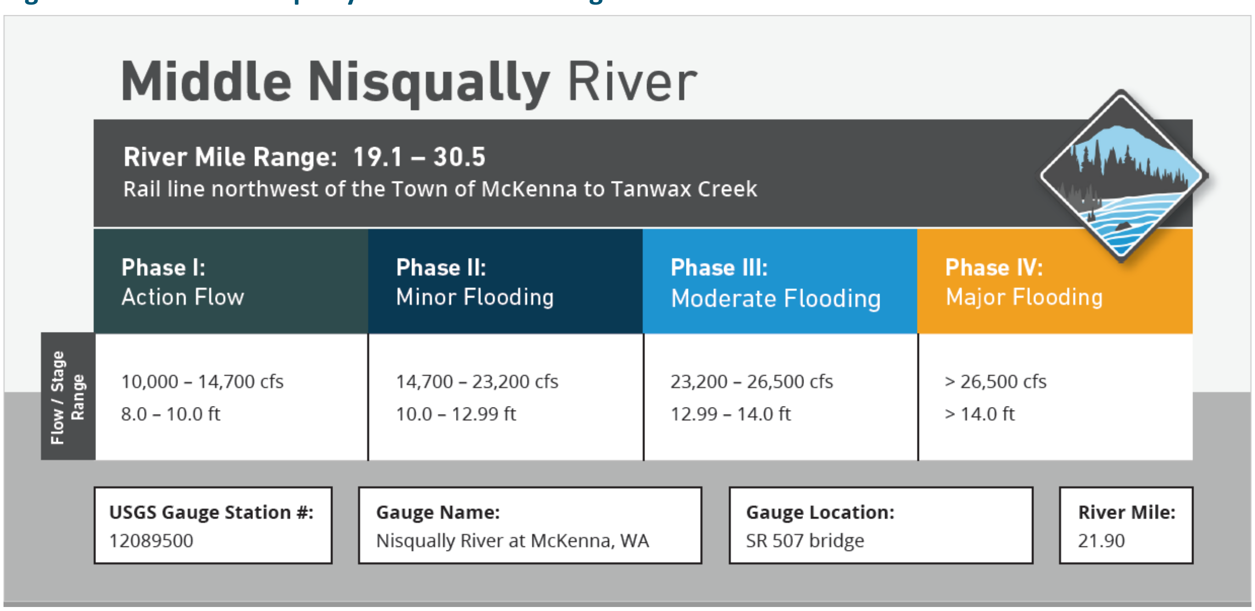
Source: Pierce County SWM records.

LB = left bank: RB = right bank; RM = river mile.

6.11.6 Middle Nisqually River Flow Warning Matrix

The middle Nisqually River has four flow categories: Phase I, Action Flow; Phase II, Minor flooding; Phase III, Moderate flooding; and Phase IV, Severe flooding. These categories describe the observed or expected severity of the flood impacts in that area. However, the severity of flooding at a given stage is not necessarily the same at all river locations. Most river reaches in Pierce County have a defined flow warning matrix that is used during flood events. Figure 6.87 shows the flow warning matrix table for middle Nisqually River.

Figure 6.87. Middle Nisqually River Flow Warning Matrix



Historical Flooding

Since 1996, there has been no known significant flooding that caused structural damage along this reach in Pierce County. Since construction of the Alder Dam in 1948, peak flow events exceeding 20,000 cfs have occurred five times. Since 1996, the highest flow recorded at McKenna is 20,800 cfs.

Flood Damage to Facilities

The 1996 flood eroded out the SR 507 bridge approach on the Pierce County side (right bank), resulting in a 2-day closure of the road and bridge. There is also ongoing scour and accumulation of large woody material on the bridge piers during high flow events. The bridge is on WSDOT's Scour Critical List for shallow spread footings, and it is monitored during all high-water events. Flooding in 1996 resulted in extensive flooding of homes and roads in the McKenna area, as well as a clean and sober facility called Fresh Start, located on the right bank downstream of SR 507, as shown in Figure 6.88.

Figure 6.88. SR 507 Bridge and Fresh Start Facility

6.11.7 Key Accomplishments since the 2018 Flood Plan Update

Since the 2018 Flood Plan Update was completed, Pierce County has carried out an annual program that includes maintenance and repair of facilities.

6.11.8 Land Acquisitions

There were no property acquisitions along the middle Nisqually River from 2018 to 2021.

6.11.9 Flood and Channel Migration Hazard Mapping

Flood Hazard Mapping

Flood hazard mapping in the middle Nisqually River was stripped of detailed flood information that was proven to understate flood risk after the 1996 flood. Many of the destroyed properties purchased after 1996 flood were shown to be outside the SFHA. A new flood study, in collaboration with multiple watershed partners, was started in 2011 and resumed with new funding in 2017. The new study, funded under RiskMAP, will provide base flood elevation and floodway assessments. Completion of this project is expected in 2023. Due to low density in this reach, flood-prone areas are limited to sparse residential areas outside of McKenna and some commercial buildings and agricultural uses. The DFIRMs for the middle Nisqually River show 886 acres within the special flood hazard area, or 100-year floodplain. The DFF areas will have to be updated after the FEMA mapping is finalized for this reach.

For additional information regarding the Nisqually River, visit FEMA Maps | Pierce County, WA - Official Website (piercecountywa.gov).

Channel Migration Hazard Mapping

Severe, moderate, and low CMZ are not planned to be mapped for the middle Nisqually River. The middle reach that is regulated by the dams has limited risk of migration damage to structures. The Nisqually River is listed in Title 18E.20 of the PCC as a river to be mapped for CMZ, and the upper portion above the dams where it runs naturally have been mapped.

6.11.10 Problem Identification

Table 6.44 includes the flooding and channel migration problems identified in the middle Nisqually River floodplain.

Table 6.44. Flood and Channel Migration Problems Identified in Middle Nisqually River

Location	Problem Description	Source
Public Safety/Emergency Rescue		
RM 21.6 – RM 21.9 RB	Flooding of McKenna in 1996 flood in vicinity of 356th/357th and 95th/96th resulted in emergency evacuations.	Pierce County
Flooding of Structures and Infrastructure (Roads/Bridges) [not already noted above]		
RM 21.6 – RM 21.9 RB	Flooding of local roads in McKenna area in mapped 100-year floodplain downstream of SR 507 on right bank in 1996.	Pierce County Roads
RM 21.6 – RM 21.9 RB	Flooding of McKenna in 1996 flood caused inundation of portions of 80 parcels and damaged numerous structures.	Pierce County (Nisqually River Basin Plan)

Location	Problem Description	Source
RM 21.9 RB	SR 507 – the 1996 flood eroded road and approach to bridge on Pierce County side resulting in 2-day road closure; as well as ongoing scour and LWM accumulation on bridge (#507/128).	WSDOT
Fish Habitat Problem Areas		
RM 23.5 – RM 24.5 RB	Large wetland complex near mouth of Brighton Creek appears to be an oxbow or remnant side channel of the mainstem Nisqually River. This river reach is the most impaired reach on the mainstem and suffers from a loss of channel complexity, LWM. and channel migration.	Pierce County, Nisqually Tribe
RM 26.3 –RM 26.5 RB	Due to floodplain restrictions by large channel-redirecting riprap levees, there is a lack of side-channels and off-channel wetlands and degraded fish habitat.	Nisqually Basin Plan (CIP11-NIS-RST01)
RM 28.0 – RM 29.5 RB	Floodplain and riparian habitat along this reach were degraded due to forest clearing, road building, and colonization by invasive species. (Now owned by Nisqually Land Trust.)	Nisqually Basin Plan (CIP11-NIS-RST02)

Source: Pierce County SWM records.

LWM = large woody material; RB = right bank; RM = river mile.

6.11.11 River Reach Management Strategies

6.11.11.1 Conditions and Constraints of the Middle Nisqually

In conjunction with updated flood hazard mapping, the recommended river reach management strategies for the middle Nisqually River take into account numerous conditions summarized below:

- Development and land use in adjacent floodplain – The middle Nisqually River floodplain consists of medium-density residential, within McKenna; rural residential; agricultural; and pasture lands.
- River management facilities – There is limited armoring along the right bank in Pierce County, mostly in the vicinity of the SR 507 bridge.
- River channel gradient and width – Channel gradient varies from 0.1 to 0.2 percent between RM 21.3 to RM 26.0. The river channel width generally varies from 100 feet to 220 feet.
- Presence of salmon spawning and rearing habitat – Species of salmon found in the middle Nisqually River include Chinook, pink, coho, and chum salmon as well as steelhead trout.
- Sediment transport accumulation and incision – The riverbed sediment is predominantly boulder and cobble, with some gravel riffles and some patch gravel strips (WRIA 11, WDFW 1977). Downstream gravel transport is greatly limited due to Alder Dam and the Centralia diversion dam.

The primary objective for the middle Nisqually River is to maintain the structural integrity of the armoring that protects public infrastructure, including the SR 507 bridge. A secondary objective is to enhance and create aquatic habitat through riparian revegetation and strategic placement of large woody material.

6.11.11.2 Middle Nisqually River Reach Management Strategies

The recommended river reach management strategies for the middle Nisqually River are listed below:

Structural Management Strategies

- The level of erosion protection for revetments should be the channel migration resistance design.

Non-structural Management Strategies

- Floodplain development regulations should be implemented by unincorporated Pierce County.
- Acquire repetitive loss properties and enable capital project construction, or purchase of development rights to prevent new floodplain development.

6.11.11.3 Interim Risk Reduction Measures

There are no IRRMs on the middle Nisqually River reach.

6.11.12 Recommended Capital Projects

There are no capital projects proposed for the middle Nisqually River reach.

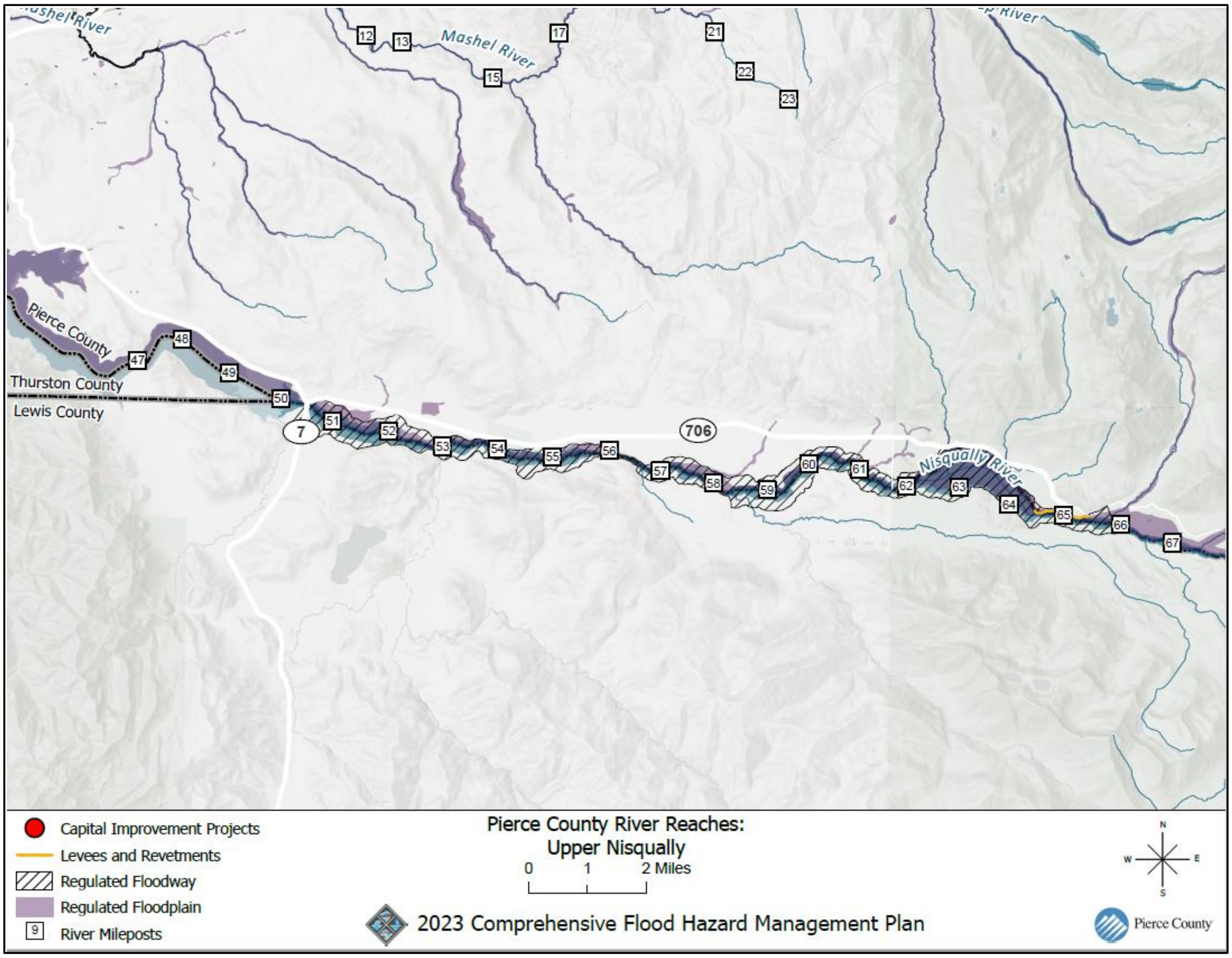
6.12 Upper Nisqually River

6.12.1 Overview

The upper Nisqually River begins on the slopes of Mount Rainier from the South Tahoma, Kautz, and Nisqually glaciers and flows generally east to west from the glaciers to Alder Lake, near the town of Elbe. The upper Nisqually River forms the boundary between Pierce County and Lewis County, as shown in Figure 6.89. Glacial meltwater and sediment flow down the mountain from Tahoma Creek, Kautz Creek, and Nisqually River. From the confluence of Tahoma Creek at about RM 65.8 to Alder Lake near RM 50.4, the upper Nisqually River flows through a broad valley, occupied by terraces, glacial features such as moraines, and occasional bedrock outcrops (GeoEngineers 2007).

The focus of this reach is from RM 50.4, at the entrance to Alder Lake in Elbe, to the upstream end of the levee/revetment at RM 65.46, near the entrance to Mount Rainier National Park. The drainage area to the USGS gauge on the Nisqually River near National is 133 square miles. The unincorporated towns of Elbe and Ashford provide residential and commercial land uses and are located on SR 706. National park, recreational, forest, and agricultural uses make up the balance of land uses within this reach study area. There are no anadromous salmon in this reach of the river due to natural barriers and the dams downstream. However, there are native resident cutthroat trout and kokanee and potentially rainbow trout stocked in Alder Lake downstream that may use this reach and available tributaries for spawning and rearing.

Figure 6.89. Planning Area for the Upper Nisqually River



6.12.2 Geology and Geomorphology

The topography of the upper Nisqually watershed is a result of the combined effects of ongoing tectonic, volcanic, glacial, and fluvial activity associated with Mount Rainier (GeoEngineers 2007). The U-shaped Nisqually River valley was carved out by alpine glaciers to the western end of Alder Lake. After the retreat of the glaciers, the valley was filled with glacial drift, including deposits of glacial outwash and till material. Lahars have also shaped the topography of the upper Nisqually River valley. Three extensive lahar deposits over the past 5,000 years each buried entire sections of the Nisqually River channel and portions of the forested floodplain (Graham 2005; GeoEngineers 2007).

Glacial outburst floods, which release large volumes of water and sediment in a short time period, are another source of fluvial and glacial material being transported downstream. Since 2001, Van Trump Creek and Pyramid Glacier drainages, which drain to the Nisqually River, have experienced five debris flows (Kennard 2009). Recent accelerated glacial retreat of the glaciers feeding the

Nisqually River watershed is exposing more terminal and lateral moraine sediments to erosion, increasing the sediment supply to the Nisqually system.

The upper Nisqually River between RM 50.4 and RM 65.8 is a braided river channel consisting of many bars and low-flow channels (see Figures 6.90 and 6.91). The character of channel migration is abrupt and unpredictable, typically occurring during high flow events (GeoEngineers 2007). Migration is expressed by both lateral bank movement through erosion and/or through channel avulsions. Channel avulsions also occur on a smaller scale annually in the Nisqually River as the sediments of the active channel are rearranged during annual snowmelt runoff. The average channel gradient varies from approximately 0.5 percent just upstream of Alder Lake to about 2.0 percent near the national park entrance. The severe channel migration zone ranges from 1,000 to 4,000 feet in width within the study area, with the exception of a short portion of the river between RM 56.0 and RM 56.5, where the river is confined in bedrock, which prevents migration.

Figure 6.90. Nisqually River Looking Upstream from Kernahan Bridge near RM 61.8

Figure 6.91. Right bank Revetment/Levee near Mount Rainier National Park Entrance Looking Downstream near RM 65.4

6.12.3 Hydrology and Hydraulics

The upper Nisqually River consists of flows primarily from Mount Rainier National Park, including the Nisqually River, Kautz Creek, and Tahoma Creek. A USGS river gauge located at National (#12082500) has been operating since 1942. The flood frequency flows for the National gauge and upstream near the national park boundary is shown in Table 6.45.

Table 6.45. Upper Nisqually River Flood Frequency Flows (based on USGS National Gauge)

	Discharge (cfs)				
Location	10-year Event	50-year Event	100-year Event	500-year Event	Method
Upper Nisqually at National Gauge (#12082500)	12,900	19,150	22,500	30,000	SWM regression analysis with data through 2009[a]

	Discharge (cfs)				
Location	10-year Event	50-year Event	100-year Event	500-year Event	Method
Nisqually River at La Grande (#12086500)	24,400	34,800	39,300	50,400	Not available
Nisqually River at McKenna (#12089500)	29,900	45,000	52,100	70,500	1987 FEMA Flood Insurance Study SWM regression analysis with data through 2009[a]

[a] Not official or formal published data.

6.12.4 Ecological Context and Salmonid Use

The upper Nisqually River reach is upstream of the Alder and La Grande dams. The La Grande Dam is the current upstream limit of salmonids within the Nisqually River. Prior to the construction of the dams, the natural falls that cascaded down the steep-walled canyon would have been a velocity barrier to salmonids and not have allowed fish passage up into the upper Nisqually reach (Kerwin 1999).

Information on resident salmonids is scarce. Interviews with Nisqually Tribe biologists indicate that resident cutthroat, kokanee, and rainbow trout are assumed to inhabit the river upstream of Alder Dam, based on observations in the upstream tributaries. Seining and electrofishing of the upstream end of this reach in 2010, 2017, and 2021 identified cutthroat trout, rainbow trout, and sculpin as the only fish species present above Alder Lake.

6.12.5 River Management Facilities, Flooding, and Flood Damage

There is one levee and one revetment in the upper Nisqually River owned and maintained by Pierce County SWM (see Figure 6.92). They are both located near the entrance to Mount Rainier National Park on the right bank, protecting both SR 706 and Nisqually Park residences (see Table 6.46). There are also revetments and bank armoring at both road and rail crossings between the national park and Elbe that are maintained by Pierce County Roads, WSDOT, and Tacoma Rail. Additionally, there is armoring on the right bank at the entrance to Alder Lake, downstream of the SR 7 Bridge (see Figure 6.93).

Mount Rainier National Park/National Park Service Agreement on Nisqually River

In 1961, Pierce County entered into an agreement with the federal government to obtain a Special Use Permit to operate and maintain Pierce County's flood control structure on the Nisqually River within the boundaries of Mount Rainier National Park. A right-of-way for such a public utility or service for domestic, public, or other beneficial uses is allowable if it is deemed to not be incompatible with the public interest. Any modifications to, or maintenance of, the flood control structure within the park requires that specific provisions be met. In discussing the recommended design and management strategies for flood hazard management or channel migration protection, it is necessary to consult and reach agreement with the National Park Service on any proposed changes. The original 1961 agreement was last amended in 2017 to extend a revetment upstream to protect the road and upstream end of the Nisqually Park levee. Key terms and conditions of the agreement may be found in the Right-of-Way Permit, #9450—04-09 in Appendix B.

The flood control structures are situated on national park land for approximately 2,150 feet, near the Nisqually park entrance. The purpose and intent of the flood control structure is to provide protection to the park's main entrance, employees working within the Nisqually entrance developed area, residents of private property adjacent to the park's west boundary along the Nisqually River and SR 706.

Figure 6.92. Nisqually Park Levee looking Upstream near RM 64.6.

Figure 6.93. Right Bank Armoring Downstream of SR 7 Bridge in Elbe

Table 6.46. Levees and Revetments on the Upper Nisqually River

Name	Location	Ownership
Right Bank		
Nisqually Park Levee	RM 64.50 – RM 65.40	Pierce County
Sunshine Point Revetment	RM 65.40 - RM 65.46	Pierce County

Source: Pierce County SWM records

RM = river mile

6.12.6 Upper Nisqually Flow Warning Matrix

The upper Nisqually River has four flow categories: Phase I, Action Flow; Phase II, Minor flooding; Phase III, Moderate flooding; and Phase IV, Severe flooding. These categories describe the observed or expected severity of the flood impacts in that area. However, the severity of flooding at a given stage is not necessarily the same at all river locations. Most river reaches in Pierce County have a defined flow warning matrix that is used during flood events. Figure 6.94 shows the flow warning matrix table for the upper Nisqually River.

Figure 6.94. Upper Nisqually Flow Warning Matrix

Upper Nisqually River

River Mile Range: 50.4 – 65.9
From the Town of Elbe to Tahoma Creek - Mt. Rainier National Park

Flow / Stage Range	**Phase I:** Action Flow	**Phase II:** Minor Flooding	**Phase III:** Moderate Flooding	**Phase IV:** Major Flooding
	< 10,000 cfs < 10.2 ft	10,000 - 15,000 cfs 10.2 – 11.7 ft	15,000 - 20,000 cfs 11.7 – 13.1 ft	> 20,000 cfs > 13.1 ft

USGS Gauge Station #:	**Gauge Name:**	**Gauge Location:**	**River Mile:**
12082500	Nisqually River near National, WA	South of SR 706 & 265th Ave E	55.95

Historical Flooding

Since the USGS gauge was installed in 1942, historical flooding has been recorded in the upper Nisqually River in 1974, 1977, 1990, 1996, 2006, and 2008 (see Table 6.47). The February 1996 and November 2006 floods both exceeded 21,000 cfs and were similar in magnitude to the estimated 1.0 percent annual chance flood (100-year) of 22,450 cfs estimated by the STARR II in 2019. The categorization of major flooding by the National Weather Service is based on discharges greater than 15,000 cfs for the Nisqually River gauge near National, Washington.

In addition to flooding, there was a major debris flow on Kautz Creek on October 2 and 3, 1947, that affected the upper Nisqually River. The debris flow was the largest in the recorded history of Mount Rainier National Park and was apparently triggered when heavy rains caused an outburst flood from Kautz Glacier (USGS 2003). The flood passed over the lowest part of the glacier, eroding a gorge through the ice, then mobilized sediment and transformed into a debris flow as it continued down valley. The Nisqually-Longmire Road was buried by 28 feet of mud and debris and about 50 million cubic yards of sediment were moved, including boulders up to 13 feet in diameter (USGS 1993). The upper Nisqually River downstream of Kautz Creek was covered in two to three feet of sediment.

Table 6.47. Historical Major Flooding on Nisqually River

Date[a]	Nisqually River Flows at National Gauge (cfs) USGS #12082500
December 1975	13,200
January 1974	15,000
December 1977	17,100
January 1990	14,500
February 1996	21,200
November 2006	21,800
November 2008	13,900
January 2009	13,400
December 2015	16,700
February 2020	14,200

Source: USGS records.

a Period of record is 1941 – 2010.

Flood Damage to Facilities

Pierce County owns two flood risk reduction structures on this reach of the upper Nisqually River. The Nisqually Park levee begins downstream of the national park boundary and extends upstream into Mount Rainier National Park. The other structure is the Sunshine Point revetment, which extends flood risk protection upstream to approximately the Tahoma Creek confluence with the Nisqually River. Both structures serve to protect the highway, the park entrance, and nearby residents.

In November 2006, Mount Rainier experienced a record-breaking rain event that resulted in severe flood damages throughout the national park. Eighteen inches of rain fell in 36 hours near Paradise. One of the hardest hit areas was near the Nisqually entrance at the Sunshine Point Campground. More than 1,000 linear feet of bank line and levee were washed away (see Figures 6.95 and 6.96). Since the 2006 flood event the structures have been frequently damaged and repaired due to the high energy of the Nisqually River. As a result, significant upgrades to the armoring were made in 2010, 2011 and 2012 along with capital improvements made in 2017 and 2021. Pierce County currently owns a flood risk reduction facility along the Upper Nisqually River. See Table 6.48 for flood damages that have occurred on this levee over the past 20 years.

Figure 6.95. Sunshine Point Area Prior to Flood Damage (RM 65.5 – 65.6), June 30, 2006

Figure 6.96. Aerial View of Sunshine Point Damage Area along the Upper Nisqually River after November 2006 Flood Event and Repair of Revetment and Levee

Table 6.48. Damage to Facilities in the Upper Nisqually River 1990–2021

Storm Season/ Bank	River Mile	Damage Lineal Feet	Damage
1991			
Right	Not available	0	Gravel removal and dike construction.
2003			
Right	64.7	219	Partial washout of the toe and levee facing.
Right	64.8	137	Partial washout of the toe and levee facing.
Right	65.0	547	Partial washout of the toe and levee facing.
2004			
Right	64.8	1200	Partial washout of the toe and levee facing.
Right	65.1	850	Partial washout of the toe and levee facing.
Right	65.13	70	Partial washout of the toe and levee facing.
2006			
Right	64.6	200	Face erosion.
Right	64.9	100	Washout.
Right	65.1 - 65.4	1600	Washout.
2008			
Right	64.8	400	Toe scour and loss of face rock.
Right	65.1 – 65.3	1150	Toe Scour and Loss of face rock.
Right	65.3 – 65.4	600	Toe scour and loss of face rock.
2010			
Right	65.25 – 65.4	700	Severe toe scour.
2011			
Right	64.6	150	Toe & face scour.
Right	65.05 – 65.25	1100	Severe toe scour.
2012			
Right	64.65	100	Active toe scour w/ face sloughing.
Right	64.75	100	Active toe scour w/ face sloughing.
Right	64.85 – 65.05	1000	Severe toe scour and loss of lower face.
2015			
Right	64.8	320	Missing face rock near toe.
Right	65.4	300	Major toe scour along the road.
2017			
Right	65.4	300	Toe scour and loss of face rock.
Right	64.77	90	Under cut toe, dislodged riprap, voids.
Right	64.97	200	Toe rock failure.

Storm Season/ Bank	River Mile	Damage Lineal Feet	Damage
Right	65.02	30	Toe rock may be missing.
Right	64.6	150	Toe rock has been scoured out.

6.12.7 Key Accomplishments since the 2018 Flood Plan Update

Major Projects

Since the 2018 Flood Plan Update, Pierce County SWM constructed a series of 28 rock deflectors called groins (as seen in Figure 6.97) along the upper Nisqually River flood control facility at approximately RM 64.5 to RM 65.4. The rock deflectors are constructed in front of and on top of the lower portion of the existing levee face and are buried as deep or deeper than the existing toe. The purpose of the deflectors is to reduce and divert erosive flows away from the levee toe in order to preserve the structure and to reduce overall maintenance costs. The facility is a combination levee and revetment and is positioned along the north bank of the Nisqually River, south of SR 706 at the Mount Rainier National Park boundary, as seen in Figure 6.98. Approximately 4,760 feet of the facility was treated with these deflectors, including approximately 2,135 feet contained within the park and 2,625 feet outside of the park. This levee protects SR 706 East, a state highway and the main entrance to Mount Rainier National Park. The road had been substantially damaged in 2006 due to a flood event. This project was completed with partners from Mount Rainier National Park and Active Construction Inc. This project was funded from a combination of Flood Control Zone District funds and local SWM fees.

Figure 6.97. Aerial View of the Nisqually Levee Project Showing the Newly Constructed Groins

Figure 6.98. A Series of "Groins" Added on the Nisqually Levee

As noted above, flood damages to the Nisqually Park levee have been quite extensive in the past three decades. Damaged portions of the levee needed repair in 1991, 1992, 1993, 1995, 1996, 2003, 2004, 2005, 2006, 2010, 2011, 2012, 2017, and 2021 (see Table 6.49 for total repair costs).

Table 6.49. Damage Repair Costs to Nisqually Park Levee

Year	Repair Costs (Pierce County)	Repair Costs (USACE)
1991	$74,610	Not available
1992	$142,718	Not available
1993	$217,000	Not available
1995	$50,000	$200,000
1996	$50,000	$200,000
2003	$122,500	Not available
2004	$203,000	Not available
2005	$131,000	Not available
2006	$900,760	Not available

Year	Repair Costs (Pierce County)	Repair Costs (USACE)
2010	$529,500	Not available
2011	$185,682	$752,529
2012	$783,529	Not available
2017	$243,440	$973,760
2021[a]	$2,834,150	Not available
Total	$6,467,545	$2,126,289

Total Cost = $8,593,834 (inflation adjusted = $10.8 million)

Source: Pierce County SWM records

[a] Capital Improvement

6.12.8 Land Acquisitions

There was no property acquisition along the upper Nisqually River from 2018 to 2021.

6.12.9 Flood and Channel Migration Hazard Mapping

Flood Hazard Mapping

Hazard mapping in the upper Nisqually River shows an unstudied Zone A SFHA on the FIRM. A new RiskMap update will continue to show the upper Nisqually as Zone A but with the flood boundaries, downstream of Kernahan Bridge, based on LiDAR topography and “base level engineering” modeling data. The FIRMs for the upper Nisqually River show 1,114 acres within the special flood hazard area, or 100-year floodplain. The DFF areas have not been mapped for this reach.

Channel Migration Hazard Mapping

Severe and moderate CMZ were mapped for the upper Nisqually River (GeoEngineers 2007). The severe CMZ covers an area of 1,830 acres along the upper Nisqually River. Pierce County regulates severe CMZ mapped areas as floodway in accordance with Chapter 18E.70 of the PCC, which was adopted for the upper Nisqually area in 2017.

6.12.10 Problem Identification

The primary hazard on the Nisqually River is erosion rather than inundation. Erosion continues to cause damage to levees, bridges, and roadways. It is also the primary flood-related risk to residential structures within the floodplain. The few residential communities are built on terraces above the floodplain and the larger lots typically have developable areas above the flood hazard. Table 6.50 includes the flooding and channel migration problems identified in the upper Nisqually River floodplain.

Table 6.50. Priority Problems Identified in Upper Nisqually River

Location	Problem Description	Source
Channel Migration Problem Areas		
RM 53.2 LB/RB	Channel migration during 2006 flood washed out left and right bank abutments for Tacoma Rail bridge.	Pierce County
RM 58.5- RM 60.3 RB	Channel migration at Echo Valley subdivision threatens 3–5 homes.	Pierce County
RM 61.7 LB/RB	Kernahan Bridge – approaches eroded/damaged in 1996 on the Pierce County side and in 2006 on the Lewis County side.	Pierce County Roads
RM 61.8 – RM 62.3 RB	Channel migration at Alpine Village subdivision threatens 12–18 homes.	Pierce County
RM 64.3 – RM 65.3 RB	Revetment and levee at Nisqually Park and Mt. Rainier entrance (Sunshine Point Campground) experienced severe channel migration in Nov. 2006; significant damage at campground and downstream; nearly 3,500 feet of levee repaired in 2006 at cost of more than $900,000.	Mt. Rainier National Park; Pierce County
Flooding of Structures and Infrastructure (Roads/Bridges) [not already noted above]		
RM 50.4 RB	Elbe sewer system (a sand septic system) located at the confluence of Alder Lake and Nisqually River that serves the entire Elbe community is at risk of flood damage.	Mt. Rainier National Park; Nisqually Advisory Comm. member
RM 61.7 LB/RB	Kernahan Bridge – Due to recent flood events, sediment and debris deposition is threatening the bridge due to scour of bridge ends and buildup of LWM. This bridge is the only access for Lewis County residents in winter months	Pierce County Roads; Nisqually Advisory Comm. member
Sediment and Gravel Bar Accumulation		
RM 50.2 – RM 50.4	Accumulation of sediment at Alder Lake inlet delta, near intersection of SR 7 and SR 706 from 1947 Kautz Creek debris flow and recent floods (1996, 2006, 2009) creates the threat of flooding and channel migration in community of Elbe.	Nisqually Advisory Comm. member
RM 50.4 – RM 66.0	Mt. Rainier National Park to Elbe – Accumulation of sediment appears to have built up in this reach, contributing to channel migration and potential for erosion of river bank infrastructure.	Nisqually Advisory Comm. Member; Pierce County

Source: Pierce County SWM records

LB = left bank; LWM = large woody material; RB = right bank; RM = river mile

6.12.11 River Reach Management Strategies

6.12.11.1 Conditions and Constraints of the Upper Nisqually River

In conjunction with updated flood hazard mapping, the recommended river reach management strategies for the upper Nisqually River take into account numerous conditions, as follows:

- Development and land use in adjacent floodplain – The upper Nisqually River floodplain contains low- and medium-density residential, a small commercial area, and forest land uses.
- River management facilities – There is one levee and one revetment near the entrance to Mount Rainier National Park. Both structures lie along or near SR 706 and the Nisqually Park subdivision on the right bank (RM 64.50 to RM 65.46). There is also armoring at bridge crossings and near the community of Elbe.
- River channel gradient and width – The river channel gradient varies from about 0.5 percent near Alder Lake to 2.0 percent at the Mount Rainier National Park entrance. The river channel width generally varies from 80 feet at its narrowest point near RM 56 to about 1,200 feet in several locations.

In the near term, the primary objective for the upper Nisqually River is to maintain the existing structural integrity of the levee and revetment system near the national park Nisqually entrance to reduce risks to public health and safety, maintain access to the park, and reduce public and private property damage. A long-term objective is to prevent channel migration of the river into the areas currently protected behind the levee and revetment downstream of Sunshine Point.

6.12.11.2 Upper Nisqually River Reach Management Strategies

The recommended river reach management strategies for the upper Nisqually River are listed below.

Structural Management Strategies:

- RM 50.2 to RM 61.7 – The following critical facilities are to be protected to maintain public safety: Tacoma Power, Tacoma Rail, and Kernahan Bridge protection (channel migration resistance design).
- RM 64.5 to RM 65.5 right bank – The goal for the Nisqually Park levee and Sunshine Point revetment should be to maintain existing infrastructure to maintain access to Mt. Rainier National Park.

Non-structural Management Strategies:

- Floodplain development regulations should be implemented by unincorporated Pierce County.
- Acquire repetitive loss properties or purchase development rights to prevent new floodplain development.

6.12.11.3 Interim Risk Reduction Measures

- There are no IRRMs on the upper Nisqually River reach.

6.12.12 Recommended Capital Projects

There are no capital projects proposed for the upper Nisqually.

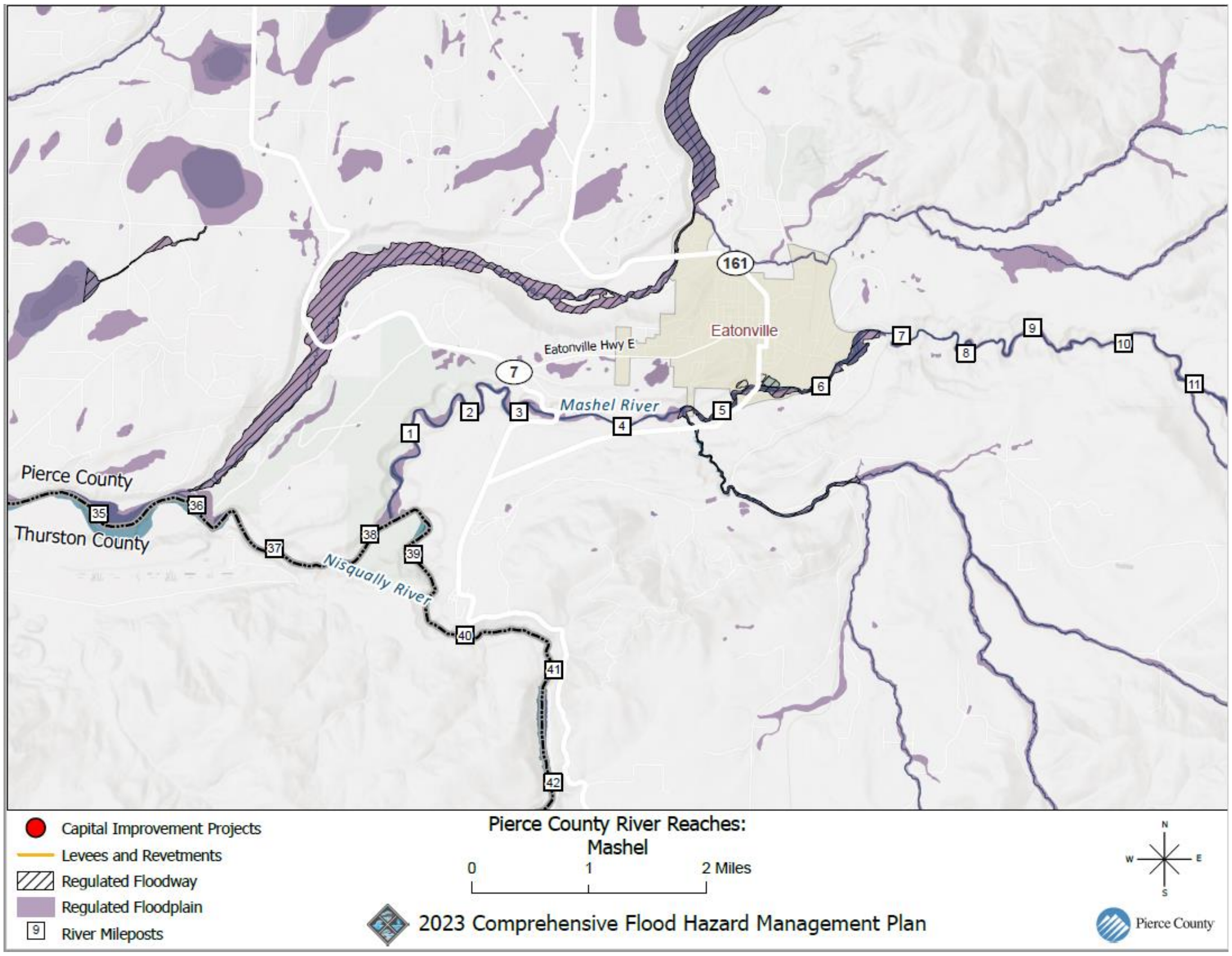
6.13 Mashel River

6.13.1 Overview

The Mashel River watershed, which covers about 85 square miles, is higher in elevation and steeper than most other tributaries to the Nisqually River (see Figure 6.99). Over 40 percent of the watershed has slopes greater than 30 percent (Pierce County 2008). Major tributaries of the Mashel River are the Little Mashel River, Beaver Creek, and Busy Wild Creek. Elevations range from 460 feet at the mouth to 4,845 feet on the flanks of Mount Rainier. The Mashel River winds through a steep, sinuous canyon as it approaches the Nisqually River, where it enters at approximately RM 38.2.

The Mashel River planning area is from the mouth of the Mashel River upstream to the town of Eatonville (near RM 6.8). Land use consists of forested terrain, some agriculture (mostly livestock), rural residential development, and urban areas in Eatonville. Eatonville draws its drinking water from the Mashel River, and the secondary-treated wastewater is discharged to the river downstream of the town. The Mashel River is the farthest upriver tributary to the Nisqually River that has anadromous fish use, including fall Chinook, coho, and pink salmon and winter steelhead trout.

Figure 6.99. Planning Area for the Mashel River



6.13.2 Geology and Geomorphology

The majority of the Mashel River basin was not covered by continental glacial ice. The underlying geology is mostly volcanic deposits and unsorted glacial sediment (Pierce County 2008). The soils are primarily of low to moderate permeability. From the mouth to RM 3.2, the Mashel River flows through a natural canyon, with some room for the channel to migrate. From RM 3.2 to Eatonville, the canyon is more confined. A large section of the Mashel River in the Eatonville area is unconfined, but the channel is lined with riprap along many places and active channel migration is restricted. Timber management practices initiated in the 1940s resulted in mass wasting events in the upper watershed, delivering large quantities of sediment to the lower reaches. The channel response to this increase of sediment resulted in a plane-bed channel

Channel Morphology

is the shape and gradient of a channel that forms due to streamflow forces and the composition of the underlying channel substrate.

Bed Material

The material of which a streambed is composed.

morphology with some interspersed pool/riffle sequences. The channel bed material is typically cobbles and large gravel, with some bedrock outcrops (Pierce County 2008).

6.13.3 Hydrology and Hydraulics

There is one USGS gauge installed on the Mashel River, located at RM 3.3 near the community of La Grande. Flood frequency flows were estimated for the 10-, 50-, 100-, and 500-year floods for existing land use conditions using Bulletin #17B procedures (Water Resources Council 1981). Computed discharges were estimated by applying a log-Pearson III analysis to 26 years of recorded annual instantaneous peak flows. Table 6.51 summarizes the resultant flow quantities.

Table 6.51. Mashel River Flow Frequencies at the USGS Mashel Gauge (#12087000)

	Discharge (cfs)				
Location/Version	10-year Event	50-year Event	100-year Event	500-year Event	Method
Upstream of confluence with Little Mashel River	3,650	5,020	5,620	7,070	1987 FEMA Flood Insurance Study (Log Pearson III Fit of Gauge Data)
Upstream of confluence with Little Mashel River	3,490	5,045	5,770	7,620	2009 FEMA Flood Insurance Study (and NHC 2006) (Log Pearson III Fit of Gauge Data)
Mashel River at mouth	4,995	7,215	8,250	10,900	1987 FEMA Flood Insurance Study (Log Pearson III Fit of Gauge Data)

6.13.4 Ecological Context and Salmonid Use

The Mashel River from its mouth at the Nisqually River to SR 7 (RM 3.2) flows through a canyon surrounded by mature riparian forests of large conifers and hardwoods. Rural residential land use predominates from RM 3.2 up to Eatonville. The river is mainly unconfined through this segment, but there are many places where the channel is lined with riprap, and active channel meandering is restricted, particularly within the town. Eatonville withdraws river water at RM 5.7 and returns water to the river about RM 5.4 after secondary treatment at its wastewater treatment plant.

Chinook, coho, and pink salmon and steelhead trout spawn throughout the Mashel River. The WDFW uses the Mashel River as an index reach for Chinook spawning. Chum usage has not been documented. The section of the river between RM 3.2 and RM 6.8 is used by coho, Chinook, and steelhead, primarily for rearing. Cutthroat and rainbow trout have also been observed. The entire lower Mashel River from Eatonville to its mouth is deficient of in-stream large woody material to provide protection from the flows of short duration but high intensity that occur in this segment of the river. In Eatonville, the Nisqually Tribe has conducted extensive habitat restoration and protection, with a particular focus on installing many large, engineered log jams.

6.13.5 River Management Facilities, Flooding, and Flood Damage

No flood control facilities are owned or maintained by Pierce County SWM along the Mashel River. Pierce County historically placed riprap along the Mashel River near SR 161 between RM 5.12 and RM 5.24. In 1950, a groin was built by dredging and straightening the river channel. A timber bulkhead paralleling the highway had become badly decayed, and the river was eroding the highway, which caused PCRI to take action. The groin was heavily blanketed with rock from the Orting quarry (PCRI 1950). The last documented action of PCRI riprapping the Mashel River was in 1962.

In Eatonville, riprap is present intermittently along both banks of the river from the wastewater treatment plant, located at RM 5.3, to the Alder cutoff road bridge, located at RM 6.25. Riprap protects the right bank from approximately 200 feet below the bridge to 50 feet above the bridge. The left bank has riprap from approximately 50 feet below the bridge to 15 feet above the bridge. Much of the riprap is old. However, in 2009, WSDOT replaced rock on the right bank above the bridge (see Figure 6.100) and on the left bank upstream and downstream of the bridge. The town built a levee around the wastewater treatment plant following the 1996 flood. In 2004, log jams replaced riprap on left bank in the vicinity of Smallwood Park, at approximately RM 5.6, and at a private residence, at approximately RM 5.33 (Watershed Professionals Network 2004).

Figure 6.100. Armoring of Bridge Approach at SR 161 Crossing (RM 5.5)

6.13.6 Mashel Flow Warning Matrix

Historically, Pierce County has had no managed facilities along the Mashel River. At this time, no flow warning matrix has been created for this reach.

Historical Flooding

Major flood events since 1991 have adversely affected transportation facilities and some private properties. There was channel migration in January 2009 along SR 161 at the bridge crossing at RM 5.5 and downstream on the left bank from RM 5.2 to RM 5.3.

The USGS gauge record from 1941 to 2021 spans 48 years of records with a 35-year data gap between 1957 and 1992. The flood of record occurred in 2020, as see in Table 6.52, and eight of the top 10 record peaks have occurred in the last 15 years, since the FEMA flood study was completed.

Table 6.52. Major Flooding on Mashel River

Date	Mashel River Flows near La Grande Gauge (cfs) USGS #12087000[a]
December 1946	6,859
February 1996	6,220[b]
December 2007	5,790
January 2009	5,610
November 2015	5,850
December 2016	8,490
February 2017	5,930
February 2020	9,520

Source: USGS records.

[a] The Mashel River gauge was not operational between 1958 and 1991.

[b] Discharge is an estimate.

Flood Damage to Facilities

There is little historical information about damage to flood control facilities along the Mashel River. As noted above, Pierce County has no current river management facilities in the study area. WSDOT has several bridge crossings of SR 161 and SR 7, and revetments (as shown in Figures 6.101 and 6.102) where the river flows adjacent to SR 161.

Figure 6.101. Left Bank Scour along SR 161, RM 5.2–5.3

Figure 6.102. Repaired Riprap Bank, RM 5.2–5.3, March 2010

6.13.7 Key Accomplishments since the 2018 Flood Plan Update

Major Projects

Since the 2018 Flood Plan Update, Pierce County has carried out an annual program that includes maintenance and repair of facilities. Specific capital projects for the Mashel River are listed below:

- Mashel River Restoration Project – Numerous engineered log jam structures have and will be installed in a multiphase Nisqually Tribe project to rehabilitate degraded in-stream and riparian habitat that will restore geomorphic and ecological functions beneficial to native salmonid species. An example of these engineered log jams is located on the right bank of the Mashel River, upstream of the SR 161 crossing.
- Mashel River Bank Protection, RM 5.2–RM 5.7 left bank – WSDOT undertook a major repair along the left bank of the Mashel River following severe bank erosion in January 2009 (see Figure 6.103). Work consisted of placing large toe and facing rock along the bank to prevent future channel migration and constructing bank roughening log structures to improve habitat and riparian conditions.

Figure 6.103. Mashel River Restoration Project, Right Bank near RM 5.5

6.13.8 Land Acquisitions

There have been no property acquisitions along the Mashel River from 2018 to 2021.

6.13.9 Flood and Channel Migration Hazard Mapping

Flood Hazard Mapping

Flood hazard mapping along the Mashel River includes detailed flood studies (FEMA and NHC 2006). Flood-prone areas along the Mashel River include limited roads and infrastructure and private property that is mostly residential and forested in Eatonville and unincorporated Pierce County. The DFIRMs for the Mashel River show 213 acres within the study area within the special flood hazard area, or 100-year floodplain. The mapped DFF water floodway area is 41 acres.

Channel Migration Hazard Mapping

Channel migration mapping has not been completed for the Mashel River. While the Mashel River is identified in Pierce County Code Chapter 18E.70 as one of seven major rivers to be mapped, there is no current plan for the geomorphic study, as the unincorporated areas of the Mashel River have very limited existing development, and future development is greatly restricted by other critical areas, including steep slopes and mapped flood hazards.

6.13.10 Problem Identification

Table 6.53 lists the flooding and channel migration problems identified in the Mashel River floodplain.

Table 6.53. Priority Problems Identified in Mashel River

Location	Problem Description	Source
Channel Migration Problem Areas		
RM 5.1 - RM 5.3 LB	Channel migration caused washout adjacent to SR 161 during January 2009 flood.	Nisqually River Council, WSDOT
Flooding of Structures and Infrastructure (Roads/Bridges)		
RM 5.5	The SR 161 bridge (bridge #161/02) approach was eroded in 2008 flooding; needed to reinforce riprap to prevent failure.	WSDOT
RM 6.3	Mashel River bridge (Center Street E. and Alder Cutoff Road E. – debris buildup on bridge piers during floods threatens bridge.	Pierce County Roads
Facility Maintenance and Repair		
RM 6.8 – RM 6.9 LB	Private property erosion due to Mashel River flooding in 1996 and 2006.	City of Eatonville public meeting

Source: Pierce County SWM records

LB = left bank; RM = river mile

6.13.11 River Reach Management Strategies

6.13.11.1 Conditions and Constraints of the Mashel River

- Recommended river reach management strategies for the Mashel River take into account numerous conditions described below:
- Development and land use in adjacent floodplain – The Mashel River floodplain is primarily rural and forested, but also includes several road and highway crossings and some residential property in Eatonville.
- River management facilities – Revetments exist along short stretches of roads and near bridges. There is also a levee at Eatonville's wastewater treatment plant.
- River channel gradient and width – Channel gradient generally varies from 1.0 to 1.5 percent between RM 0.0 to RM 6.8. The river channel width varies from approximately 40 feet to 160 feet.
- Presence of salmon spawning and rearing habitat – Chinook, coho, and pink salmon and steelhead trout all spawn and rear in the Mashel River.
- Sediment transport accumulation and incision – Caldwell and Kuzis (2001) note a cobble/boulder substrate with some gravel around and below the confluence with the Little Mashel River at RM 4.4. Little information is available about sediment transport conditions in the Mashel River. The river was not included in the 2010 USGS sediment transport study.

The county's primary objective for the Mashel River is to protect the public infrastructure (roads, bridges). Another objective is to enhance and create aquatic habitat through riparian re-vegetation and strategic placement of large woody material.

6.13.11.2 Mashel River Management Strategies

River reach management strategies for the Mashel River are listed below:

Structural Management Strategies:

- The level of erosion protection for revetments should be the channel migration resistance design in areas near bridges and where the creek flows adjacent to public roads.

Non-structural Management Strategies:

- Pierce County floodplain should continue to implement development regulations; Town of Eatonville floodplain development regulations should be consistent with Pierce County critical area regulations for flood hazard areas.

- Property acquisition or purchase of development rights should be considered on a case-by-case basis to remove the most flood-prone structures and people from the flood hazard area. Encourage the property owners within the flood hazard area to purchase flood insurance.

6.13.11.3 Interim Risk Reduction Measures

- There are no IRRMS on the Mashel River study reach.

6.13.12 Recommended Capital Projects

There are no capital projects proposed for Mashel River.

6.14 Urban Flooding

6.14.1 Overview

Urban flooding occurs when intense rainfall overwhelms the capacity of streams, lakes, wetlands, subsoil, and stormwater infrastructures' ability to accommodate the stormwater. Street intersections, low lying bowl-shaped areas, and lands adjacent to natural wetlands and streams are the most likely areas to be inundated by flood waters. Large-scale urbanized flood risk is highest within the valley floodplain associated with the Puyallup River system and Nisqually River system. Urban flooding that occurs due to high groundwater is addressed in Section 6.16. Groundwater Flooding.

Localized urban flooding doesn't typically cause widespread damages, but it can disrupt daily activities, increase maintenance costs, and necessitate structural repairs caused by water inundation and intrusion, as seen in Figure 6.104 Polluted stormwater degrades water quality and habitat that supports fish and wildlife. For example, the chemical 6PPD-Quinone leaches from tires and enters polluted stormwater when it rains and was identified in 2021 as the cause of pre-spawn mortality syndrome in adult coho salmon.

Figure 6.104. Observed Urban Flooding in Residential Area, Dupont

Management of urban flooding in Pierce County has evolved with urbanization, and especially since the 1970s, when federal laws were passed regulating and protecting water quality. What was once a rural undeveloped landscape of forests and farmlands, served by localized rural roadways, was consumed by urban and suburban-level development with limited stormwater controls to manage the rain runoff. Today, urban infill development is challenged with a patchwork of ageing stormwater infrastructure and reduced natural areas to contain the stormwater, which results in urban flooding of roadways, homes, and businesses, and fish habitat. The latest localized climate change models from University of Washington Climate Impacts Group predict increased heavy rain events during the wet season, which will only exacerbate urban flooding.

Urbanization is characterized with the following concerns often associated with urban flooding:

- Untreated runoff from cumulative development not addressed with stormwater controls.
- **Conversion of forest tree cover, vegetation groundcover, and open spaces to impervious surfaces** such as roofs, roads and parking lots that convey rather than infiltrate, store, or evaporate water.
- **Groundwater or surface water flooding** not previously mapped as flood hazard areas.
- Filling and grading in wetlands and floodplains that reduces stormwater storage capacity.
- **Decreased channel capacity** in segments of urban creeks due to sedimentation, shoreline hardening, and invasive vegetation growth.
- **Ineffective coordination** between responsible jurisdictions and community groups involved in protecting and enhancing the basin's natural water resources and natural areas.
- **Lack of public awareness** of the hazards associated with flooding and steps to take to protect themselves and their property.
- **Culvert and stormwater conveyance capacity deficiencies,** undersized infrastructure for both stormwater and fish conveyance.

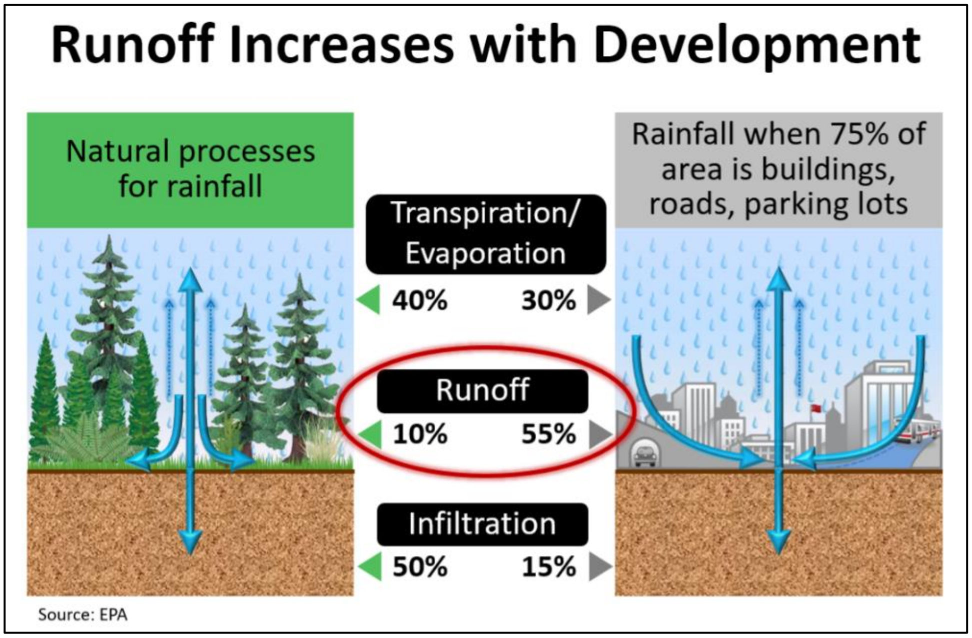
Causes of Urban Flooding

Urban flooding in Pierce County typically occurs during a weather event called an atmospheric river, or colloquially, a "Pineapple Express." An influx of warm air from the tropics or subtropics rapidly raises winter temperatures. The mix of higher air temperature levels and increased water vapor levels can produce heavy precipitation, resulting in flooding. These events often happen in winter but have occurred in late fall and early spring as well.

In a natural landscape such as a forest or prairie, rainfall and snowmelt collects and is stored by the vegetation and in the soil column or low depressional areas such as wetlands or lakes. When storage capacity is exceeded, runoff begins to flow overland and through the soil column as subsurface flow entering drainage channels and streamways.

In contrast, urbanization results in increased impervious surfaces and reduced capacity of the landscape to absorb intense rainfall events, as demonstrated in Figure 6.105. Native vegetation, wetland areas, and soils that once acted to slow stormwater runoff to support infiltration are substantially reduced, thus resulting in increased velocity and volume of polluted stormwater runoff followed by surface erosion.

Figure 6.105. Effects of Urbanization on Stormwater



Effects of Urban Development on Flood Discharge and Frequency

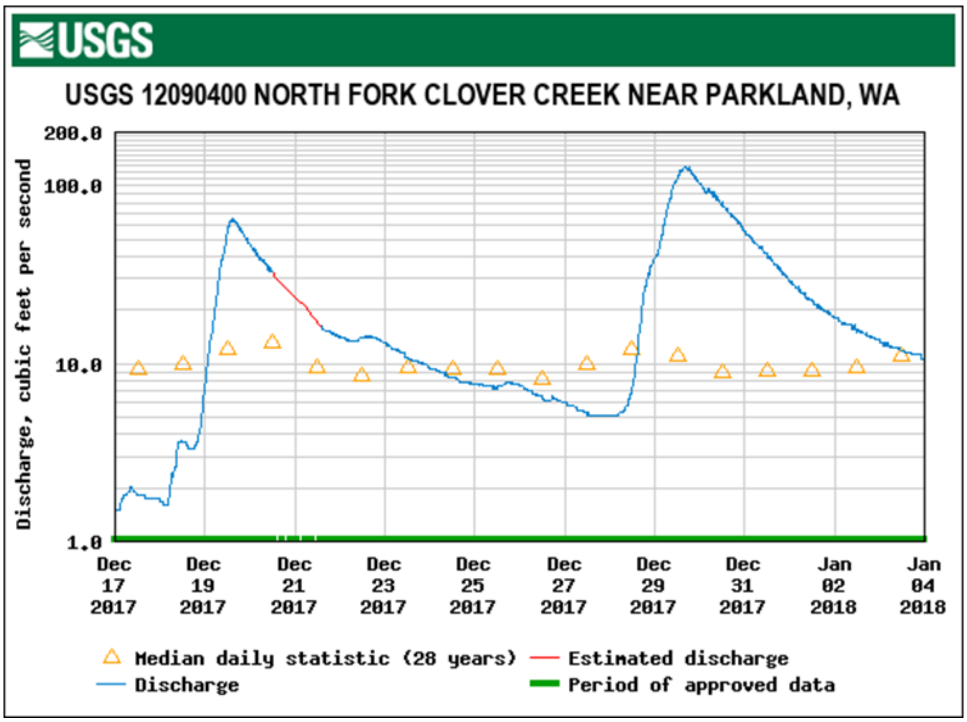
The point where stormwater flow exceeds the capacity of natural drainages or waterbodies is the peak discharge point. The annual peak discharge of a flood will typically increase with urban development but can be influenced by many factors, including the intensity and duration of storms and snowmelt, the topography and geology of stream basins, vegetation, and the hydrologic conditions preceding storm and snowmelt events. Figure 6.106 shows the peak discharge on North Fork Clover Creek near Parkland.

Land use and other human activities also influence the peak discharge of floods by modifying how rainfall and snowmelt are stored on and run off the land surface into streams. When storage capacity is reached, runoff infiltrates slowly through the vegetation and soil as subsurface flow. Where flow is interrupted, such as when the water table is fully saturated, or by a hardened or impervious surface, the flow will result in ponding upon the surface area or possible erosion of the natural landscape.

The hydrologic effects of urban development on the hydrologic regime are often greatest in small stream basins, where prior to development, much of the precipitation falling on the basin would have become subsurface flow and recharge aquifers or discharge to the stream network further downstream. Urban development constrains the capacity of streams, wetlands, and filled depressions, further reducing the ability of the urban landscape to accommodate stormwater runoff.

Dense networks of ditches and culverts in urbanized areas reduce the distance that runoff must travel overland or through subsurface flow paths to reach streams and rivers. With less storage capacity for stormwater in urban basins and more rapid runoff, urban streams and ditches rise more quickly during storms and have higher peak discharge rates than in rural areas.

Figure 6.106. Peak Discharge of North Fork Clover Creek

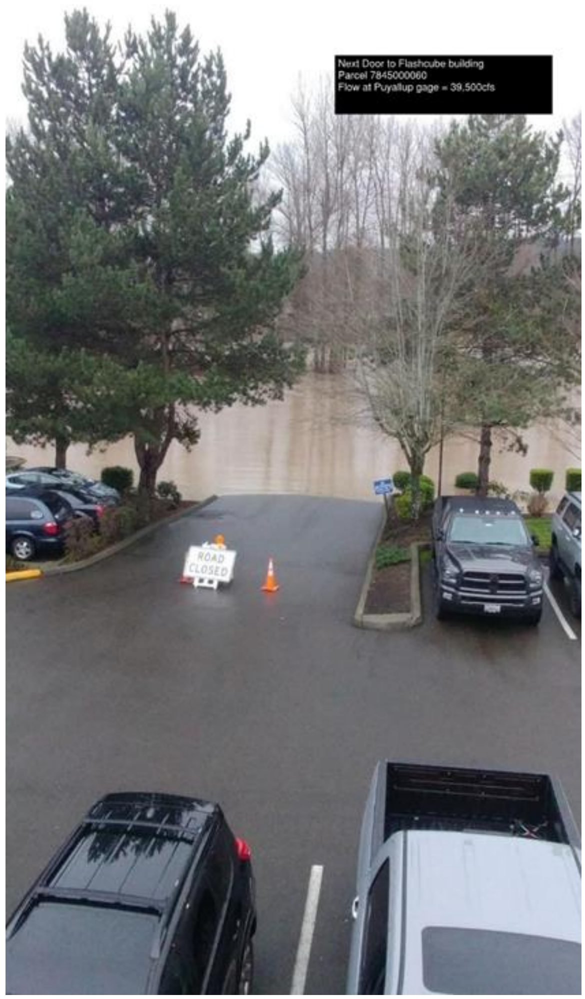


Stormwater control systems are designed to control both stormwater quantity and quality through a system of collection, treatment, conveyance, and storage facilities designed to minimize impacts on the built urban landscape and natural areas. Infiltration (retention) of stormwater is preferred to detention because it tends to better mimic natural conditions. Where detention is necessary due to soils with low percolation rates, the ponds must be sized to pre-development release rates. Much of the urban landscape was developed prior to current standards, resulting in peak discharge rates much higher than natural events. Streams, lakes, and wetlands were historically used as discharge points for stormwater control systems, often beyond natural levels. Once stormwater enters a drainage network, it flows faster than either overland or subsurface flow, thus resulting in downstream impacts evident in point discharge erosion impacts to receiving water bodies. If the point discharge exceeds the capacity of the stream channel, then overbank flooding will occur (see Figure 6.107). If the stormwater conveyance system capacity is exceeded, then stormwater will back up in the system and result in stormwater overtopping roadways, ponding of parking areas, and inundation of the urban landscape.

The relative increase in peak discharge is greater for frequent, small floods than infrequent, large floods.

Erosion in urban streams caused by accelerated stormwater runoff rates represents another consequence of urban development that can add to urban flood risk. Where channels have been straightened or hardened and vegetation has been removed from channel banks, streamflow velocities will increase and allow a stream to transport more sediment more quickly downstream

Figure 6.107. Overbank flooding at Keller Williams Building in Puyallup (February 2020)



where it might accumulate. Stream bank and bed erosion releases debris that is carried by the stream flow, further constricting conveyance channels. This hazard is greatest upstream of culverts and bridges, as well as natural constriction points in the channel, causing channel flow to back up, overtop, and inundate the adjacent area.

Uncontrolled flows can collect and drain to areas that would naturally not be affected by flooding. Undersized culverts and bridge crossings can cause similar effects, raising flood waters above normal base flood elevations. Conveyance channels can be designed to convey water more quickly downstream, but if not engineered properly, could also result in additional impacts downstream by increasing the velocity resulting in erosion and a likely rise in the base flood elevation.

The Pierce County Stormwater Management Manual provides BMPs, including Low Impact Development Standard (LID) concepts, that will help improve or restore natural conditions to complement traditional flow control measures and help mitigate the effects of erosion and urban flooding (PCC Title 17A “Stormwater Control Manual”).

Potential flood hazard areas are described in PCC Title 18E.70 and depicted on the County Critical Areas Atlas-Flood Area map.

Integrated Flood Risk Management of Urban Flooding

Much of the urban landscape was built without modern stormwater controls to properly address the effects of cumulative development upon the natural landscape and hydrologic regime. Flood risk can be reduced through an integrated flood risk management approach that integrates analytical data with structural and non-structural solutions, is adaptable through time with urban growth and climate change, and incorporates BMPs.

An integrated flood risk management approach incorporates the following elements:

- **Pathways Approach –** providing a long-range adaptable vision for reducing urban flood risk that adjusts to changing conditions as new information is available. Incorporate BMPs into an adaptable approach to reducing flood risk.
- **Analysis –** understanding the hydrological regime—how rainfall events exceed the capacity of stormwater systems and natural areas resulting in urban flooding. This approach requires a clear understanding of subbasin (hydrological unit) through analysis of how rainfall events will result in urban flooding.
- **Structural solutions –** integrating engineered solutions with natural systems affected by the hydraulic regime (wetlands, streams, open spaces, natural buffer areas, groundwater). Integrate flood risk management into land use planning, design, regulations, and management. Identify opportunities for multi-benefit solutions, such as recreational areas that can also provide attenuation of stormwater, improve water quality, and enhance stream low water flows.
- **Non-Structural solutions –** implementing solutions that are adaptable to urban growth and climate change, including public policy; advance warning and education; and preservation and enhancement of open spaces, forests, and natural drainage features.

- **Public/Private coordination –** providing multiple flood risk reduction benefits for the community and natural environment.

6.14.2 Stakeholder Engagement and the Pathways Approach

After a series of meetings with several cities (see Figure 6.108), Pierce County developed a pathway that illustrates near- and long-term actions to address urban flood hazards in unincorporated Pierce County, as shown in Figure 6.109. The pathway includes near-term programmatic actions to inform the development of targeted projects throughout unincorporated Pierce County. Meeting participants were asked to identify flooding problems in their community. Those locations were mapped and are shown in Figure 6.110. Several cities also developed a list of urban flood hazards along with potential solutions to those hazards. Cities were encouraged to develop their own pathway to address urban flood hazards within their cities, which are included in Appendix E.

Figure 6.108. Participants of Urban Flood Hazard Disappearing Task Group Meeting, February 2, 2022

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In the near-term, Pierce County identified three programmatic actions to address urban flood hazards:

- Create roadside/driveway culvert replacement program.
- Develop urban flood hazard working group in partnership with cities and special districts.
- Map, analyze, and monitor urban flood events.

Following the above-mentioned actions, specific projects could occur at locations where urban flooding is a concern. These would be subject to further study before initiating. The Urban Flood Hazard Working Group, which will be composed of Pierce County, cities, special districts, and other interested stakeholders, will meet regularly to analyze past flood events, propose solutions, and monitor outcomes.

Figure 6.109. Urban Flood Hazards Pathways

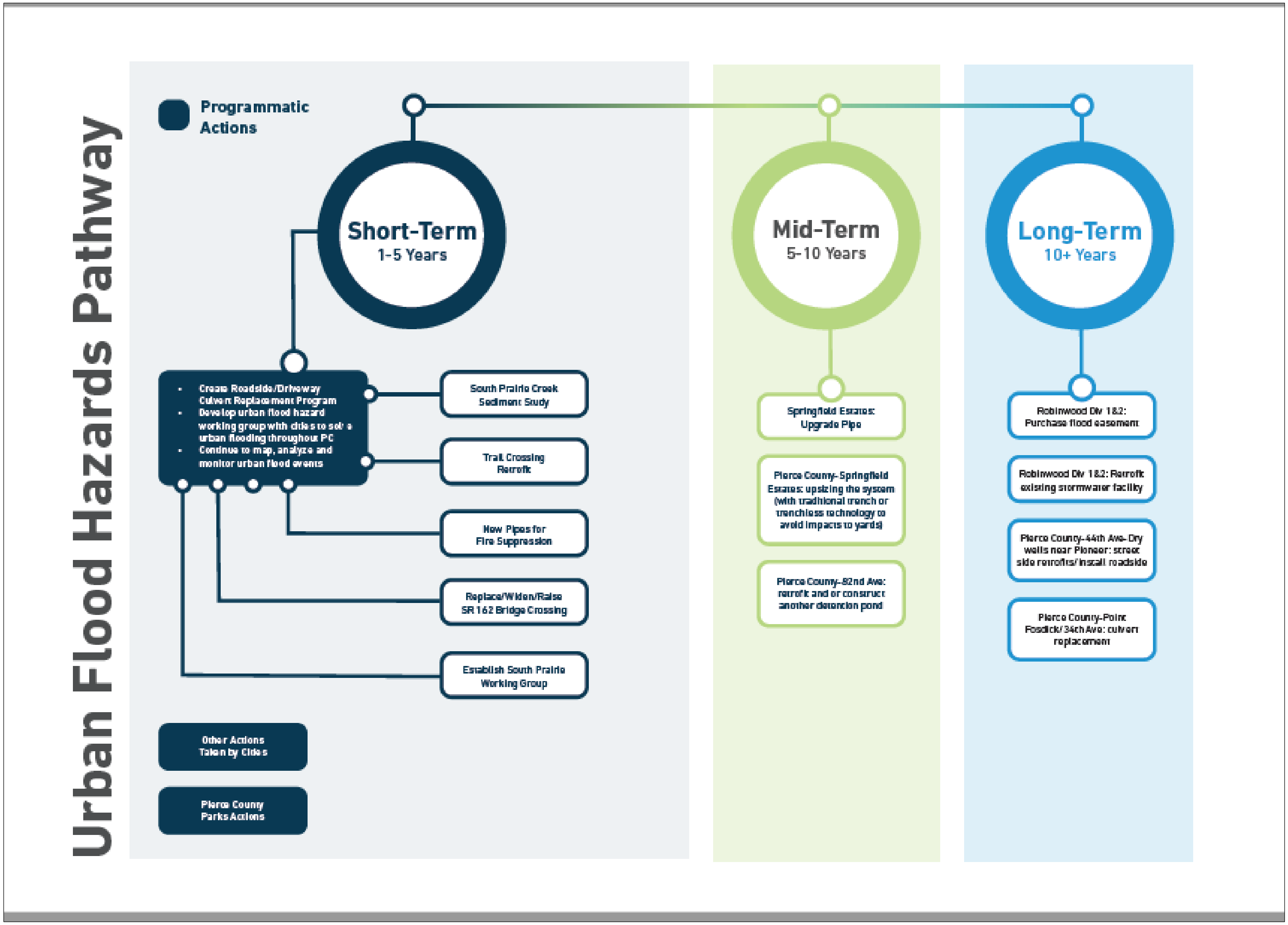
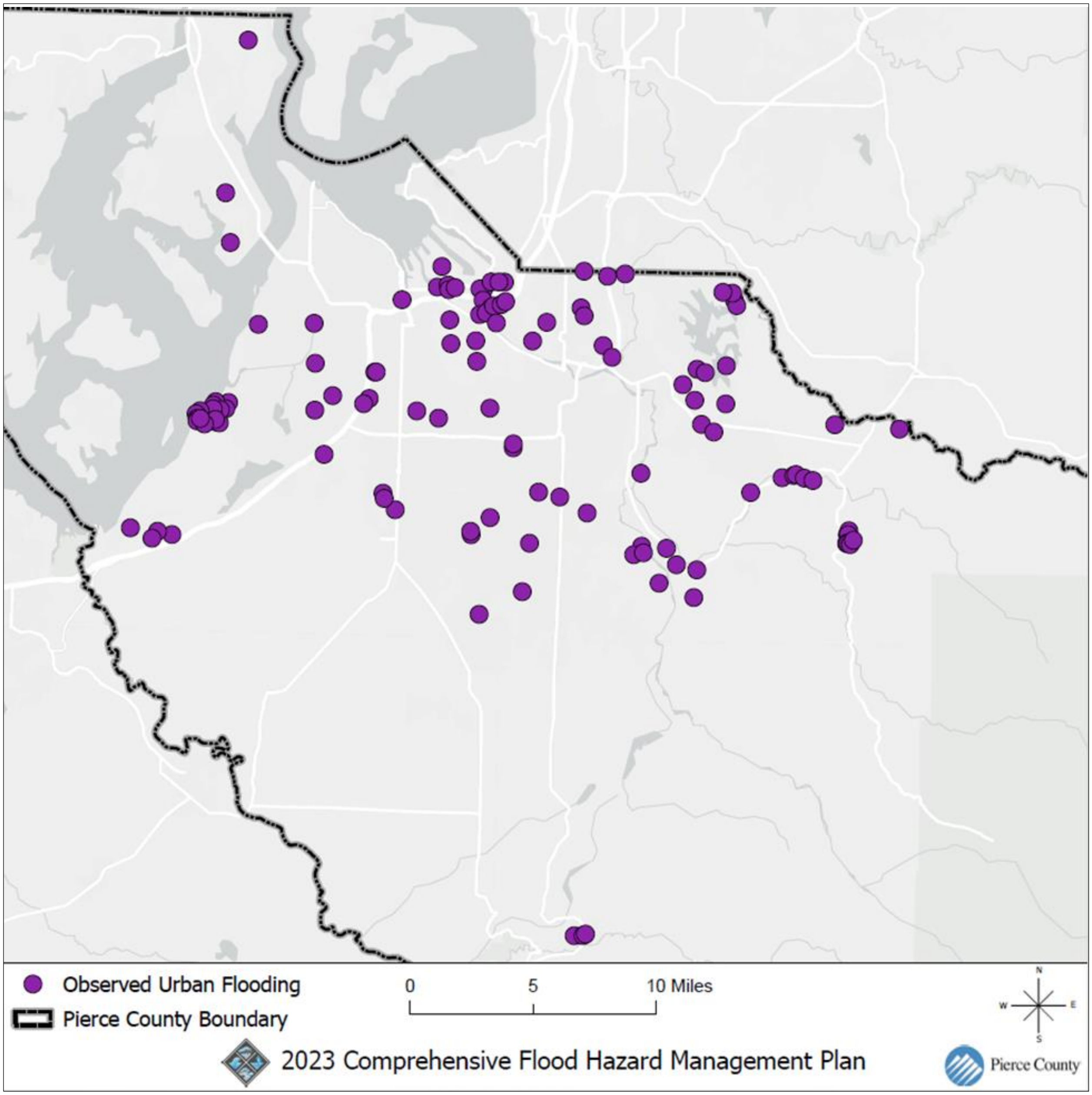


Figure 6.110. Observed Urban Flood Locations



6.15 Coastal Flooding

6.15.1 Overview

Tides are a key component in predicting potential coastal flooding. Unlike most other forms of flooding, tidal cycles are regular and predictable. Puget Sound marine shorelines experience two high tides and two low tides every 24 hours and 50 minutes (one lunar day), and it is possible to calculate tide levels for specific locations, months, and even years before they occur. Tidal elevations are measured against a zero-tide level, which for a given area is calculated by averaging the height of all of the lowest tides for that area over a certain period of time. When the average water level height has been determined, it is set to zero and all of the other water levels are baselined from that level. Most tides are represented as the number of feet above the zero level. However, there can be several days each year in which Puget Sound will experience “minus tides” that are lower than zero. In Puget Sound, the highest tides of each year typically occur in the winter, over a 5- to 7-day period. These high tide events are sometimes referred to as “King Tides,” which are watched carefully as early indicators of sea level rise impact areas (see Figure 6.111).

Figure 6.111. King Tide event on Day Island, December 2022

Geology is another key variable in coastal flooding. Shoreline bluffs consisting of sand or other loosely sorted soils are at higher risk of erosion and failure. Groundwater often surfaces on shoreline bluffs and banks in the form of seeps. This moisture can loosen soils above and cause slope failures or erode softer soils below.

Currents and waves are the third key factor in coastal flood risk. Currents are constantly moving shoreline sediments and create areas that are either losing or gaining. Loosing areas are most susceptible to flood risk since the sediments leaving may have provided protection or support to nearshore bluffs and banks. Wave energy can exacerbate these effects. Wave energy increases in areas with long stretches of open water, which is impacted by wind and the wakes made by boats. Bigger, faster boats create bigger waves, so areas along routes used by commercial vessels experience greater wave energy. In Pierce County, those areas include Commencement Bay, Dalco Passage, and the Tacoma Narrows. Wind-related wave energy is of greatest concern in the winter when storm events are most likely to coincide with the year’s highest tides.

Human activities have tremendous impacts on coastal flooding risk. Of course, much of this is because humans build things in flood-prone areas and afterwards want to protect them. In addition to the usual residential, commercial, and industrial land uses, at-risk structures often found in coast flood areas include roads, bridges, railways, utility lines, and recreational facilities like parks. There are water-dependent industries like aquaculture, marinas, and ports that have to be located in marine areas. Even if the primary development on a parcel is not within a flood zone, shoreline parcels often include accessories that can be at risk, such as docks, boat ramps, boat houses, and stairs. Once these structures are in place, property owners will seek to protect them from potential flood and erosion damage. In Pierce County, this is typically accomplished by installing shoreline armoring.

Shoreline armoring usually consists of installing a bulkhead or seawall using rock, treated lumber or concrete parallel to the water line as shown in Figure 6.112. Permits to install bulkheads and other shoreline stabilization structures in Pierce County are regulated under Title 18S Development Policies and Regulations – Shorelines and require a Shoreline Substantial Development Permit. Applications are submitted to Pierce County for review and require SEPA review. SEPA documents are reviewed by Ecology and WDFW. Any construction below the ordinary high-water mark (OHWM) may trigger additional reviews by Washington Department of Natural Resources, USACE, NMFS, NOAA, and/or the U.S. Coast Guard. If a new or replacement bulkhead is located above the OHWM and associated with an existing residence, the property owner may apply for an exemption to a Shoreline Substantial Development permit. A majority of the bulkheads in Pierce County have been installed through this exemption process. Shoreline stabilization is challenging because new structures can easily change the wave energy and sediment movement within a stretch of shoreline and negatively impact neighboring parcels.

Figure 6.112. Best Practices for Building Near a Shoreline

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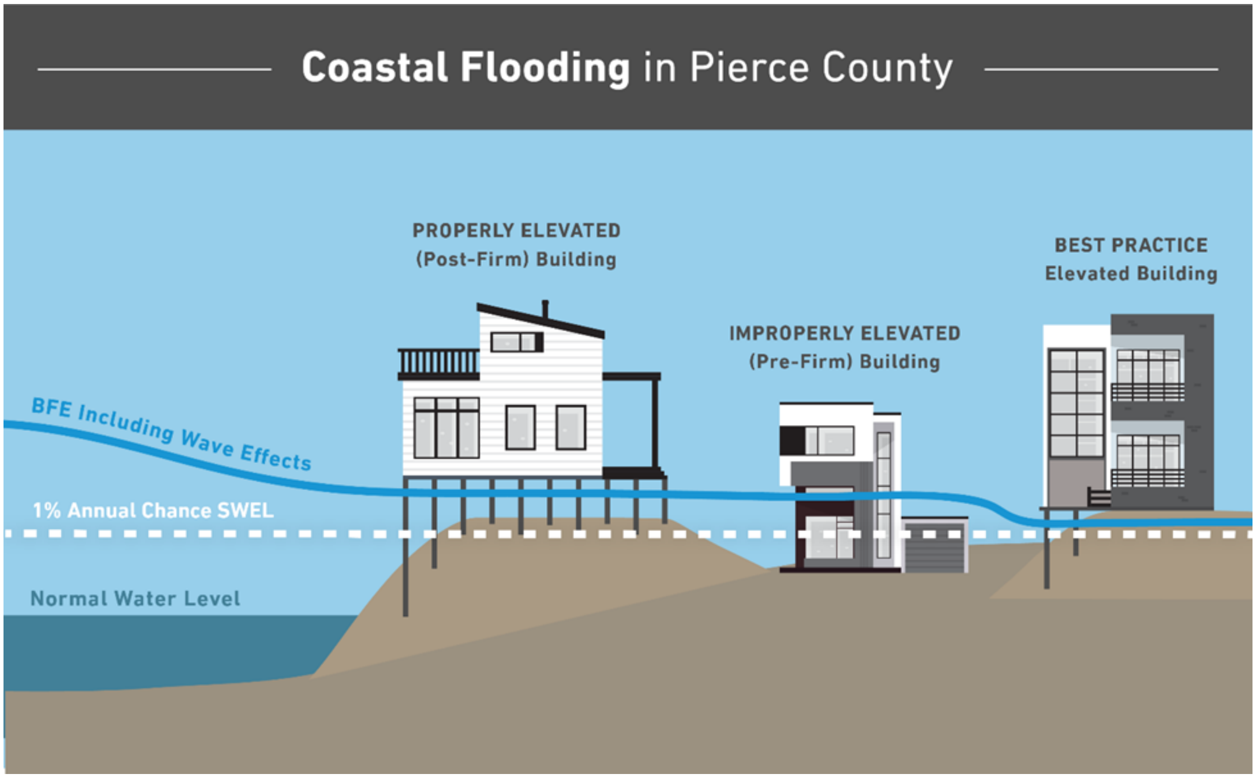


The structures used to convey and manage stormwater in coastal areas are similar to those used in other areas, with some exceptions. Nearshore facilities may need to be designed to accommodate back flow if they could become inundated during a high tide event. Materials chosen should tolerate exposure to saltwater. Tide gates are sometimes employed to prevent flood tide waters from backing up into streams or pipes. This creates a trade-off since the water from the upland side cannot discharge normally.

In landslide hazard areas, infiltration structures (which would normally be preferred) may cause slope stability issues. Pipes conveying stormwater over a bank need to be extended to the base of the slope and an energy dissipator incorporated to prevent erosion problems. Finally, any structures at the interface between fish-bearing streams and marine waters need to allow for the passage for anadromous fish.

The first stage in addressing coastal flooding is to complete an inventory of potential flood areas. This would include structures that have already experienced flood damage as well as determining which structures fall below the elevation of the highest tide recorded to date combined with a surge estimate for 10-year storm. Once mapped, this information should be used to estimate the percent of the community that could be flooded as well as the amount of employment, the demographics, and the economic capacity of the flood-prone area. These criteria can be used to assess the community's capacity to recover from a coastal flooding event.

The second stage would be to assess the capacity (or limitations) of existing flood control infrastructure to reduce the current risk. This would include identifying repairs and retrofits that could be done to existing facilities as well as recommendations for new facilities. Armor removal and soft armoring alternatives should be favored (where practical) because they create habitat and allow for natural sediment regimes. Improving flood protection facilities should be viewed as a means to prevent damage to existing infrastructure, not as justification to add additional development to the inventory of at-risk structures. Long-term plans should prioritize moving non-water-dependent development out of hazard areas. Projects in communities with less capacity to recover from flood events should be prioritized over those with more capacity.

Long-term monitoring and adaptive management need to be incorporated into coastal flood management planning. Evidence of future sea-level rise has been confirmed, and land that will be recruited into coastal flood hazard zones must be calculated, inventoried, and mapped. This predictive map should incorporate information on both the extent and expected frequency of future coastal flooding over time to allow for adaptive decision making. Also, ongoing sediment migration may change future hazard areas and should be tracked. Installing additional tide gauges within Pierce County, particularly in areas that are likely to respond to sea level rise in different ways, like the Vaughn area, would help inform predictions of future conditions.

6.15.2 Stakeholder Engagement and the Pathways Approach:

Over the course of a series of meetings with several cities (as shown in Figure 6.113), Pierce County developed a pathway that illustrates near- and long-term actions to address coastal flood hazards in unincorporated Pierce County. Meeting participants were asked to identify recent flooding problems in their community. Those locations were mapped and are shown in Figure 6.114. The pathway consists of a few near-term programmatic actions that will inform the development of targeted projects throughout unincorporated Pierce County, as shown in Figure 6.115. Some cities have also developed a general list of coastal flood hazards along with potential solutions to those hazards. Cities were encouraged to develop their own pathway to address coastal flood hazards within their jurisdiction, and these are included in Appendix E.

Figure 6.113. Participants of Coastal Flood Hazard Disappearing Task Group Meeting, March 2, 2022

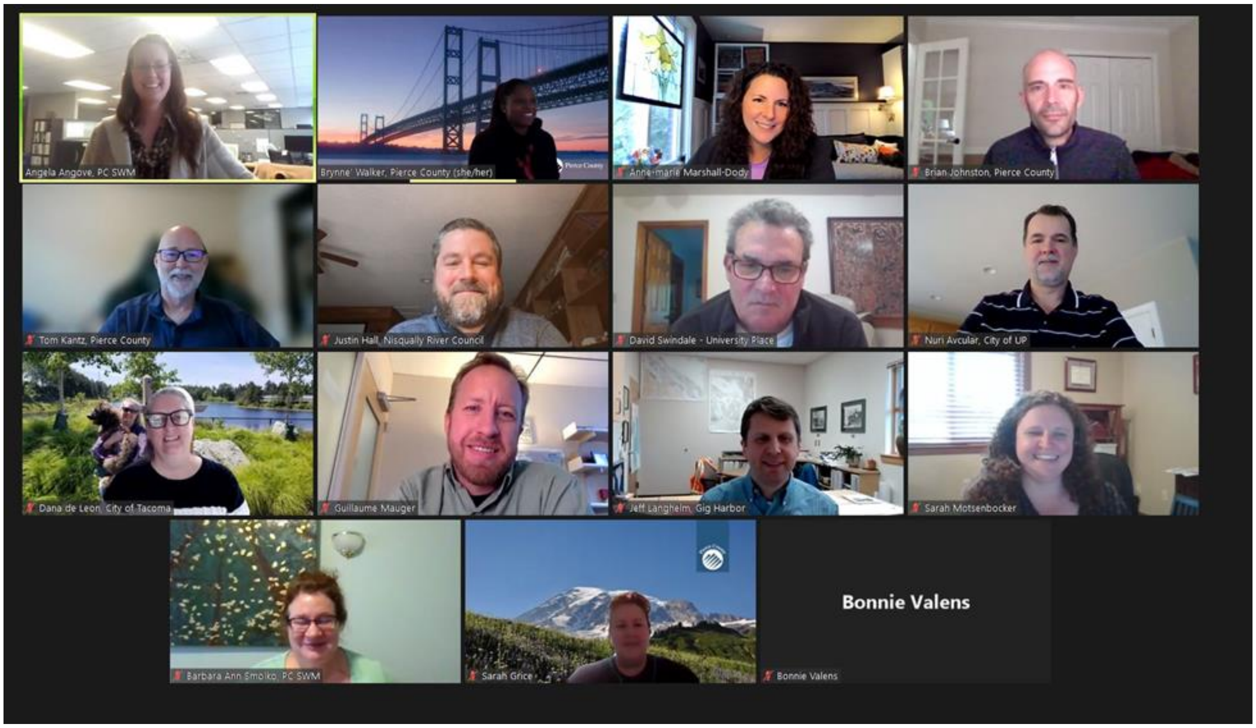


Figure 6.114. Observed Coastal Flooding Locations

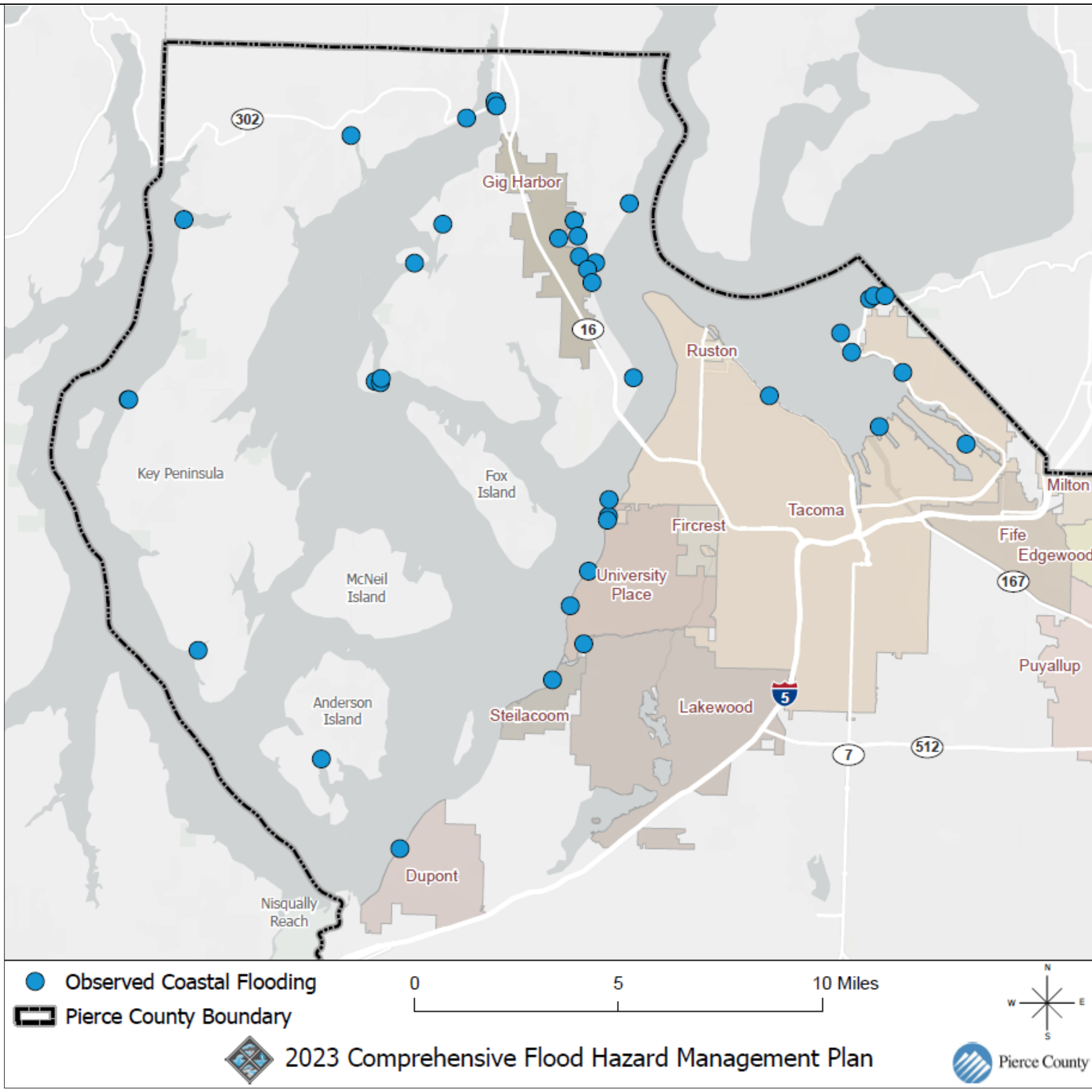
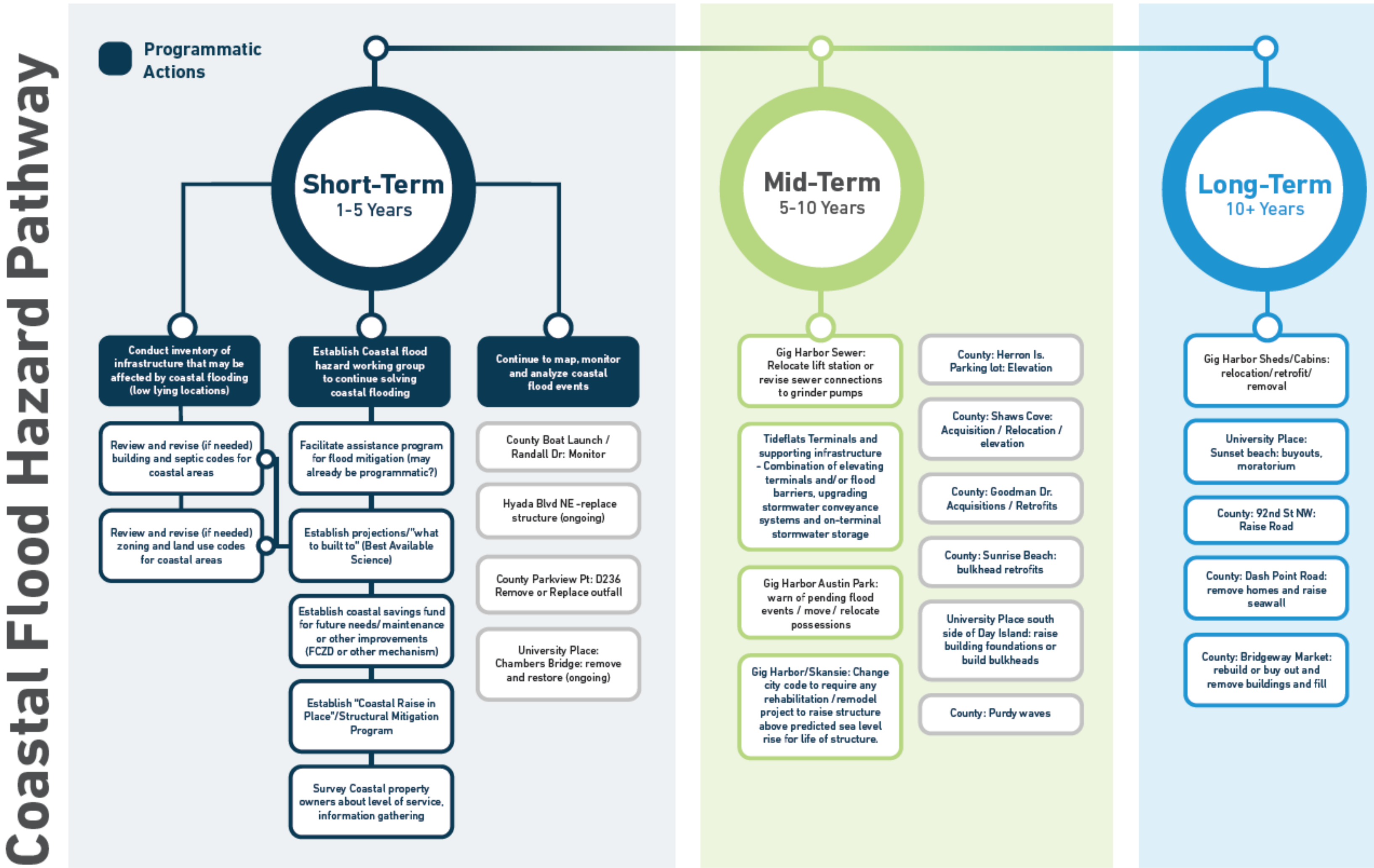


Figure 6.115. Coastal Flood Hazard Pathway



In the near-term, Pierce County has identified six programmatic actions that could take place to address coastal flood hazards:

- Review and revise building codes for septic retrofits.
- Establish coastal flood hazard working group in partnership with cities.
- Map, analyze, and monitor coastal flood events.
- Facilitate assistance program for flood mitigation.
- Establish a coastal “raise in place” mitigation program.
- Conduct inventory of infrastructure potentially affected by coastal flooding.

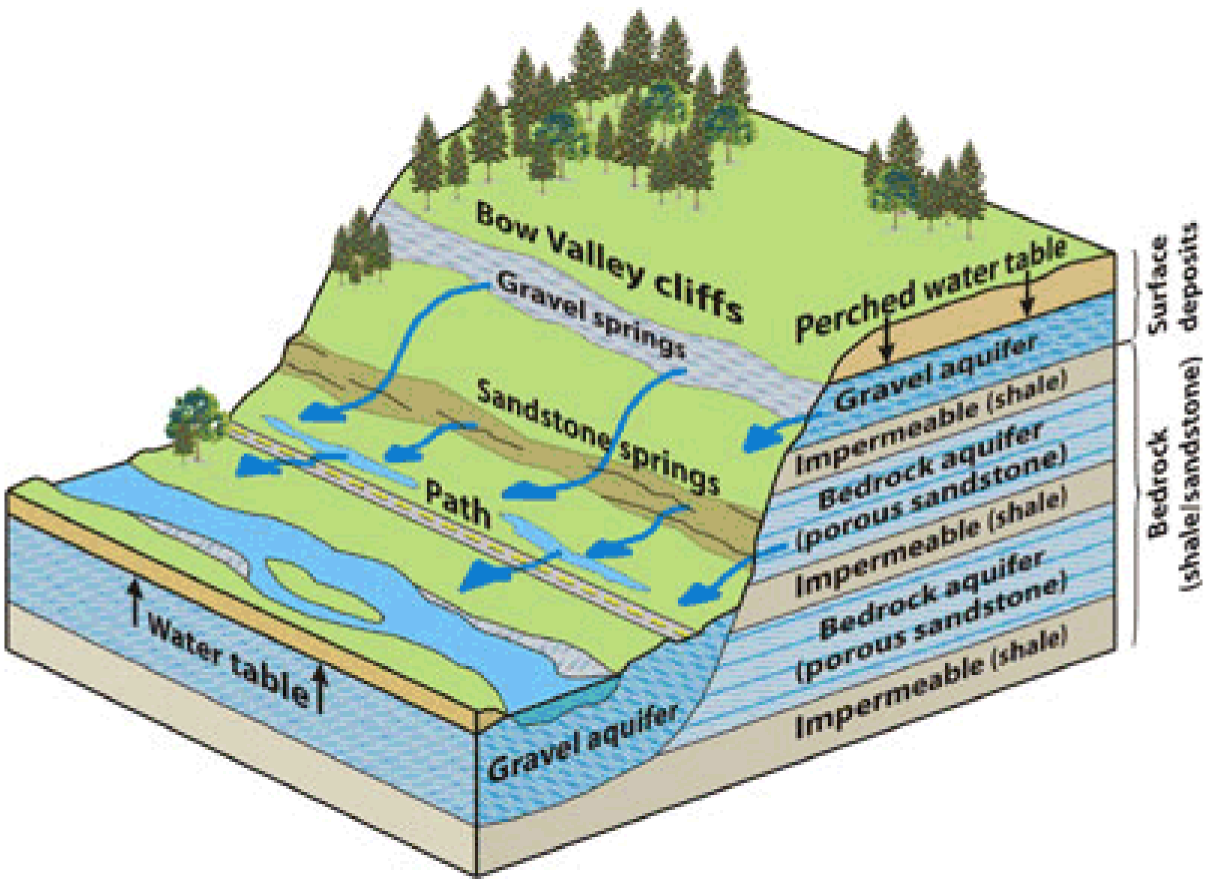
Following the above-mentioned actions, specific projects could occur at locations where coastal flooding is an ongoing concern. These would be subject to further study before initiating. The coastal flood hazard working group, comprised of Pierce County, cities, and other interested stakeholders, would meet regularly to analyze past flood events, propose solutions, and monitor outcomes.

6.16 Groundwater Flooding

6.16.1 Overview

Categorically, there are five general types of flooding that occur. Most people associate flooding with scenes of overbanking rivers, inundated lakefronts, or coastal flooding due to storm surges penetrating inland. Many residents of Pierce County have also observed or experienced other types of flooding, such as when heavy rain overwhelms the urban storm drains and disrupts the local road system. However, there's a lesser-known type of flooding called groundwater flooding. This condition implies the rise of the groundwater table to saturate the normally unsaturated upper part of the soil profile (see Figure 6.116).

Figure 6.116. Geomorphology and its Effect on Groundwater-Surface Water Connections
Source: USGS 2016



This daylighting of soil water can create temporary surface water flow paths, which sometimes cause flooding at further downslope locations. Groundwater flooding is often slower to occur than river flooding—it will usually happen days, weeks, or even months after heavy or prolonged rainfall. Also, during some particularly wet years, the seasonally high-water table may persist for weeks or even months before it subsides.

Groundwater flooding is common in landscapes where the underlying bedrock or hard pan is shallow and located just beneath the topsoil. However, it can also occur in highly porous soils, such as sand and gravel deposits. There are places in Pierce County where the groundwater periodically rises up through building foundations to create flooding in cellars and basements. Some parts of the county are more prone to groundwater flooding than others, including Pioneer Valley and Frederickson, where the groundwater level in March is strongly influenced by the amount of cumulative precipitation received during November, December, and January.

Soil Hydrodynamics and the Prediction Groundwater Flooding

The water table represents an underground boundary between the soil surface and the area where groundwater saturates the pore spaces between soil particles and rock. Water pressure and atmospheric pressure are equal at this boundary. Below the water table is the saturated zone, where water occupies all the interstitial spaces (voids) between soil particles. Hydrodynamics describes how the forces acting on or exerted by subsurface water are strongly governed by the soil and geologic materials it flows through. In order to plan for groundwater flooding and seasonal high-water tables, good predictive tools are critical. Since the behavior of groundwater is not usually observable, models must also be used to determine how groundwater will respond under different climatic scenarios or development-related conditions.

Groundwater Table Fluctuation within the Soil Profile (Hydroperiod)

Predicting groundwater flooding often starts by defining an area's hydroperiod. A detailed understanding of the depth, duration, and frequency of water table fluctuations over time makes it possible to calculate the hydroperiod. Throughout the year, the groundwater water table varies according to the amount of cumulative precipitation it receives by infiltration. When the entire soil profile below the ground surface is saturated, flooding occurs because all subsequent precipitation is forced to remain on the surface. This water may then runoff or pond. The amount of water a soil body can hold is largely dependent upon the vadose zone's thickness, texture, density, and the amount of intergranular porosity. These properties have a strong influence on a soil's ability to infiltrate, absorb (store), and transmit (drain and evacuate) water.

A helpful visual tool for understanding groundwater movement is the water table hydrograph. A hydrograph takes the hydroperiod data and plots the information over the course of a year. If hydrographs are created for several locations within a watershed, a comparison of the data can provide useful insight into the pattern of groundwater movement over time.

The information needed to define the hydroperiod can also provide the dataset necessary for developing a water budget, which attempts to quantify the amount of water entering and leaving a soil body over a designated period of time. The groundwater budget measures water inputs against water outputs to estimate the water storage capacity of the vadose zone. Inputs can include precipitation, surface water inflow, and groundwater inflow from higher elevation areas. Outputs can include groundwater outflow to lower elevation areas, deeper seepage to subjacent aquifers, and evapotranspiration (evaporation or uptake by plants).

Hydrologic Connectivity and its Influence on Hydroperiod

The stratigraphy and geomorphology of the lower Puget Sound is naturally complex. Our regional geology has a profound influence on the depth, duration, and areal extent of groundwater. The inherent complexity of our groundwater systems is compounded when the variability of inflows and outflows associated with a highly developed human landscape are added to the picture. This three-dimensional variability creates a seasonal groundwater table with significant ranges in depth, duration, and frequency. Land surface variability can create subtle elevational differences that create wetter and drier locations with different seasonal durations of saturation or ponding. This variability is driven by the local meteorology, the inherent physical geography, and amount of human-related development.

Land surface variability in a watershed is described as microtopography. Microtopographic features are defined as depressions and ridges that deviate less than a few feet in height or depth from the average land surface. The shape, pattern, and randomness of microtopographic features makes them difficult to delineate but they can have a profound effect on where areas of repeated groundwater flooding are located. Subtle microtopographic features can be naturally occurring, or they can be created by human development, but both can have a profound effect of the local soils hydroperiod.

> **The *Vashon Glaciation* is a local term for the most recent period of very cold climate during which at its peak, glaciers covered the entire Salish Sea as well as present day Seattle, Tacoma, Olympia, and other surrounding areas in the western part of present-day Washington.**

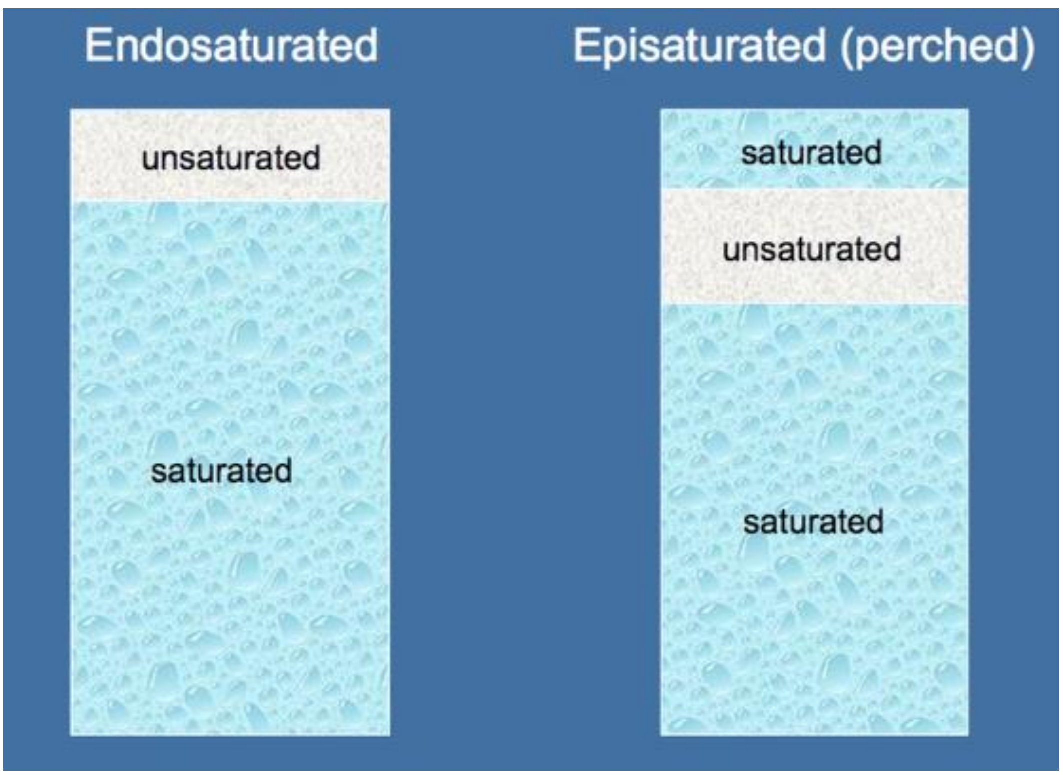
The Vashon glaciation significantly shaped the surface geomorphology of central and western Pierce County. This geologic period produced layers of soil deposits with distinctive physical characteristics. For example, there are highly permeable layers composed of coarse sand and gravel deposited by the advancing ice sheet (outwash), but there are also layers of densely compacted silt, sand, and gravel that were formed underneath the ice sheet (basal till) that are highly impermeable. The advancing and retreating ice sheets were responsible for scouring large landforms and depositing a wide assortment of sediments. Groundwater connectivity across the landscape is strongly controlled by this geologic architecture. Water moves easily through the permeable layers but is constrained by impermeable till and clay layers. Water will flow down vertically until it reaches an impermeable layer, then perch on top of it or move sideways. Because Pierce County is located in an area that has experienced a number of glacial events, there are many alternating layers of permeable and impermeable soils, with each permeable layer hosting a different aquifer.

Groundwater is strongly influenced by precipitation. The water table can rise slowly as water accumulates over the wet season or it can rise quickly during storm events. A storm event that occurs when groundwater levels are already high at the end of the wet season can have very different outcomes than one that occurs after a long dry period. The water table elevation is typically at its lowest during the summer and at its highest during the winter. If high enough, surface water elevation can be a direct reflection of the groundwater elevation. When microtopographic depressions fill with water, it is assumed to be at the same elevation as the water table in the surrounding soil. For example, the ponds located near 192nd Street East and 204th Street East in the Frederickson area only fill -up when the surrounding groundwater table rises. Pierce County staff report that the water surface level of the ponds consistently fluctuates in relation to the level of the surrounding groundwater table.

Endosaturation as a Source of Groundwater Flooding

Endosaturated soils have a water table that starts at the surface and extends downward to a connect with the groundwater table, as seen in Figure 6.117. Under these conditions, the water table moves laterally and vertically to saturate the soil profile up to the surface (upwelling). The water inputs can be supplied through precipitation or from subsurface interflow migrating downslope to settle and overwhelm the storage capacity of the valley soils (raising the water table). Confirming the presence of endosaturation is very informative for managing areas that experience repeated flooding due to high groundwater. In endosaturated soils, there is often a high degree of correspondence between the stream or coastal tidal gauge and the groundwater table elevation.

Figure 6.117. Episaturation versus Endosaturation
Source: ASWM 2017



When an endosaturated bottomland has microtopographic depressions filled with surface water, it is assumed to be at the same elevation as the water table in the surrounding soil. For example, the ponds located near 192nd Street East and 204th Street East are apparently experiencing endosaturation because they only fill-up when the surrounding groundwater table rises. Pierce County staff report that the water surface level of the ponds fluctuates in relation to the level of the surrounding groundwater table.

Episaturation as a Source of Groundwater Flooding

Episaturated conditions are when the water table is supplied only through the infiltration of precipitation or the concentrated collection of surface runoff, as seen in Figure 6.118. These soils can experience inundation for long periods of time in a perched water table or ponded condition. This condition is commonly associated with topographic features such as vernal pools or other shallow undulations, or concavities found across the landscape. In these features, rainwater is collected and retained (ponds) after the runoff has receded across most of the landscape. The ponding occurs because the saturated soil and standing water are suspended or perched on a low permeability layer of fine-grained compacted sediment.

Episaturated soils are those where the dominant water source affecting the water table is exclusively supplied from the surface through precipitation and runoff concentrating in depressions. Long-term ponding of surface water exists because the saturated hydraulic conductivity (permeability) of the perching layer is low due to a high clay content or the cementation of sediments. A perched water table is a localized accumulation of groundwater that saturates a vertically suspended body of soil located above the unconfined aquifer and separated by an unsaturated zone. The groundwater is trapped above an impermeable soil layer to create an isolated inclusion of saturated soil and high-water table in the otherwise unsaturated soil body (layer). Ponded water that is perched on a low -permeability soil tends to be ephemeral, forming in the winter or spring and disappearing in the summer due to evaporation and slow infiltration. The Kapowsin gravelly loam is a local soil with a low permeability substratum known to perch groundwater during the rainy season.

Groundwater Flooding and Water Quality

Water quality is of particular importance when managing groundwater. A large portion of Pierce County has been designated a sole source aquifer by the U.S. Environmental Protection Agency, and most residents rely on groundwater as their only source of drinking water. Preventing contamination of groundwater is a significant human health issue and responsibility for the county. Ironically, discharging wastewater and stormwater into the ground is a common practice for removing pollutants. Some vadose zone soils can provide excellent filtration and treatment and others cannot. Understanding these limitations and managing them effectively is an important part of groundwater planning.

The *vadose zone* is the layer of subsurface that extends from the ground surface to the regional groundwater table.

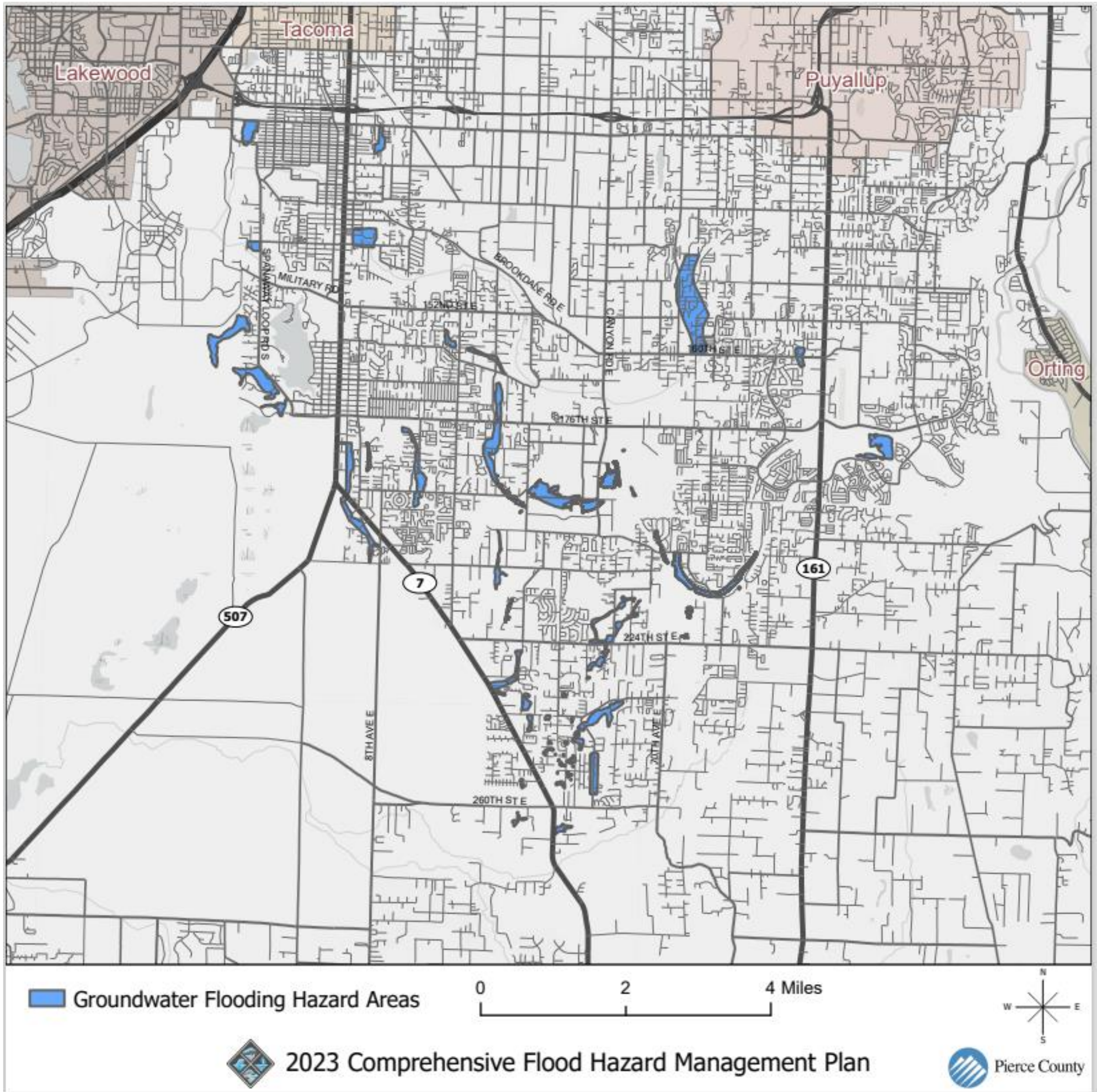
Septic or on-site wastewater treatment systems are the most common systems to rely on soil to treat water pollution. Septic systems discharge effluent to shallow soils for treatment. The vadose zone provides the aerobic treatment after the anaerobic treatment that occurs within the septic tank. This combination allows for more complete processing of the waste. These systems rely heavily on the suitability of the native soil to effectively treat the effluent. Ideally, the soil would be well-drained, have an appropriate mix of sand and clay, have a healthy community of microbes, and the depth to the seasonal high-water table would be substantial. On-site septic system designers are responsible for confirming the vertical separation between the top of the seasonal high-water table and the bottom of the drainfield. Most on-site septic system designs require an accurate assessment of the soil profile to ensure the vadose zone's ability to treat effluent will function properly for the entire life of the system. Groundwater flooding or vadose zone inundation by high groundwater levels can cause septic system failures, including septic tank overflows, in-home backups, and/or a direct discharge of untreated effluent to the county's receiving waters.

Pollutants common to septic tank effluent include total suspended solids; biochemical oxygen demand; nutrients such as nitrogen and phosphorus; and pathogens such as protozoa, bacteria, and viruses. In general, the vadose zone presents a hostile living environment for septic microorganisms. Unsaturated, aerobic soils contain naturally occurring microbes that provide many vital biological wastewater treatment processes. Soil microbes play a major role in organic matter degradation and consumption of nitrogen, including the removal of pathogenic bacteria, protozoa, and viruses. If aerobic conditions are maintained in the vadose zone, soil microbe populations can actually benefit from the addition of nutrients, organic matter, and other microbes present in septic tank effluent. The important point is that the ability of the vadose zone to remove or inactivate these contaminants depends upon whether it available for treatment (unsaturated) or not (inundated by high groundwater).

Planning for Groundwater Flooding Hazard Areas

Figure 6.118 represents Pierce County's first version of a Groundwater Flood Hazard Areas map. It was compiled from overlaying a number of different sources of information for the Clover Creek watershed and central Pierce County. The county used its FEMA groundwater flooding maps and a number of different groundwater studies it had sponsored over the years to help delineate the areas shown. The map was reviewed with the USGS and veteran staff at the county to help confirm this initial overlay of areas known to be susceptible to groundwater flooding. The county will continue to develop additional information to refine its understanding as to where these areas are, and to cover the remaining areas of the county where there are limited data available to map these hazard areas.

Figure 6.118. Observed Groundwater Flood Hazard, Central Pierce County



In 2006, the USGS Washington Water Science Center and the Department of Ecology began a substantive project to help improve our understanding of the groundwater-flow system in the Chambers-Clover Creek watershed. In 2023, the USGS will officially release its Chambers-Clover Creek groundwater-flow model. This model will provide a more accurate simulation of groundwater dynamics in the Chambers-Clover Creek watershed and central Pierce County. The availability and use of this model will greatly enhance the county's ability to predict groundwater flooding and further develop its groundwater management strategies.

One of those strategies that will be developed in the near-term is the installation of a sentinel groundwater monitoring network to track the advancement and subsidence of the seasonally high-water table in areas prone to groundwater flooding. The purpose of a sentinel network is to provide advanced warning of a local groundwater table's rise to saturate the area's vadose zone and cause surface flooding.

The vadose zone provides a critical service to Pierce County residents because it provides hydrologic storage during the winter and spring, and it provides water quality treatment for on-site septic systems year-round. If the vadose zone is saturated and a significant cluster of properties are experiencing groundwater flooding, then the county should know how many on-site wastewater treatment systems may be operationally impaired due to a persistently high-water table. Until a long-term set of solutions are conceived and implemented, a predictive sentinel groundwater monitoring network could be useful as an early warning tool for each potential flooding season and for delineating areas likely to be flooded under various precipitation scenarios.

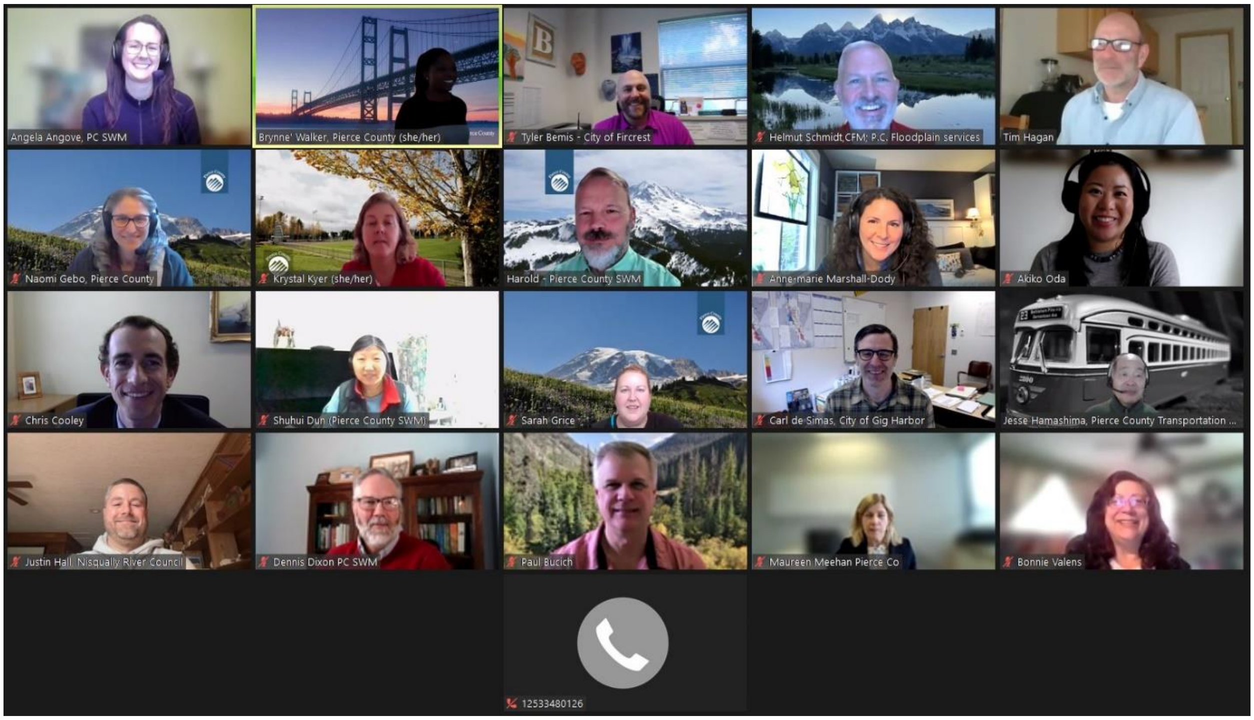
Pierce County works diligently to reduce flood risks in many ways. Planning and Public Works has a well-coordinated program for living with rivers, reducing flood risks, restoring floodplains, educating the public, and working with our local partners to increase resiliency. However, many of the traditional methods of riverine flood risk reduction are not effective when attempting to manage the occurrence and impact of groundwater flooding. This is because many stormwater management designs rely on infiltrating excess water to the vadose zone, which is not an option when the ground is already saturated. Pierce County currently manages groundwater flooding by requiring new development projects to mitigate the risk through planning, avoidance, elevating structures, and monitoring. This 2023 Flood Plan has a strategic vision for managing multiple sources of flooding, including recommendations for some areas of the county that have experienced repeated groundwater flooding.

6.16.2 Stakeholder Engagement and the Pathways Approach:

Over the course of a series of meetings with several cities (as seen in Figure 6.119), Pierce County developed a pathway that illustrates near- and long-term actions to address groundwater flood hazards in unincorporated Pierce County. Meeting participants were asked to identify flooding problems in their community. Those locations were mapped and are shown in Figure 6.118.

The pathway consists of a few near -term programmatic actions that will inform the development of targeted projects throughout unincorporated Pierce County. Some cities have also developed a general list of groundwater flood hazards along with potential solutions to those hazards. Cities were encouraged to develop their own pathway to address groundwater flood hazards within their cities and are included in Appendix E.

Figure 6.119. Participants of the April 13, 2022, Groundwater Flood Hazard Disappearing Task Group Meeting



In the near-term, Pierce County has identified several near-term actions to address groundwater flood hazards:

1. Pierce County groundwater flood hazard team to work on the following near-term actions:

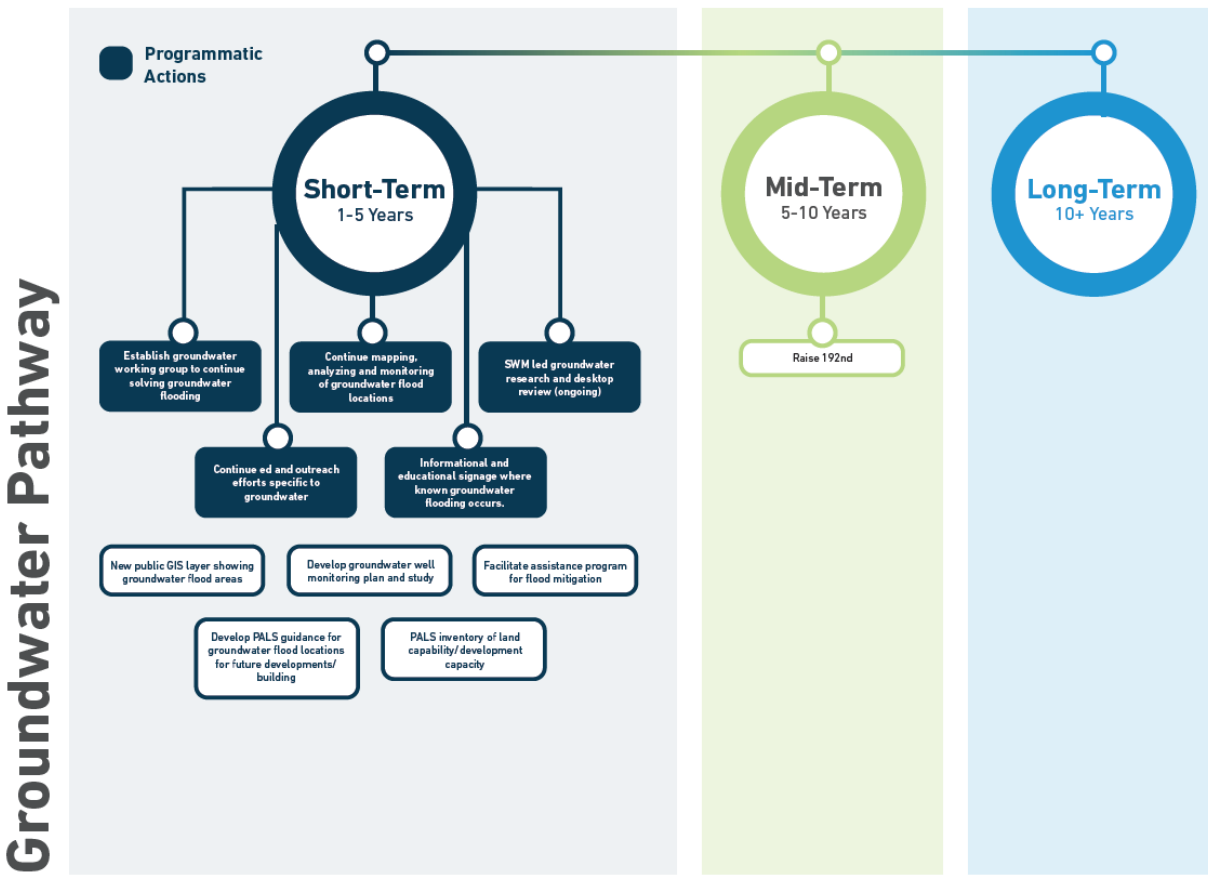
- Conduct staff and stakeholder interviews to develop groundwater flooding area boundaries.
- Conduct surface rainfall-runoff and shallow groundwater data collection and modeling.
- Conduct literature review of county sponsored flood reports.
- Review county wetland inventory to confirm, refine, or correct groundwater flooding delineations from previous efforts.
- Review county FIRMs for groundwater flooding.
- Review National Resource Conservation Service Soil Service Geographic Database to confirm, refine, or correct groundwater delineations developed from previous efforts.
- Run USGS Chambers-Clover regional groundwater model to confirm, refine, or correct groundwater flooding delineations from previous efforts.
- Develop Pierce County GIS groundwater flooding hazards map.

2. Establish groundwater flood hazard working group in partnership with cities.

- Map, analyze, and monitor groundwater flood events.
- Continue educational and outreach efforts specific to groundwater flood hazards.
- Create and install informational and educational signage in areas affected by groundwater flooding.

Following the above-mentioned actions, specific projects could occur at locations where groundwater flooding is an ongoing concern. Those future project locations would be subject to further study before initiating. The groundwater flood hazard working group, composed of Pierce County, cities, and other interested stakeholders, would meet regularly to analyze past flood events, propose solutions, and monitor outcomes. These actions are outlined in the pathway in Figure 6.120.

Figure 6.120. Groundwater Pathway



7 Flood Plan Implementation and Funding

This chapter describes the implementation framework, implementation steps, and funding options to accomplish the projects and programmatic recommendations of this 2023 Flood Plan. This plan, and its proposed policies, projects, and programs, is based on the premise that major flooding in Pierce County is a regional issue that requires regional collaboration, partnerships, and funding.

Maintaining and improving Pierce County's flood risk reduction infrastructure and programs is important for public safety and for the economic vitality of the county. The current limited recommended design and management strategies for ongoing maintenance, repair, and other river-related flood hazard reduction programs will result in Pierce County residents facing safety issues and flood and channel migration risks that have severe effects on personal finances and economic stability.

Pierce County faces significant challenges in the years ahead, including an aging system of flood risk reduction facilities along the river systems; many of these facilities were built between the 1930s and 1960s and constructed to a lower level of protection than is required today. In addition, areas with levees and revetments that were unincorporated at the time of construction are now in cities and towns. Failure of these facilities would have significant adverse impacts on public safety, public infrastructure, private property, and the regional economy. In some areas, the dynamic nature of rivers, increases in sediment transport, channel migration, and more frequent and intense high flows are resulting in rising riverbeds, reduced river channel conveyance capacity, and increased flood risks. The environmental requirements resulting from administration of the ESA, the Clean Water Act, the Growth Management Act, and other legislation has significantly increased the difficulty and cost of maintaining flood risk reduction facilities. Coastal, urban, and groundwater flood loss reduction projects are similarly financially constrained.

Existing funds generally pay for maintenance and repair of flood risk reduction facilities. Major repairs usually are associated with damage from flood events, thus making them eligible for federal and state funds. New construction is almost entirely dependent upon funding from the Pierce County Flood Control Zone District, which is limited, and grants, which are difficult to secure and often do not provide enough funds to contribute a meaningful amount of total project costs. Other sources of existing funding include a portion of SWM fees collected from residents and businesses in unincorporated Pierce County, a small portion of the Real Estate Excise Tax (REET) and designated federal and state funds that are conditionally available in declared flood disasters.

Flooding and channel migration risks on the major rivers in Pierce County transcend political boundaries, so funding of major flood control projects requires regional coordination. Similarly, actions taken in one area of the watershed can affect flooding downstream or across the river, which also requires multi-jurisdictional coordination. Solutions for coastal, urban, and groundwater flood issues tend to be more localized; however, such solutions result in many benefits from an interjurisdictional approach.

7.1 Plan Implementation

The 2023 Flood Plan implementation will result in multiple public benefits, including reduction in the impacts of riverine, coastal, urban, and groundwater flooding; protection of roads and other critical facilities that support regional mobility, public safety, and economic viability; enhancement of aquatic habitat; and protection of open space within floodplains.

Changing conditions within natural systems and improved understanding of flood risk reduction facilities, sediment management, and overall floodplain management will influence how recommendations of this plan are carried out. New data, mapping, studies, and monitoring information will be used to expand on conceptual projects designs.

The rate of implementation for this 2023 Flood Plan will depend on several factors: the funding available, the extent and severity of future flooding, the benefit-cost analysis existing at the time of potential funding, and other considerations. The order of project implementation for this plan will vary due to factors such as availability of funds, completion of other projects or activities on which a project relies, cooperation from private landowners, and new information or emerging issues that need to be addressed sooner rather than later.

7.2 Pierce County Role in Plan Implementation

This 2023 Flood Plan will be adopted by reference as part of PCC, Title 19D.60, as well as other comprehensive planning documents and the Pierce County Storm Drainage and Surface Water Management Plan, which is a part of the Pierce County Comprehensive Plan (Comprehensive Plan). This 2023 Flood Plan will replace Pierce County's 2013 Flood Plan.

After adoption of this plan, SWM will identify the capital improvement projects presented herein to add to the Capital Facilities Element of the Comprehensive Plan, which is updated bi-annually and includes projects capital expenses over six years. Pierce County will seek to partner with local governments on capital projects and maintenance and operations of flood risk reduction facilities in incorporated areas.

When implementing capital recommendations, Pierce County uses its Project Delivery Manual to ensure that design, permitting, and property rights acquisition are coordinated for reliable project delivery. The Project Delivery Manual is a combination of checklists, scheduling guidelines, and template documents, which are updated continuously to accommodate changes in regulatory processes and best practices for engineering design.

Pierce County, in its historical role of providing facilities and services to reduce flooding and channel migration risks, will lead the 2023 Flood Plan implementation and build upon the county's history of coordinating and partnering with other local governments, Tribes, state and federal agencies, and the public to reduce flood risks.

The Pierce County SWM provides regional flood risk reduction services primarily to unincorporated areas of the county as well as maintaining levees and revetments in incorporated areas. This includes maintenance, repair, and capital projects on levees and revetments on the Puyallup, White, Carbon, and Nisqually rivers as well as numerous programs to reduce flood risks, such as education and outreach, floodplain mapping, technical assistance, floodplain acquisition, monitoring, and sediment management. Close coordination will be necessary between SWM other Pierce County departments, cities, Tribes, state and federal agencies, and other stakeholders to successfully implement this 2023 Flood Plan and reduce the risks of flooding and channel migration.

Other county services that will assist plan implementation include emergency management operations; road maintenance and bridge projects; private development permitting; habitat restoration projects and programs; and parks and recreation, open space, and regional trail management. SWM coordinates flood warning and emergency response with Pierce County Emergency Management; cities; and other regional, state, and federal partners. Regulation of floodplain development and technical assistance are coordinated with Pierce County Planning and Land Services and private landowners.

7.3 Role of Cities, Towns and Special Purpose Districts in Plan Implementation

All communities that are required to plan under the Washington State Growth Management Act (Chapter 36.70A Revised Code of Washington [RCW]) must adopt regulations for the protection of frequently flooded areas. Communities must also comply with regulations for floodplain management adopted under the Flood Control by Counties Act (Chapter 86.12 RCW). Additionally, to remain eligible for the National Flood Insurance Program, communities must comply with the requirements of the Biological Opinion issued by the NMFS for compliance with the ESA. The Biological Opinion includes habitat conservation recommendations to further the recovery of listed species.

Chapter 86.12 RCW requires all jurisdictions within the planning area to participate in the development of a comprehensive flood hazard management plan and adopt the plan for implementation in their own community. Pierce County recognizes that each local jurisdiction has different levels of existing floodplain development, resources for implementing flood hazard management programs, and staff for enforcing regulations. Complete adoption of the policies and other elements of this 2023 Flood Plan may not be appropriate, but it is critical that flood hazard regulations and programs not have an adverse impact on other jurisdictions.

Special Purpose Districts are limited local purpose governments separate from a county, city or town. In Pierce County, several special purpose districts have an interest in or are impacted by flood hazards, including, but not limited to, the Port of Tacoma, drainage districts, water districts, and fire protection districts. Coordination with interested special purpose districts will be critical to successful implementation of this plan.

Following adoption of this 2023 Flood Plan and commitment of funding, Pierce County will provide technical assistance to help incorporated cities and towns develop policies, regulations, and programs that are consistent with this plan, when funding and staffing are available. City, town and special purpose district participation is integral in implementing the programmatic recommendations that are listed in this plan.

7.4 Role of Tribes in Implementation

The Puyallup Tribe, Nisqually Tribe, Squaxin Island Tribe, and Muckleshoot Tribe have lived along the river systems and coastal areas of Pierce County for thousands of years. Prior to and during treaty times, the Tribes have had usual and accustomed fishing grounds throughout the Puyallup and Nisqually river basins. Ongoing coordination between Pierce County and the Tribes is integral in implementing capital projects in Pierce County as well as the programmatic recommendations listed in this flood plan.

7.5 Role of State and Federal Agencies

The state and federal agencies play an important role in flood hazard management program implementation. State agencies include Ecology, WDFW, and WDNR. Ecology is responsible for reviewing and approving this 2023 Flood Plan, administers the state's Flood Control Account Assistance Program, provides guidance on channel migration zone mapping, and administers the Section 401 water quality certification program for proposed projects. The WDFW issues hydraulic project approvals for capital projects and gravel removal activities. The WDNR has a role in gravel removal activities.

Federal agencies active in flood hazard management activities include the USACE, FEMA, NMFS, USFWS, and National Park Service. The USACE sponsors emergency response and rehabilitation activities under Public Law (PL) 84-99 and issues permits for Section 404 activities, gravel removal, and work in navigable waters. The USACE also operates Mud Mountain Dam on the White River for flood control on the lower White and Puyallup rivers. FEMA provides federally backed insurance through the National Flood Insurance Program, maps special flood hazard areas, and oversees implementation of the new requirements under the Biological Opinion through the NMFS. The NMFS and USFWS provide consultation on all projects and programs with a federal nexus (funding or permits) to ensure compliance with the ESA (particularly as it relates to Chinook salmon, steelhead, and bull trout). The National Park Service works closely with Pierce County along the upper Nisqually River in relation to the gateway levee and revetment that helps protect the year-round entrance to Mount Rainier National Park. Ongoing state and federal coordination is integral in implementing the capital projects and programmatic recommendations that are listed in this plan.

7.6 Funding

One of the five goals of this 2023 Flood Plan is to "address all flooding in this plan in a cost-effective and financially achievable manner over a 10-year period" (see Section 1.3, Goals, in

Chapter 1, Introduction). Although this plan does not recommend a particular type of funding, it does advocate for equitable funding and system-wide continuity of flood control maintenance, operations, and improvements. The integrity of the flood management system relies on its continuity, which relies on long-range planning, construction, monitoring, maintenance, and a reliable funding source.

7.7 Current Funding

The primary source of funding to implement the recommendations of this 2023 Flood Plan is Pierce County's SWM fund, which collects a user fee from residents and businesses in unincorporated Pierce County. Another major source of funding is the Pierce County Flood Control Zone District, which collects tax revenue from all parcels in Pierce County, including within incorporated areas. The district allocates funding to Pierce County for both capital projects and in support of maintenance of the existing levee system.

Other fund sources include a portion of the REET; state grant programs focused on fish passage, habitat restoration, and resource conservation; and occasional federal and state funds that are available in declared flood disasters. Table 7.1 shows the amount of SWM, FCZD, and REET funds expended on river programs, maintenance and operations, capital projects, and acquisitions over the past 20 years. In recent years, cities, including Orting and Sumner, have also expended city revenues and other funds to advance levee and floodwall capital projects, including acquisition, design, and permitting, but this is not included in Table 7.1.

Table 7.1 Annual Expenditures for River Management Programs, Operations and Maintenance, Capital Projects, and Acquisitions (2010–2021)

Year	SWM Fund	REET	Flood Control Zone District	Total
2010	$2,597,370	$2,003,128	N/A	$4,600,498
2011	N/A	$3,289,932	N/A	$3,289,932
2012	$4,899,599	$7,883,820	$118,451	$12,901,870
2013	$6,861,920	$850,172	$1,207,570	$8,929,662
2014	$8,960,385	$2,846,921	$8,230,052	$20,037,358
2015	$10,273,127	$3,240,949	$6,809,082	$20,323,158
2016	$6,873,590	$2,630,119	$4,444,406	$13,948,115
2017	$14,093,998	$8,429,897	$ 2,444,000	$24,967,895
2018	$9,516,707	$2,336,280	$2,479,900	$14,332,887
2019	$8,065,338	$1,546,900	$3,060,000	$12,672,230
2020–2021	$5,966,912	$1,313,000	$3,743,000	$11,022,912
Total	**$78,108,946**	**$36,371,118**	**$32,536,461**	**$147,026,517**

State and federal funding assistance are occasionally available to Pierce County; however, none of these can be relied upon. For nationwide federal programs, Pierce County often competes with flood and hazard damages that occur elsewhere in the U.S., such as flooding in the Mississippi River valley, forest fires in California, and hurricanes in the Gulf of Mexico. These areas are often able to secure the majority of available federal disaster relief funds, often eliminating or reducing available money for Pierce County.

Sources of federal and state funding to implement flood damage and mitigation projects include the following:

- Federal Emergency Management Agency
  - Hazard Mitigation Grant Program, which is typically made available following a Presidential Declared Disaster and administered by local jurisdictions
  - Building Resilient Infrastructure and Communities
  - Flood Mitigation Assistance

- U. S. Department of Interior
  - Natural Resource Damage Assessment Restoration Program

- Washington State Department of Ecology
  - Flood Control Account Assistance Program
  - Coastal Protection Fund – Terry Husseman Account
  - Floodplains by Design Grant Program
  - Stormwater Capacity Grant
  - Stormwater Grants of Regional or Statewide Significance
  - Streamflow Restoration Program
  - Water Quality Combined Funding
  - Wetlands Conservation Grant

- State of Washington Recreation and Conservation Office
  - Brian Abbott Fish Barrier Removal Board
  - Salmon Recovery Funding Board
  - Salmon Recovery and Puget Sound Acquisition and Restoration

The availability of these competitive fund sources is dependent on both federal and state budgeting processes, with funding levels varying dramatically from year to year. Others are only available following federally declared disasters. There is no dedicated fund or amount that is made available to Pierce County under these sources. State and federal funds can only help supplement implementation of the 2023 Flood Plan but cannot be relied on for predictable, reliable, or long-term operational and capital needs.

Additionally, most of the grant programs listed above require local matching funds, typically 25 percent, which underscores the need for reliable local funding.

7.7.1 Potential New and Enhanced Local Funding Options

Pierce County's current funding levels do not provide sufficient funding to address the existing needs for flood risk reduction facilities, including maintenance, repair, and capital needs. The county currently relies heavily on grants and other non-dedicated funding sources to provide some of these essential programs. As noted previously, grants cannot be relied upon as a stable funding source. Existing dedicated funding sources must be enhanced in order for Pierce County to provide consistent flood and channel migration zone hazard services and implement preventive projects and programs to reverse the trends of declining levels of protection. The section below describes new and enhanced funding options.

7.7.2 Flood Control Zone District Levy or Fee

The RCW 86.15.025 gives the Pierce County Council the authority to establish either county-wide or basin-level FCZDs that create additional opportunities for new, dedicated funding sources. An FCZD is a special purpose district (government agency) established to specifically address flooding issues. The purpose of the FCZD is to construct, operate, and maintain flood control projects to reduce flooding and channel migration risks. Funding for an FCZD can be initiated through a levy based on total assessed value of taxable property within the district's designated boundaries or through the imposition of fees.

On April 3, 2012, the Pierce County Council passed Ordinance 2011-95s, which created the Pierce County Flood Control Zone District. This FCZD can levy up to $0.50 per $1,000 assessed value. To date, the FCZD has chosen to limit its levy to $0.10 per $1,000 of assessed value. In 2023, the FCZD levy amount was $19.1 million per year.

Just as Pierce County periodically undertakes a rate study for SWM, the FCZD is encouraged to periodically review its levy rate to ensure that the needs of the community it serves are fully met.

7.7.3 River Improvement Fund Levy

The RCW 86.12.010 gives the Pierce County Council the authority to establish a county tax for a river improvement fund (e.g., flood control maintenance account). Washington state law allows it to be assessed up to $0.25 per $1,000 of assessed value. The River Improvement Fund levy is limited because the levy competes with other mandatory and essential services that are also funded by levies, and together they cannot exceed statutory levy limits.

Pierce County does not currently use this funding option.

7.7.4 Surface Water Management Service Charge

The RCW 36.89 allows Pierce County the authority to assess surface water management service charges for managing surface water. Pierce County provides surface water management services in unincorporated Pierce County that are funded by an annual surface water management service charge assessed on residential and commercial properties. The SWM service charge helps fund a variety of ongoing county projects and programs including flood management, levee repairs, NPDES municipal stormwater permit compliance, preventing water pollution, salmon recovery, and drainage system construction and maintenance. Additionally, incorporated cities within Pierce County, as well as King, Lewis, Mason and Thurston counties, can or do have local surface water management service charges. The SWM service charge from all these jurisdictions could be increased to specifically pay for additional flood management programs and capital projects.

7.7.5 Interlocal Agreements

Local governments within Pierce County, including cities and towns, can jointly fund implementation of this 2023 Flood Plan through an interlocal agreement (ILA), as authorized by RCW 39.34, Interlocal Cooperation Act. Through the ILA, local governments can use any variety of local funds they choose, such as general funds, the SWM fund, or road funds. Local governments would agree on the regional flood management services to be provided by Pierce County and the fair funding share. Individual ILAs would be developed between Pierce County and all participating jurisdictions.

7.8 Financial Rate Study

The last formal rate study for SWM was completed in 2015. The current rate structure is based on work done by SWM staff, leveraging the 2015 study. Given the continued evolution of services provided by SWM, and the comprehensive nature of this flood plan, SWM anticipates performing an updated rate study in 2024.

Pierce County SWM anticipated the near-term recommendations of this 2023 Flood Plan during preparation of the 2023-2025 Budget. A future updated rate study will inform implementation of mid term and long term recommendations.

Implementation of an updated rate structure would require an amendment of PCC 11.02 by Ordinance, approved by the Pierce County Council; this action will occur independently of Council action to adopt this study.

7.9 Future Plan Revisions and Updates

It is expected that the Pierce County Comprehensive Flood Hazard Management Plan will be updated every five years, as required by the Community Rating System (CRS) of the National Flood Insurance Program. Progress of the plan will be monitored on an annual basis to support the CRS recertification process. Future updates will include the following:

- Creating a Levee Vacation study
- Creating infrastructure pathways diagrams for the following flood problems in Pierce County:
  - North Levee Road
  - River Road Levee & Flood Wall
  - Riverside

- Leach Road Puyallup Left Bank
- Puyallup Ford Levee
- High Cedars

- Study future flooding conditions from sea level rise on drainage throughout the County
- Conducting a hydrology recalibration analysis
- Provide a status update on the programmatic recommendations and capital projects listed in this plan.
- Provide a status update on the problem descriptions identified in the 2013 Rivers Flood Hazard Management Plan (Appendix G)
- Conduct a Financial Rate Study to that meet the needs of the SWM utility

The next scheduled full update is targeted for adoption in 2033. Our understanding of flood hazards continues to be more refined as we continue to study each flood hazard.

References List

Chapter 1

Pierce County Public Works and Utilities, Water Programs. 2006. Pierce County Clear/Clarks Creek Basin Plan Volume I and II. <https://www.piercecountywa.gov/ArchiveCenter/ViewFile/Item/380>. <https://www.piercecountywa.gov/ArchiveCenter/ViewFile/Item/1302>.

Pierce County Public Works and Utilities, Water Programs. 2006. Pierce County Hylebos Browns-Dash PointBasin Plan Volume I and II.<https://www.piercecountywa.gov/ArchiveCenter/ViewFile/Item/2012>.

Pierce County Public Works and Utilities, Water Programs. 2005. Mid-Puyallup Basin Plan Volumes I and II. <https://www.piercecountywa.gov/ArchiveCenter/ViewFile/Item/384>. <https://www.piercecountywa.gov/ArchiveCenter/ViewFile/Item/1220>.

Pierce County Public Works and Utilities, Water Programs. 2005. Pierce County Clover Creek Basin Plan, Volumes I and II. <https://www.piercecountywa.gov/ArchiveCenter/ViewFile/Item/381>. <https://www.piercecountywa.gov/ArchiveCenter/ViewFile/Item/1263>.

Pierce County Public Works and Utilities, Water Programs. 2005. Pierce County. Gig Harbor Basin Plan Volumes I and II. 2005. <https://www.piercecountywa.gov/ArchiveCenter/ViewFile/Item/1218> and <https://www.piercecountywa.gov/ArchiveCenter/ViewFile/Item/1219>.

Pierce County Public Works and Utilities, Water Programs. 2006. Key Peninsula-Islands Basin Plan, Volumes I and II. <https://www.piercecountywa.gov/ArchiveCenter/ViewFile/Item/383>. <https://www.piercecountywa.gov/ArchiveCenter/ViewFile/Item/3021>.

Pierce County Public Works and Utilities, Water Programs. 2005. Muck Creek Basin Plan Volumes I and II. <https://www.piercecountywa.gov/ArchiveCenter/ViewFile/Item/385>. <https://www.piercecountywa.gov/ArchiveCenter/ViewFile/Item/1224>.

Pierce County Public Works and Utilities, Surface Water Management. 2014. Nisqually River Basin Plan, Volumes I and II. <https://www.piercecountywa.gov/ArchiveCenter/ViewFile/Item/2300>. <https://www.piercecountywa.gov/ArchiveCenter/ViewFile/Item/2301>.

References

Pierce County Public Works and Utilities, Surface Water Management. 2013. White River Basin Plan, Volumes I and II. <https://www.piercecountywa.gov/ArchiveCenter/ViewFile/Item/2200>. <https://www.piercecountywa.gov/ArchiveCenter/ViewFile/Item/2215>.

Chapter 2

Anderson, S., Jaeger, J., 2019, Coarse Sediment Dynamics in the White River Watershed: King County Department of Natural Resources and Parks, Water and Land Resources Division.

Czuba, J.A., Magirl, C.S., Czuba, C.R., Curran, C.A., Johnson, K.H., Olsen, T.D., Kimball, H.K., and Gish, C.C., 2012, Geomorphic analysis of the river response to sedimentation downstream of Mount Rainier, Washington: U.S. Geological Survey Open-File Report 2012-1242, 134 p.

King County. 2007. 2006 King County Flood Hazard Management Plan. King County, Washington.

Locke et al. 2008. Integrated Approaches to Riverine Resource Stewardship: Case Studies, Science, Law, People and Policy. Instream Flow Council. Cheyenne, Wyoming King County 2007

Pierce County. 2013. Nisqually Watershed Characterization 2008 as cited in Pierce County Rivers Flood Hazard Management Plan <https://www.piercecountywa.gov/DocumentCenter/View/96736/Pierce-County-Rivers-Flood-Hazard-Management-Plan-Volume-I-2-19-13compressed>.

Pierce-County-Rivers-Flood-Hazard-Management-Plan-Volume-IIcompressed <piercecountywa.gov>.

Pierce County Department of Public Works, River Improvement Division. 1991. Puyallup River Basin Comprehensive Flood Control Management Plan. Pierce County, Washington.

Pierce County. 2013. Department of Ecology 2007 as cited in Pierce County Rivers Flood Hazard Management Plan <https://www.piercecountywa.gov/DocumentCenter/View/96736/Pierce-County-Rivers-Flood-Hazard-Management-Plan-Volume-I-2-19-13compressed>.

Wald, A.R. 2009. High flows for fish and wildlife in Washington. Washington State Department of Fish and Wildlife. Olympia, Washington.

Chapter 3

Behnke, Robert J. 2002 Trout and Salmon of North America. Illustrated by Joseph R. Tomelleri.

EPA Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards, April 2003

Knutson, K. L., and V. L. Naef. 1997. Management recommendations for Washington's priority habitats: riparian. Wash. Dept. Fish and Wildl., Olympia, Washington. 181 pp

Marks, E.L. et al.2009. 2008-2009 Annual Salmon, Steelhead, and Bull Trout Report: Puyallup/White River Watershed—Water Resource Inventory Area 10. Puyallup Tribal Fisheries. 220pp. Puyallup, Washington.

Rapp, R.G, Abbe, T.B. 2003. A Framework for Delineating Channel Migration Zones. November.

South Puget Sound Salmon Enhancement Group, 2019, Thermal IR- WRIA 10, Thermal IR - WRIA 10 (arcgis.com)

U.S. Army Corps of Engineers (USACE). 2002. Section 905(b) Analysis, General Investigation Reconnaissance Study, Puyallup/White River Watershed, Washington, prepared by HDR.

U.S. Army Corps of Engineers (USACE). 2004. Water Control Manual, Mud Mountain Dam, White River, Washington, USACE, Seattle District, September 2004.

United States Environmental Protection Agency, Watershed Branch, Assessment and Watershed Protection Division (WH-553). 1991. Guidance for Water Quality-based Decisions: The TMDL Process. Washington, D.C. April.

Washington StreamCatalog/V1_PugetSound/10-WRIA_PUYALLUP.pdf

Chapter 4

Cardno, 2019. Climate Impacts to Groundwater in the Lower Snohomish and Stillaguamish River Basins. Report prepared for the Snohomish Conservation District.

Chegwidden, O. S., Nijssen, B., Rupp, D. E., Arnold, J. R., Clark, M. P., Hamman, J. J., ... & Xiao, M. 2019. How do modeling decisions affect the spread among hydrologic climate change projections? Exploring a large ensemble of simulations across a diversity of hydroclimates. Earth's Future, 7(6), 623-637.

FEMA, 2017. Flood Insurance Study: Pierce County, Washington and Incorporated Areas. Federal Emergency Management Agency. Flood Insurance Study Number: 53053CV001A. Volume 1 of 5. Effective: March 7, 2017.

Horner-Devine, A.R. and G.S. Mauger, 2022. Salt intrusion in the lower Puyallup River under current and future conditions. Report prepared for Pierce County. Civil and Environmental Engineering and Climate Impacts Group, University of Washington.

IPCC. 2021. Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.). Cambridge University Press, Cambridge, United Kingdom and New York, New York. pp. 3−32, doi:10.1017/9781009157896.001

References

Madsen, T., & E. Figdor. 2007. When it rains, it pours: global warming and the rising frequency of extreme precipitation in the United States. Report prepared for Environment California Research and Policy Center. 47pp.

Mass, C. et al., 2011. Extreme Precipitation over the West Coast of North America: Is There a Trend?. Journal of Hydrometeorology, 12(2), 310-318.

Mauger, G.S.,J.H. Casola,H.A. Morgan, R.L. Strauch, B. Jones, B. Curry, T.M. Busch Isaksen, L. Whitely Binder, M.B. Krosby, and A.K. Snover, 2015. State of Knowledge: Climate Change in Puget Sound. Report prepared for the Puget Sound Partnership and the National Oceanic and Atmospheric Administration. Climate Impacts Group, University of Washington, Seattle. doi:10.7915/CIG93777D

Miller, I.M., Morgan, H., Mauger, G., Newton, T., Weldon, R., Schmidt, D., Welch, M., Grossman, E. 2018. Projected Sea Level Rise for Washington State – A 2018 Assessment. A collaboration of Washington Sea Grant, University of Washington Climate Impacts Group, University of Oregon, University of Washington, and US Geological Survey. Prepared for the Washington Coastal Resilience Project. updated 07/2019

Miller, I.M., Yang, Z., VanArendonk, N., Grossman, E., Mauger, G. S., Morgan, H., 2019. Extreme Coastal Water Level in Washington State: Guidelines to Support Sea Level Rise Planning. A collaboration of Washington Sea Grant, University of Washington Climate Impacts Group, Oregon State University, University of Washington, Pacific Northwest National Laboratory and U.S. Geological Survey. Prepared for the Washington Coastal Resilience Project.

Mote, P. W., Li, S., Lettenmaier, D. P., Xiao, M., & Engel, R. 2018. Dramatic declines in snowpack in the western US. Npj Climate and Atmospheric Science, 1(1), 1-6.

Newton, T. J., Weldon, R., Miller, I. M., Schmidt, D., Mauger, G., Morgan, H., & Grossman, E. 2021. An Assessment of Vertical Land Movement to Support Coastal Hazards Planning in Washington State. Water, 13(3), 281.

Riedel J and Larrabee MA. 2015. Mount Rainier National Park glacier mass balance monitoring annual report, water year 2011: North Coast and Cascades Network. Natural Resource Data Series. NPS/NCCN/NRDS—2015/752. National Park Service. Fort Collins, Colorado. <https://irma.nps.gov/DataStore/Reference/Profile/2219351>.

Riedel, J., M. A. Larrabee, and K. L. Ladig. 2020. Mount Rainier National Park glacier mass balance monitoring report, water years 2012-2019: North Coast and Cascades Network. Natural Resource Data Series NPS/NCCN/NRDS—2020/XXXX. National Park Service, Fort Collins, Colorado. (in press)

Rosenberg, E. A. et al., 2010. Precipitation extremes and the impacts of climate change on stormwater infrastructure in Washington State. Climatic Change, 102(1-2), 319-349.

Salathé, E. P., Hamlet, A. F., Mass, C. F., Lee, S. Y., Stumbaugh, M., & Steed, R. 2014. Estimates of twenty-first-century flood risk in the Pacific Northwest based on regional climate model simulations. Journal of Hydrometeorology, 15(5), 1881-1899.

Sisson, T. W., J. E. Robinson, and D. D. Swinney. 2011. Whole edifice ice volume change A.D. 2970 to 2007/2008 at Mount Rainier, Washington, based on LiDAR surveying. Geology 39(7):639-642.

Washington State Department of Ecology (Ecology). 2019. "Stormwater Management Manual for Western Washington" Publication Number 19-10-021, July. 2019SWMMWW.

Wilhere, G., J. Atha, T. Quinn, L. Helbrecht, and I. Tohver. 2017. Incorporating Climate Change into the Design of Water Crossing Structures: Final Project Report. Washington Department of Fish and Wildlife. November.

Vose, R. S. et al., 2014. Improved historical temperature and precipitation time series for US climate divisions. Journal of Applied Meteorology and Climatology, 53(5), 1232-1251.

Chapter 5

Alliance for Healthy South Sound (AHSS). 2016. Alliance for Healthy South Sound, Ecosystem Recovery Plan.

Annual Salmon, Steelhead and Bull Trout Report: Puyallup/White River Watershed Water Resource Inventory Area. Puyallup Tribal Fisheries. <http://puyallup-tribe.com/fisheries/research.html>.

Blair, Greg. Nisqually Steelhead Recovery Team. Nisqually River Steelhead Recovery Plan. 2014.

Czuba ,J., C. Magirl, C. Czuba, E. Grossman, C. Curran, A. Gendazek, R. Dinicola. 2011. Sediment Load from Major Rivers into Puget Sound and its Adjacent Waters. U.S. Geological Survey. <https://pubs.usgs.gov/fs/2011/3083/pdf/fs20113083.pdf>. August.

Gig Harbor Basin Plan Volumes I and II. 2005. Pierce County Public Works and Utilities, Water Programs. <https://www.piercecountywa.gov/ArchiveCenter/ViewFile/Item/1218>. <https://www.piercecountywa.gov/ArchiveCenter/ViewFile/Item/1219>.

Nisqually Chinook Recovery Plan. 2001. Nisqually Chinook Recovery Team.

Nisqually Chinook Stock Management Plan. 2011. Prepared by Nisqually Chinook Working Group with ICF International. <https://www.slideshare.net/Nisqually/nisqually-chinook-stock-management-plan>. January.

Nisqually River Council. Nisqually Watershed Stewardship Plan-Our Path to Environmental, Social, and Economic Sustainability Third Edition. 2020. <https://drive.google.com/file/d/1nZKcaboO6QdvWaqdRYFzaP46XuU6NaXs/view>.

ICF. 2021. Evaluation of Salmon Habitat Protection and Restoration in Puyallup/ White and Chambers/ Clover watersheds using Ecosystem Diagnosis & Treatment (EDT). February.

References

Kerwin, J. 1999. Salmon Habitat Limiting Factors Report for the Puyallup River Basin (Water Resource Inventory Area 10). Washington Conservation Commission. Olympia, Washington.

Kerwin, J. 2000. Salmon and Steelhead Habitat Limiting Factors, Water Resource Inventory Area 11 Nisqually Watershed. Washington Conservation Commission. Olympia, Washington.

Key Peninsula-Islands Basin Plan, Volumes I and II. 2006. Pierce County Public Works and Utilities, Water Programs. <https://www.piercecountywa.gov/ArchiveCenter/ViewFile/Item/383>. <https://www.piercecountywa.gov/ArchiveCenter/ViewFile/Item/3021>.

Mobrand Biometrics, INC, 2001, Watershed Analysis for the Development of Salmonid Conservation and Recovery Plans Within Pierce County. Vashon, Washington. June.

Pierce County Department of Public Works, River Improvement Division. 1991. Puyallup River Basin Comprehensive Flood Control Management Plan. Pierce County, Washington.

Pierce County, Emergency Management. 2020. 2020 Hazard Identification and Risk Assessment. <https://www.piercecountywa.gov/6599/Hazard-Identification-and-Risk-Assessmen>. Pierce County, Washington.

Pierce County Planning and Public Works, Surface Water Management. 2017. System Wide Improvement Framework Plan. <https://www.piercecountywa.gov/ArchiveCenter/ViewFile/Item/5596>. Pierce County, Washington.

Puget Sound Steelhead East Kitsap DIP Recovery Plan. 2020. Prepared by ESA with the Suquamish Tribe.

Puyallup and Chambers Watersheds Salmon Recovery Lead Entity (Lead Entity). 2018. Salmon Habitat Protection and Restoration Strategy for Puyallup and Chambers Watersheds.

Puyallup-White River Ecosystem Recovery Plan (ERP). 2021. Puyallup-White River Local Integrating Organization (PWR-LIO).

Shared Strategy for Puget Sound (Shared Strategy). 2005. Draft Puget Sound Salmon Recovery Plan, Volume I. Submitted by Shared Strategy Development Committee.

Shared Strategy for Puget Sound (Shared Strategy). 2005. Draft Puget Sound Salmon Recovery Plan, Volume II, South Sound Chapter.

Strategic Identification of Areas and Projects for Nearshore Restoration throughout Key Peninsula-Gig Harbor Islands Watershed, WRIA 15, Washington. 2011. Prepared for the West Sound Watershed Lead Entity by South Puget Sound Enhancement Group

U. S. Department of the Interior, Bureau of Reclamation. 1988. Downstream Hazard Classification Guidelines. ACER Technical No.11.Denver, Colorado. December.

U.S. Geological Survey. 2011. Sediment Load from Major Rivers into Puget Sound and its Adjacent Waters. <https://pubs.usgs.gov/fs/2011/3083/pdf/fs20113083.pdf>.

Washington State Department of Fish and Wildlife. 2003.Integrated Streambank Protection Guidelines. <https://wdfw.wa.gov/sites/default/files/publications/00046/wdfw00046.pdf>.

Watershed Restoration and Enhancement Plan WRIA 12-Chambers-Clover Watershed June 2021, Ecology Publication 21-11-012

Chapter 6

Collins, B.D. and Sheikh, A.J, 2004. Historical Aquatic Habitats in the White River Valley, RM 5 - RM 28, King County, Washington

EcoNorthwest. 2022. Flood Risk Assessment and Economic Analysis Pierce County, Washington. Seattle, Wahington. April

Entrix. 2008. Preliminary Assessment and Erosion Protection Concept for Lower Puyallup River North Levee. Fife, Pierce County, Washington.

Federal Emergency Management Agency. 2009. Flood Insurance Study, Pierce County, Washington, and Incorporated Areas (Vols. 1-5).

Federal Emergency Management Agency. 2017. Flood Insurance Study, Pierce County Washington. March.

Frissell, C. A., P. H. Morrison, S. B. Adams, L. H. Swope, and N. P. Hitt. 2000 (in press). Identifying Priority Areas for Salmon Conservation in the Puget Sound Basin. Pacific Biodiversity Institute Open File Report Number 2000-1.

GeoEngineers. 2017. Channel Migration Zone Delineation Lower Greenwater River. Pierce County, Washington. November.

GeoEngineers. 2007. Channel Migration and Avulsion Potential Analyses, Upper Nisqually River, Pierce County, Washington.

GeoEngineers. 2005. Geomorphic Evaluation and Channel Migration Zone Analysis, South Prairie Creek, Pierce County, Washington.

GeoEngineers. 2003. Geomorphic Evaluation and Channel Migration Zone Analysis, Puyallup, Carbon and White Rivers, Pierce County, Washington.

Kerwin, J. 1999. Salmon Habitat Limiting Factors Report for the Puyallup River Basin (Water Resource Inventory Area 10). Washington Conservation Commission. Olympia, Washington.

King County. 2013. 2013 King County Flood Hazard Management Plan Update and Progress Report. King County, Washington.

King County. 2007. 2006 King County Flood Hazard Management Plan. King County, Washington.

King County, 1988. Inter-County River Improvement. Submitted to the King County Council.

References

Marks, E.L. et al. 2009. 2008-2009 Annual Salmon, Steelhead, and Bull Trout Report: Puyallup/White River Watershed—Water Resource Inventory Area 10. Puyallup Tribal Fisheries. 220pp. Puyallup, Washington.

Northwest Hydraulic Consultants. 2006. Flood Insurance Mapping Study for Puyallup River Community No. 530138. October.

Pierce County Public Works and Utilities. 2013. Pierce County Rivers Flood Hazard Management Plan. Pierce County, Washington.

Pierce County. 2013. Williams 1975 as cited in Pierce County Rivers Flood Hazard Management Plan. <https://www.piercecountywa.gov/DocumentCenter/View/96736/Pierce-County-Rivers-Flood-Hazard-Management-Plan-Volume-I-2-19-13compressed>.

Pierce-County-Rivers-Flood-Hazard-Management-Plan-Volume-IIcompressed <piercecountywa.gov>.

Pierce County. 2013. USGS 1993-124 as cited in Pierce County Rivers Flood Hazard Management Plan. <https://www.piercecountywa.gov/DocumentCenter/View/96736/Pierce-County-Rivers-Flood-Hazard-Management-Plan-Volume-I-2-19-13compressed>.

Pierce County Public Works and Utilities, Surface Water Management. 2008. Nisqually River Basin Plan, Volume 1. Pierce County, Washington.

Pierce County River Improvement. 1950. PCRI Annual Report 1950.

Shared Strategy 2007 Development Committee. 2007. Puget Sound Salmon Recovery Plan, Volume 1. Adopted by National Marine Fisheries Service January 19,2007.

Shared Strategy 2007 Development Committee. 2007. Puget Sound Salmon Recovery Plan, Volume 2. Puyallup Basin Plan.

STARR II. 2019. Hydrology Report Nisqually River, Washington. <https://www.starrteam.com/starr/RegionalWorkspaces/RegionX/NisquallyWatershed/Shared%20Documents/Nisqually%20Hydrology%20Report_Final.pdf>. January.

TetraTech, Northwest Hydraulic Consultants, ESA Adolfson, and Shannon & Wilson. 2009. Lower Puyallup River Flood Protection Investigation – Without-Project Analysis. Pierce County, Washington.

U.S. Army Corps of Engineers (USACE). 2002. Section 905(b) Analysis, General Investigation Reconnaissance Study, Puyallup/White River Watershed, Washington, prepared by HDR

U.S. Army Corps of Engineers (USACE). 2009. Section 905(b) (WRDA 86) Analysis, General Investigation Reconnaissance Study, Puyallup River, Washington, USACE, Seattle District, March.

References

USGS (Czuba et al.). 2010. Channel-Conveyance Capacity, Channel Change, and Sediment Transport in the Lower Puyallup, White and Carbon Rivers. Scientific Investigations Report 2010-5240. U.S. Geological Survey. <https://pubs.usgs.gov/sir/2010/5240/pdf/sir20105240.pdf>.

USGS (Sikonia, W.G.). 1990. Sediment Transport in the Lower Puyallup, White, and Carbon Rivers of Western Washington. Water Resources Investigation Report 89-4112. U.S. Geological Survey. Tacoma, Washington.

USGS,1981. Guidelines for Determining Flood Flow Frequency. Bulletin #17 of the Hydrology Subcommittee. Revised September 1981. Reston, Virginia.

Vallance, J.W, M.L. Cunico, S.P. Schilling.2003. Debris-Flow Hazards Caused by Hydrologic Events at Mount Rainier, Washington. United States Geological Survey Open-File Report 03-368. Vancouver, Washington.

Washington WRIA Catalogue. 1977. Water Resource Inventory Area 10. Puyallup River, Puget Sound Region.

Watershed Professionals Network, LLC. 2004. Mashel River Restoration Design. Technical Memorandum. Final Report – June 2004. Prepared for Pierce Conservation District.

Other Random or extra references (if needed during draft and final)

ICF. 2021. Evaluation of Salmon Habitat Protection and Restoration in Puyallup/ White and Chambers/ Clover watersheds using Ecosystem Diagnosis & Treatment (EDT). February 2021

Puyallup and Chambers Watersheds Salmon Recovery Lead Entity (Lead Entity). June 2018. Salmon Habitat Protection and Restoration Strategy for Puyallup and Chambers Watersheds.

U.S. Environmental Protection Agency. 2003. EPA Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards. EPA 910-B-03-002. Region 10 Office of Water, Seattle, Washington.

Behnke, Robert J. 2002 Trout and Salmon of North America. Illustrated by Joseph R. Tomelleri.

2010 Pierce County Unified Sewer Plan Update: <https://www.piercecountywa.gov/7181/2010-Unified-Sewer-Plan>.

Pierce County Rivers Flood Hazard Management Plan, 2013: <https://www.piercecountywa.gov/DocumentCenter/View/96736/Pierce-County-Rivers-Flood-Hazard-Management-Plan-Volume-I-2-19-13compressed>.

Pierce-County-Rivers-Flood-Hazard-Management-Plan-Volume-IIcompressed (piercecountywa.gov)

References

Pierce County Rivers Flood Hazard Management Plan, 2018:
<https://www.piercecountywa.gov/DocumentCenter/View/96738/River-Flood-Hazard-Management-Plan-Progress-Report-Volume-1-2018>.
<https://www.piercecountywa.gov/DocumentCenter/View/96177/Volume-1-2018-Errata>.
<https://www.piercecountywa.gov/DocumentCenter/View/96179/Volume-II-Progress-Report>.
<https://www.piercecountywa.gov/DocumentCenter/View/96178/Volume-II-Errata>.

Levee Certification vs. Accreditation:
<https://www.mvk.usace.army.mil/Portals/58/docs/LSAC/LeveeCertification.pdf>.

Statewide Levee Inventory and Flood Protection Study: Report on Certification and Accreditation:
<https://app.leg.wa.gov/ReportsToTheLegislature/Home/GetPDF?fileName=1006029_177e2167-e0f5-4725-8d7c-174d4449e8ed.pdf>.

Channel-Conveyance Capacity, Channel Change, and Sediment Transport in the Lower Puyallup, White, and Carbon Rivers, Western Washington:
<https://pubs.usgs.gov/sir/2010/5240/pdf/sir20105240.pdf>.

2010-2015 Juvenile Fish Ecology in the Nisqually River Delta and Nisqually Reach Aquatic Reserve. 2016. Hodgson et al.

Puyallup and Chambers Watersheds Salmon Recovery Lead Entity (Lead Entity). 2018. Salmon Habitat Protection and Restoration Strategy for Puyallup and Chambers Watersheds.

Shared Strategy for Puget Sound (Shared Strategy). 2005. Draft Puget Sound Salmon Recovery Plan, Volume I. Submitted by Shared Strategy Development Committee. Available at:
<http://www.psp.wa.gov/salmon-watershed-recovery-plans.php>.

Washington State Department of Ecology (Ecology). Watershed Restoration and Enhancement Plan WRIA 12 – Chambers-Clover Watershed June 2021, Ecology Publication 21-11-012

Clarks Creek Dissolved Oxygen and Sediment Total Maximum Daily Load, Water Quality Improvement Report and Implementation Plan. 2014. Washington State Department of Ecology. < https://apps.ecology.wa.gov/publications/SummaryPages/1410030.html>

Clarks Creek Restoration Plan. 2017. Pierce County Public Works, Surface Water Management. < https://www.piercecountywa.gov/Archive/ViewFile/Item/5609>

Clarks Creek Sediment Reduction Action Plan. 2013, Final. Prepared for Puyallup Tribe of Indians by Brown and Caldwell, Seattle, WA, March 21, 2013.

Puget Sound Salmon Recovery Plan:
<https://www.fisheries.noaa.gov/resource/document/recovery-plan-puget-sound-chinook-salmon>.

Glossary

100-Year Flood/Event	A flood having a one percent annual chance of occurring any given year. This is determined by a statistical projection developed by analyzing the highest flow on a river/stream for the period of record. Each year adds to the period of record and the 100-year flood threshold is (or should be) re-evaluated. This is also known as the Base Flood event or one percent annual chance flood. Pierce County and FEMA set building design standards and flood insurance requirements for this flood recurrence.
200-Year Flood/Event	A flood having a 0.5 percent annual chance of occurring any given year.
500-Year Flood/Event	A flood having a 0.2 percent annual chance of occurring any given year.
Adaptive Management	A systematic approach for continually improving management policies and practices by learning from the outcomes of operational programs.
Administration	Involves activities associated with the management, planning, budgeting, and coordination of the overall asset. Examples of administration activities include the management of boards or committees, planning activities such as basin planning or work on an Environmental Impact Statement. In PWD, maintaining records and participating in department-wide programs is also considered an administration activity.
AE Zones	Areas inundated by the 1 percent annual chance flood, including areas with the 2 percent wave runup, elevation less than 3 feet above the ground, and areas with wave heights less than 3 feet.
Aggradation	A progressive buildup or raising of the channel bed due to sediment deposition. Permanent or continuous aggradation is an indicator that a change in the stream's discharge and sediment characteristics is taking place.
Alluvial Fan	A sedimentary deposit located at a topographic break, such as the base of a mountain front, escarpment, or valley side, that is composed of stream flow and/or debris flow sediments and which has the shape of a fan, either fully or partially extended.
Alluvium	A general term for all deposits laid down by present-day rivers, especially at times of flood.
Anabranching	Refers to rivers that have distributary channels that depart from the main channel, run parallel or nearly so to the main channel and then reenter the main channel downstream.
Anadromous	Migrating up rivers from the sea to spawn.
Aquatic	Pertaining to water.
Aquifer	A saturated permeable material (often sand, gravel, sandstone, or limestone) that contains and carries groundwater and acts as a water reservoir.
Avulsion	The rapid abandonment of a channel with the formation of a new channel.

Glossary

Backwater	Stream water, obstructed by some downstream hydraulic control that is slowed or stopped from flowing at its normal, open-channel flow condition.
Base Flood/Event	The flood having a one percent chance of being equaled or exceeded in any given year, also referred to as the "100-year flood." The base flood surface water elevation is measured in feet above mean sea level and referenced to the National Geodetic Vertical Datum of 1929 (or the most current vertical datum accepted by Pierce County).
Base Flood Elevation (BFE)	The water surface elevation, measured in feet, above the mean sea level for the base flood and referenced to a vertical datum accepted by Pierce County (North American Vertical Datum of 1988 – NAVD88 or National Geodetic Vertical Datum of 1929 – NGVD29);); the elevation which is the basis of the insurance and floodplain management requirements of the National Flood Insurance Program.
Basin	A geographic and hydrologic sub unit of a watershed, shortened reference to drainage basin.
Bed Material	The material which makes up a streambed.
Benefit-Cost Analysis (BCA)	A quantitative procedure that assesses the desirability of a hazard mitigation measure by taking the long-term view of avoided future damages as compared to the cost of a project. The outcome of the analysis is a benefit-cost ratio, which demonstrates whether the net present value of benefits exceeds the net present value of cost.
Best Management Practices (BMPs)	Physical, structural, or managerial practices that have gained general acceptance for their ability to prevent or reduce environmental impacts.
Boil	A concentration of seepage in one spot, usually caused by pressure from the river on a strata of coarse sand or gravel.
Buffer	A tract or strip of land that separates one type, category, or use of land from another. Buffers typically serve to provide a defined area between a more intensive use of land and a land use that is less intensive. Buffers are typically referenced by the associated critical area such as wetland buffer, riparian buffer, etc.
Capital Improvement Project	A capital improvement project is a constructed project facility such as a road improvement, flood or stormwater control facility that is generally of a durable nature. Capital improvement projects may be considered assets rather than as expenses for accounting purposes.
Channel	Natural or artificial waterway long enough to periodically or continuously contain moving water. It has a definite bed and banks that serve to confine water.
Channel Complexity	Channel complexity describes salmon habitat. A complex channel contains a mixture of habitat types that provide areas with different velocity and depth for use by different salmon life stages. In contrast, a simple channel contains more uniform flow and few habitat types.
Channel Erosion	The widening, deepening, and headward cutting of small channels and waterways due to erosion caused by moderate to large floods.

Glossary

Channel Migration Zone (CMZ)	The area within the lateral extent of likely stream channel movement due to stream bank destabilization and erosion, rapid stream incision, and shifts in location of stream channels. The CMZ is approximated by evidence of channel locations in the last 100 years, but is not strictly bounded by that criterion alone. The area within which a river channel is likely to move over a period of time is referred to as the channel migration zone.
Channel Morphology	The shape and gradient of a channel that forms due to streamflow forces and the composition of the underlying channel substrate.
Channelization	The straightening, deepening, or widening of a stream channel for the purpose of increasing the stream's carrying capacity.
Compensatory Storage	New excavated storage volume equivalent to the flood storage capacity eliminated by filling or grading within the floodplain. For any fill placed below the base flood elevation, an equal volume will be removed from the floodplain at the same elevation as the placed fill. In addition, the excavated area must be hydraulically connected to the floodway through its entire depth (that is, it must drain out).
Confluence	The location where two streams meet.
Conservation	Includes protection, maintenance, and restoration of habitat characteristics to support the species of interest.
Continuing Eligibility Inspection	An evaluation of Active federal and non-federal flood risk management projects conducted in order to make a status determination.
Conveyance Capacity	A term generally referring to the maximum capability of the physical drainage system to safely transport water.
Critical Areas	Wetlands, flood hazard areas, fish and wildlife habitat areas, aquifer recharge areas, and geologically hazardous areas.
Critical Facilities	
Cubic Feet per Second (cfs)	Units assigned to the volume of water that flows past a fixed point in a stream channel, drainage outlet, or other water flow path every second; equivalent to 449 gallons per minute (gpm).
Culvert	A single length of pipe, open to the ground surface at both ends, that carries stream flow under a road grade or other type of fill embankment. Typically, no manholes or catch basins are installed along its length.
Deep and Fast Flowing Water (DFF)	A combination of water depth and/or velocity, as shown in the graph in Pierce County Code Section 18E.70, that can be dangerous to walk or drive through and can cause structural failures. For the purposes of Title 18, Pierce County considers deep and/or fast-flowing water to be a floodway area.
Degradation	The lowering of the streambed or widening of the stream channel by erosion; the breakdown and removal of soil, rock and organic debris.
Easement	The legal right to use a specified piece of land for a particular purpose.
Ecosystem	A biological community together with the chemical and physical environment with which it interacts.
Ecotones	A region of transition between two biological communities.

Glossary

Effectiveness Monitoring	The evaluation of whether an action achieved the desired effect. For example, in a sediment reduction project, effectiveness monitoring would determine whether sediment supply was actually reduced.
Endosaturation	The soil is saturated with water in all layers from the upper boundary of saturation to a depth of 200 cm or more from the mineral soil surface, or to paralithic or lithic contact, whichever is shallower,
Ephemeral	A dry stream course or waterbody, except during or immediately after extreme rainfall or surfacing groundwater due to heavy annual rainfall; often no ordinary high water mark is evident.
Episaturation	The condition of a soil, saturated with water, that lies above an unsaturated layer.
Erosion	Detachment of soil or rock fragments by water, wind, ice and gravity.
Estuary	The tidal mouth of a large river, where the tide meets the stream.
Evapotranspiration	The process by which water is transferred from the land to the atmosphere by evaporation from the soil and other surfaces and by the transpiration from plants.
Evolutionary Significant Unit (ESU)	A population that is substantially reproductively isolated from conspecific (others of the same species) populations and represents an important component in the evolutionary legacy of the species.
Federal Emergency Management Agency (FEMA)	A division of the Department of Homeland Security, authorized by Congress to regulate the National Flood Insurance Program (NFIP).
Fill	Earth, sand, gravel, rock, asphalt, or other solid material placed to raise the ground elevation or to replace excavated material.
Fish Passage Barrier	An obstacle that prevents fish from moving either upstream or downstream, such as certain dams, weirs, floodgates, roads, bridges, causeways and culverts.
Flood	An overflow or inundation that comes from a river or any other source, including but not limited to streams, tides, wave action, storm drains, or excess rainfall.
Flood Control	Physically controlling a river or stream by structural means such as dikes and levees, which separate people and property from damaging floodwater.
Flood Elevation	Height of flood waters above an elevation datum plane.
Flood Hazard Areas	Areas of land within floodplains that are subject to a one percent or greater chance of flooding in any given year. Such areas include, but are not limited to, streams, rivers, lakes, coastal areas, wetlands, and the like.
Flood Hazard Management	A comprehensive approach to flood control issues that encompasses both flood control management and floodplain management and uses both structural and nonstructural methods of reducing flood hazards. Flood hazard management is not limited to areas within the floodplain but can extend to the entire watershed.
Flood Frequency Discharge	How often or frequent the discharge magnitude occurs.

Glossary

Flood Insurance Rate Map (FIRM)	The official map on which the Federal Insurance Administration, a division of FEMA, has delineated areas of special flood hazard and the risk premium zones applicable to Pierce County. Through FEMA's Map Modernization program, the FIRM is being replaced with the Digital Flood Insurance Rate Map (DFIRM), which utilizes modern computer Geographic Information Systems (GIS) to show the flood hazard areas.
Flood Insurance Study	The official report provided by the Federal Insurance Administration, a division of FEMA, that includes flood profiles, a map of the 100-year floodplain and floodway boundaries, and the water surface elevation of the base flood.
Flood Fringe	The area subject to inundation by the base flood, but outside the limits of the floodway, and which may provide needed temporary storage capacity for flood waters. Structures in fringe areas in Pierce County must be elevated at least two feet above the 100-year flood elevation.
Flood Warning	A warning issued by the NWS to warn of river flooding which is imminent or occurring. A flood warning is issued when a river first exceeds its flood stage, and it may be reissued if a new river forecast for a forecast point or reach is significantly higher than a previous forecast.
Floodplain	The total area subject to inundation by the base flood including the flood fringe and floodway. The low area adjoining a stream or river channel that overflows at times of high river flow.
Floodproof(ing)	Structural provisions or adjustments to nonresidential buildings for the purpose of eliminating flood damages to those structures, including their utilities and contents.
Floodway	The channel of a river and the adjacent land areas that must be reserved in order to convey and discharge the base flood without cumulatively increasing the water surface elevation by more than one foot, those areas designated as deep and/or fast-flowing water, and Channel Migration Zones where detailed CMZ studies have been adopted by Pierce County. No filling or development is allowed in the floodway.
Freeboard	Freeboard is the added capacity above the design flood to account for dynamic variables and uncertainties. Freeboard is typically reported as additional elevation above expected water surface elevation.
FT	The gauge height (in feet) of the lowest bank of the river reach in which the gauge is located.
Geomorphology	The study of landforms and the processes that shape them. Fluvial geomorphology is the study of processes associated with riverine or stream environments.
Gradient (of stream)	The degree of inclination of a stream channel parallel to stream flow; it may be represented as a ratio, fraction, percentage or angle.
Hard Armoring	The use of large rock and/or human-made materials to protect property from shoreline erosion. Such techniques include cement/concrete bulkheads, steel structures, rock wall revetments, and rock gabion structures. Hard armoring typically does not use or integrate any soft armoring or soil bioengineering techniques.
Hazard Mitigation	Action taken to reduce or eliminate long-term risk to people and property from hazards such as floods, earthquakes and fires.

Hesco Barrier	A modern gabion used for flood control and military fortification and the name of the British company that developed it in the late 1980s. It is made of a collapsible wire mesh container and heavy duty fabric liner, and used as a temporary to semi-permanent dike.
Hydraulic Project Approval	Permit issued by Washington State Department of Fish and Wildlife required for projects with construction activity in or near state waters (RCW 75.20.100-160) that affect the bed or flow of a stream.
Hydrology	The science of the behavior of water in the atmosphere, on the surface of the Earth, and underground.
Hydroperiod	The number of days per year that an area of land is wet or the length of time that there is standing water at a location.
Imminent Threat	Likely to occur at any moment; implies an immediate threat of harm.
Impervious Surface	(1)A hard surface, which either prevents or retards the entry of water into the soil mantle as under natural conditions prior to development, (2)A hard sur
Improvement	The activities of improving the capacity or function of an existing asset or adding additional assets. Construction of setback levees, adding engineered log jams, upsizing rock armoring or constructing flow retarding structures are examples of improvement activities.
King Tides	Colloquial term used to describe exceptionally high tides.
Large Woody Material (LWM)	Any piece of woody material, generally 12 inches or larger in diameter, that intrudes into a stream channel or nearby (e.g., logs, stumps or root wads) and that functions to form pools, regulate sediments, disperse stream energy, create channel complexity, stabilize channels, provide instream organic matter, and provide cover for fish.
Lahar	A landslide or mudflow of volcanic fragments on the flanks of a volcano.
Left Bank	The land area to the left, adjacent to the river channel, looking downstream.
Levee	A flood-control structure designed to protect an area from flooding. Levees are often rated by the level of protection they offer. Pierce County currently does not have any levee certified to provide 100-year flood protection per FEMA criteria.
Levee Accreditation	A levee system that FEMA has shown on a FIRM that is recognized as reducing the flood hazards posed by a 1-percent-annual-chance flood. This determination is based on the submittal of data and documentation as required by 44CFR§65.10 of the NFIP regulations.
Levee Certification	Process that deals specifically with the design and physical condition of the levee, and is the responsibility of the levee owner or community in charge of the levee's operations and maintenance.
Main Stem	The principal channel of a stream to which tributaries join.
Maintenance	The routine activities associated with repairing or keeping a physical asset functioning to its constructed design standard during the asset's useful life. Vegetation management, adding supplemental rock, grading access roads, cleaning culverts are examples of maintenance activities.
Mitigation	Avoiding, rectifying, minimizing, reducing, compensating for, or eliminating probable significant adverse impacts to a natural resource or environment.

Model	Conceptual and mathematical descriptions or analogies used to help visualize something that cannot be directly observed. Models provide frameworks that organize concepts, data, and information into a system of inferences that can be presented as mathematical descriptions of situations or conditions.
Operations	The activities associated with keeping an asset or system best meeting customer needs. Annual condition assessments, monitoring, and inspections, prioritization of maintenance work needs are examples of operation activities.
Ordinary High Water Mark (OHWM)	The mark on all lakes, streams, and tidal water that can be found by examining the bed and banks and determining where the presence and action of waters has marked upon the soil a character distinct from that of the abutting upland, in respect to vegetation. In any area where the ordinary high water mark cannot be found, the ordinary high water mark adjoining fresh water shall be the line of mean high water.
Osceola Mudflow	A lahar in the Washington that descended from the summit and northeast slope of Mount Rainer during the period of eruptions about 5,600 years ago.
Oxbow	Generally, a U-shaped bend or meander in a channel. Oxbows are sometimes “cut off” and abandoned when a channel is straightened. This can occur either naturally or by man-made means.
Peak Flow	The maximum instantaneous rate of flow during a storm, usually in reference to a specific design storm event.
Perfluoroalky and Polyfluoroalkyl Substances (PFAs)	Widely used, long-lasting chemicals, components of which break down very slowly over time. Scientific studies have shown that exposure to some PFAS in the environment may be linked to harmful health effects in humans and animals.
Preservation	The activities related to the replacement, rehabilitation and/or improvement of an existing asset after it has reached its useful life to accomplish the same overall function. Replacement of a levee or revetment along its existing alignment or reconstruction of a damaged levee are examples of preservation activities.
Programmatic	Relating to a plan or procedure for dealing with some matter, e.g., regulations, policy guidelines, site design standards, operational policies and procedures, technical assistance, enforcement, and public outreach and educational programs.
Rapid Damage Assessment	Surveys carried out by trained emergency services personnel in the immediate aftermath of disaster events.
Reach	A segment of a stream channel where the cross-section, slope, and roughness of the channel are constant. Simulation of the flow in streams is done by dividing the stream channel into reaches.
Redd	Nests made in gravel (particularly by salmonids), consisting of a depression that is created and then covered.
Regulatory Floodplain	A portion of the geologic floodplain that may be inundated by the base flood where the peak discharge is 100 cubic feet per second (C.F.S.) or greater. Regulatory floodplains also include areas which are subject to sheet flooding, or areas on existing recorded subdivision plats mapped as being flood prone.

Repetitive Loss	Homes or structures that have received more than $1,000 of flood insured damage two or more times in the last ten years will appear on the National Flood Insurance Program (NFIP) repetitive loss database and receive higher priority for certain types of buyout.
Revetment	A structure that reduces erosion or channel migration along a riverbank.
Right Bank	The land area to the right, adjacent to the river channel, looking downstream.
Rip Rapp	Broken stone placed on shoulders, slopes, or other such places to protect them from erosion. Stones typically range in size from 6 inches to several feet in diameter.
Riparian	The area adjacent to aquatic systems with flowing water that contains elements of both aquatic and terrestrial ecosystems that mutually influence each other. Riparian habitat begins at the ordinary high water mark and includes riparian areas of wetlands that are directly connected to the stream course; it may include the entire extent of the floodplain.
Riverine	Of or produced by a river.
Rock Groins	Rock groins are structures perpendicular to a river and designed to reduce the potential of erosion along the shoreline.
Salmonids	Fish of the family Salmonidae, including salmon, trout, char (salmon and steelhead stock inventory), whitefish, and grayling native to Washington State.
Scour	Process by which floodwaters remove soil around objects that obstruct flow, such as a levee, the channel or a stream.
Secluded	Refers to an area at risk of flooding behind a non-accredited levee.
Section 303(d)	Section 303(d) of the Clean Water Act authorizes EPA to assist states, territories and authorized tribes in listing impaired waters and developing Total Maximum Daily Loads (TMDLs) for these waterbodies.
Sediment	Solid material settled from suspension in a liquid.
Sedimentation	The process of settling and depositing suspending matter carried by runoff, usually occurring by gravity when the velocity of the surface water is reduced below the point at which it can transport the suspended material.
Setback Levee	A levee that is set away from the river in a manner to allow the river channel to migrate in the areas between levees. Setback levees in Pierce County include the Soldiers Home and Ford Levees on the Puyallup River.
Side Channel	The portion of the active channel that does not carry the bulk of the stream flow. Side channels may carry water only during high flows, but they are still considered part of the active channel.
Sole Source Aquifer	Aquifers that provide at least 50 percent of the drinking water for it's service area.
Spawning Habitat	Areas used by adult fish for laying and fertilizing eggs.
Special Flood Hazard Area	Term used by FEMA to describe areas with a one percent or greater chance of flooding in any given year. Such areas are required to be regulated by communities participating in the NFIP, and structures in a Special Flood Hazard Area are required to purchase flood insurance.
Stream	A channel of perennial or intermittent flowing water.

Sub-basin	A drainage area that drains to a watercourse or water body named and noted on common maps and which is contained within a basin; a basin or area that is part of a larger drainage basin or area.
Subjacent	Lying under or below.
Substantial Damage	Damage to a structure for which the valuation for the reconstruction or restoration work exceeds 50 percent of the valuation of the existing structure prior to receiving damage.
Substrate	The rock or soil material present in the bottom of the stream or river, including muck, sand, gravel, boulders, and bedrock.
Thalweg	A line connecting the lowest points of successive cross-sections along the course of a valley or river.
Topography	The shape or configuration of the land, represented on a map by contour lines or relief shading.
Transition Zone	Area within estuaries between river environments and ocean environments subject to both marine influences, such as tides, waves, and the influx of saline water; and riverine influences, such as flows of fresh water and sediment.
USGS (United States Geological Survey)	Agency within the federal Department of the Interior responsible for collecting and distributing stream flow data for the nation.
Vadose Zone	Is the unsaturated part of the soil profile that extends from the ground surface down to the groundwater table.
Vashon Glaciation	A local term for the most recent period of very cold climate during which at its peak, glaciers covered the entire Salish Sea as well as present day Seattle, Tacoma, Olympia, and other surrounding areas in the western part of present-day Washington.
Watershed	The region drained by or contributing water to a stream, lake, or other body of water.
Weir	A dam or obstruction in a stream or river to raise the water level or divert streamflow.
Zero Rise	No impact or no changes to base flood elevations.
Zone A	Zone A areas have a one percent annual chance of flooding; such a flood is also called the 100-year flood.

Appendix A

Pierce County Basin Flood Problems

Appendix B

Legal Agreements

Appendix C

Climate Change Projections for Pierce County

Appendix D

Capital Project Ranking Criteria

Appendix E

Identified Flood Problems and Projects

Appendix F

River Gauge Flood Warning Threshold Matrix

Appendix G

USACE General Investigations for the Puyallup River Next Steps

Appendix H

Local, State, and Federal Regulations and Programs

Appendix I

Plans, Studies, and Initiatives

Appendix J

Flood Risk Assessment and Economic Analysis

Flood Problems identified in the Nine Pierce County Basin Plans

The management of surface water in unincorporated Pierce County is guided by a series of nine basin plans which identify flooding within the watershed, identify existing conditions which affect storm drainage and surface water, forecasts future drainage conditions, and identify potential solutions for the streams and tributaries not included within the *1991 Puyallup River Basin Comprehensive Flood Control Management Plan* or in its updates the 2013 and 2018 *Pierce County Rivers Flood Hazard Management Plan*. These plans were used to develop capital improvement projects, property acquisition, programmatic recommendations, as well as schedules and budgets.

Basin specific plans are:

- Clear / Clarks Creek Basin
- Clover Creek Basin
- Gig Harbor Basin
- Hylebos Browns - Dash Point Basin
- Key Peninsula - Islands Basin
- Mid-Puyallup Basin
- Muck Creek Basin
- Nisqually Basin
- White River Basin

As part of the planning effort to create a comprehensive flood plan for Pierce County, each basin plan was reviewed to identify flood-related problems. The following sections provide a brief description of each basin, a description of the flood types in that basin, along with a list of flood problems that were identified during the development of each basin plan. Staff from Surface Water Management and Maintenance and Operations have provided a status update to each problem that was identified.

The basin plans that are listed above are used by Surface Water Management and other departments as source documents for various topics that are discussed in the plans. These basin plans are anticipated to be updated in the future.

Clover Creek Basin Plan

Basin Description:
In 2003 the Clover Creek Basin plan was adopted by the Pierce County Council. This plan serves as a comprehensive guide to surface water management in unincorporated areas of the Clover Creek Basin. Chambers- Clover Creek flows generally northwest for 13.8 miles from its headwaters about 6 miles east of the Spanaway community to Steilacoom Lake. Its 74-square-mile drainage basin makes up about half of the combined Chambers-Clover Creek drainage area (Chambers Creek is the 5-mile creek flowing from Steilacoom Lake to Puget Sound). Significant tributaries to Clover Creek include Morey Creek and the North Fork of Clover Creek. The largest lakes in the basin are Spanaway, Tule, and Steilacoom Lakes.

The Clover Creek Basin contains portions of unincorporated Pierce County, including the Parkland and Spanaway communities, a significant portion of the City of Lakewood, a small portion of the City of Tacoma, and portions of McChord Air Force Base and Fort Lewis. A small portion of the Wards Lake watershed contained within unincorporated Pierce County is also addressed in this planning effort.

Flood problems in the basin:
The majority of the flooding and drainage problems identified in the Clover Creek Basin plan are site-specific problems. Basin-wide flooding and drainage issues are generally regulatory and programmatic issues, with the exception of flooding on Spanaway Creek and the main stem of Clover Creek that appear to have the same cause. These flooding problems are further characterized as follows:

- Groundwater or surface water flooding that occurs with regularity or is expected to occur again in the future in areas not previously mapped as flood hazard areas.
- Illegal filling and grading in wetlands and floodplains, or filling and grading in storage areas that are unmapped and unprotected.
- Decreased channel capacity in segments of Spanaway Creek and the main stem of Clover Creek due to sedimentation and invasive vegetation, primarily reed canary grass.
- Ineffective coordination between community groups and volunteer organizations involved in protecting and enhancing the basin’s natural water resources.
- A lack of public awareness of the hazards associated with flooding and steps to take to protect themselves and their property

Flooding and drainage problems in the Upper Clover Creek Basin are related primarily to infrequent groundwater flooding and development encroaching into wetlands, areas of depression storage, and potholes. Groundwater flooding is the dominant type of flooding problem in this basin. During years of high annual rainfall, groundwater levels in the aquifer come to the surface in low-lying depressions and potholes. Groundwater flooding in the subbasin follows the path of groundwater flow, originating in the southeast and moving to the northwest toward Puget Sound. This movement of groundwater can be observed by the timing of flooding. Floods occur first in areas such as 204th Street East and 67th Avenue East. They then move northwest to Stoney Lake and then north to the Brook Tree additions by Clover Creek. These areas have no surface connection but appear to be entirely connected by the groundwater system. Since the frequency and magnitude of flooding is controlled by cumulative annual precipitation, this type of flooding may not occur even during heavy rainstorms when other surface flooding is occurring. In between times of groundwater flooding, the areas can appear very dry and suitable for development.

When the groundwater reaches the surface in low spots of the topography, the flooding is an extension of the groundwater elevation. This flooding can last for days, weeks, or even months depending on the amount of precipitation recharging the aquifer and the rate of movement of the groundwater through the subsurface as it moves northwest to the Sound. This is the case in the Frederickson area at 192nd Street East, where flooding occurred for several months in 1996, again for several weeks in 1997, and for just a few days in 1999.

Identified flood problems in the Clover Creek Basin:

Table 1 lists the flood problems that were identified during the development of this basin plan. A status update for each flood problem has been provided below along with information on the type of flood hazard the problem is associated with (riverine, urban, groundwater, and coastal). Figure 1 provides the location of each identified flood problem.

Table 1: Clover Creek Basin Plan Flood Problems				
Type of Flooding	Project Number	Problem Name: Description	Status of the problem?	Additional Information (if available)
U	CL_01	Spanaway: Lakeside Dr. and 169th St. S, residential floodproofing (3 Houses): Floodproofing	Not started	The County continues to provide assistance to property owners by improving mapping and avoidance of the hazard.
U	CL_02	Spanaway: Lakeside Drive, elevating homes and floodproofing (3 bldgs.): Floodproofing & Elevation	Not started	The County continues to provide assistance to property owners by improving mapping and avoidance of the hazard.

U	CL_03	Spanaway: 8th Ave. Ct. S and 173rd St. S (for 3 bldgs): Floodproofing	Not started	The County continues to provide assistance to property owners by improving mapping and avoidance of the hazard.
U	CL_04	Spanaway: 8th Ave. Ct. S and 173rd St. S (for 3 houses): Floodproofing & Elevation	Not started	The County continues to provide assistance to property owners by improving mapping and avoidance of the hazard.
U	CL_05	Spanaway: Creso Road Elevate houses and raise road: Elevate & floodproof; raise road	Not started	The County continues to provide assistance to property owners by improving mapping and avoidance of the hazard.
U	CL_06	Spanaway: Field Rd. E Storage Units: Dry-floodproof; raise road	Not started	The County continues to provide assistance to property owners by improving mapping and avoidance of the hazard.
G	CL_07	Spanaway: 203rd St CT E: Construct berm for flooding	Not started	This is a groundwater issue and will be addressed further in the plan.
G	CL_08	Spanaway: 203rd St CT E: Floodproof house (cost per house)	Not started	This is a groundwater issue and will be addressed further in the plan.
U	CL_09	Spanaway: 51st Ave E and 219th St. Ct. E (B) overflow/floodproofing: Floodproof & install overflow pipe	Not started	Build a Berm and conveyance system upgrade to contain the water from the wetlands.
U	CL_10	Spanaway: 51st Ave E and 219th St. Ct. E property	Not started	Build a Berm and conveyance system upgrade

		acquisition and wetland restoration: Purchase three properties that flood		to contain the water from the wetlands.
U	CL_11	Spanaway: 51st & 219th ST CT E Overflow pipe from Drywell, Elevate & Flood Proof: Elevate & floodproof; install pipe	Not started	Build a Berm and conveyance system upgrade to contain the water from the wetlands.
U	CL_12	Ward Lake: Flooding of 2 homes, E of Larchment estates, elevate and floodproof: Floodproof or elevate	Not started	Protection of individual property will be addressed in the programmatic recommendations section of the plan.
G	CL_13	Upper Clover: 160th ST E & 22nd Ave E Elevate & Flood Proof houses: Elevate and floodproof	Not started	This is a groundwater issue and will be addressed further by the programmatic recommendations in this plan.
G	CL_14	Upper Clover: Stoney Lake Elevate & Flood Proof houses: Elevate and floodproof	Not started	This is a groundwater issue and will be addressed further by the programmatic recommendations in this plan.
G	CL_15	Spanaway: 8th Ave E. Floodproof structures: Elevate BFE; possible floodproof	Not started	This is a groundwater issue and will be addressed further by the programmatic recommendations in this plan.

G	CL_16	Spanaway: 208th St. E. Floodproof house and mobiles: Elevate BFE; possible floodproof	Not started	This is a groundwater issue and will be addressed further by the programmatic recommendations in this plan.
G	CL_17	Spanaway: Mountain Highway Mobile Home Park Elevations: Elevate four to five mobile homes for flooding.	Not started	This is a groundwater issue and will be addressed further by the programmatic recommendations in the plan.
G Groundwater	R Riverine	U Urban	C Coastal	

Additional information for the Chambers-Clover basin plan, can be found at the following link:
[Archive Center • Pierce County, WA • CivicEngage (piercecountywa.gov)]

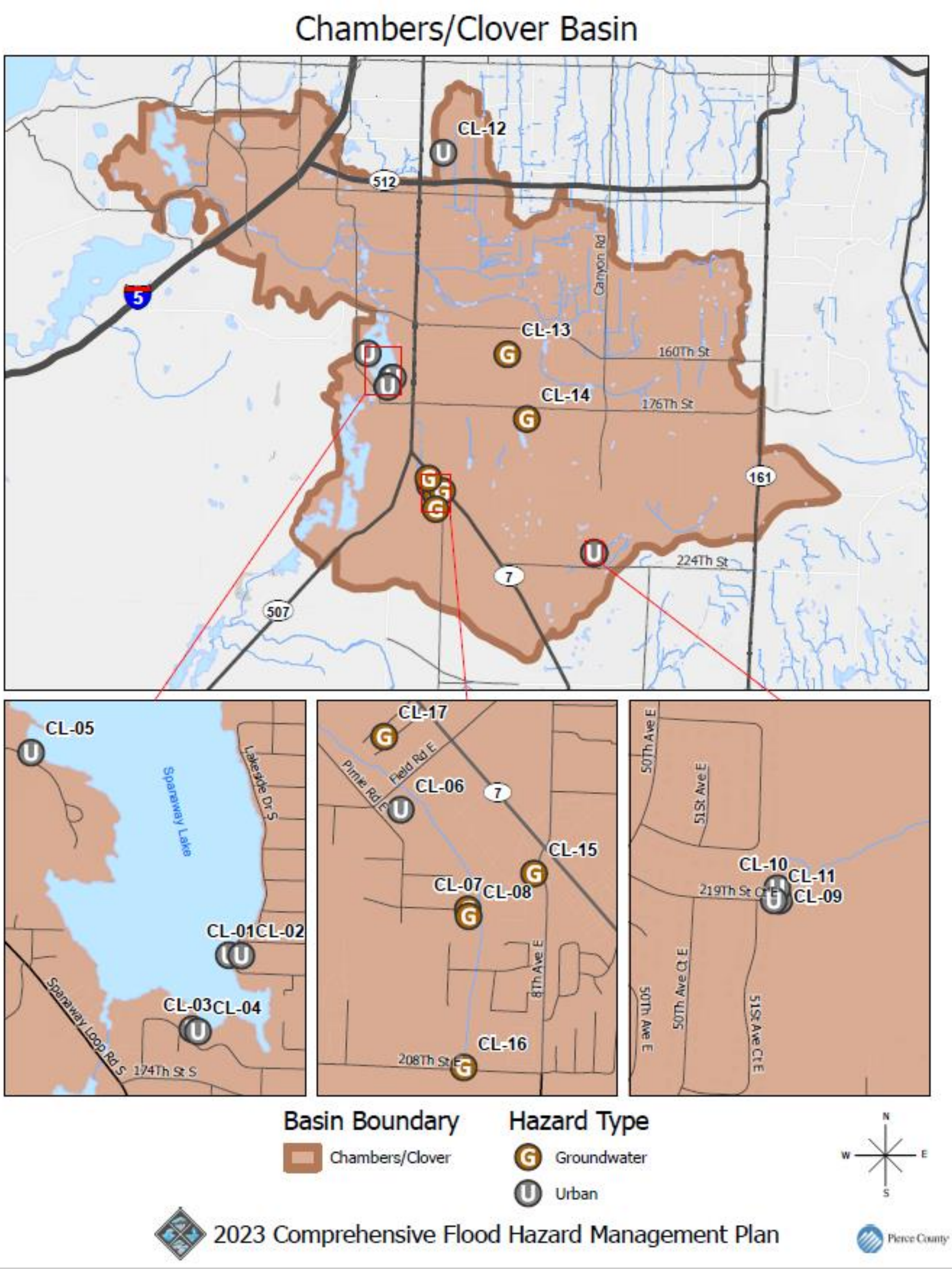


Figure 1 Locations of flood problems Chambers/ Clover Basin

Clear/Clarks Creek Basin Plan

Basin Description:

The Clear/Clarks Creek Basin drains approximately 32.9 square miles (21,038 acres) of northcentral Pierce County, of which 27.4 square miles (83 percent) exist within unincorporated Pierce County. The remaining 5.5 square miles (17 percent) lie in the cities of Tacoma and Puyallup. The tributaries within the basin generally flow north before discharging into the Puyallup River just west of the City of Tacoma. Clear Creek drains the western portion of the basin; Clarks Creek drains the eastern portion of the basin, including a portion of the City of Puyallup. The major tributaries to Clear Creek include Swan Creek, Squally Creek, and Canyon Creek. The major tributaries to Clarks Creek include Rody Creek, Meeker Ditch, Diru Creek, and Woodland Creek. The Clear/Clarks Creek Basin also includes the Pothole area, an 8.3-square-mile originally internally drained area on South Hill. The Clear/Clarks Creek Basin is part of Washington State Water Resource Inventory Area (WRIA) 10, the Puyallup-White River Basin. The four basins are as follows:

- Roosevelt Ditch Drainage Area which flows into the City of Tacoma and the T Street drainage
- Clear Creek Drainage Basin, areas draining to Clear Creek
- Clarks Creek Drainage Basin, areas draining to Clarks Creek
- Potholes Drainage Area, areas draining to the potholes on South Hill

In 2005, the Clear/Clarks Creek Basin plan was adopted by the Pierce County Council. This plan serves as a comprehensive guide to surface water management in the portions of the Clear/ Clarks Creek Basin that are under Pierce County's jurisdiction.

Flood problems in the basin:

Early maps show Clear Creek emptying a vast wetland complex feed by streams flowing off the south valley wall. This Clear Creek wetland provided the low water velocity/high prey habitat that juvenile salmon require for survival. At the turn of the 20th century, the confluence of Clear Creek with the Puyallup River was moved further downstream to its present location to help drain the wetland for agriculture.

Daily tidal fluctuations, coupled with flow conditions in the Puyallup River, affect the water level within the creek. To prevent backwater flooding behind the River Road Levee, two flood gates were installed. These gates prevent the Puyallup River from flooding the lowlands behind the levee, but also result in Clear Creek not being able to discharge. Clear Creek then floods approximately 400 acres of farmland, commercial and residential properties valued in excess of $42 million.

The lower Puyallup River levees were constructed in the early 20th century. FEMA's first flood map was based on a risk assessment done in the 1970's. In 1986 FEMA established its first national levee standards (44 CFR 65.10). Between 2002-2006 FEMA re-studied the Puyallup River and this risk assessment showed that the levees did not meet the national levee standards. Pierce County has been regulating to this updated levee since the spring of 2005.

The primary objective is to minimize the impact of flooding on the lowlands behind the existing levee while preserving existing farmland. Preliminary design efforts also revealed that with proper design, the project will be able to provide refuge and habitat for juvenile salmon and other wildlife in the lower Puyallup River system.

Identified flood problems in the Clear-Clarks Creek Basin:
Table 2 lists the flood problems that were identified during the development of this plan. A status update for each flood problem has been provided below along with information on the type of flood hazard the problem is associated with (riverine, urban, groundwater, and coastal). Figure 2 provides the location of each identified flood problem.

Table 2: Clear-Clarks Creek Basin plan Flood Problems

Type of Flooding	Project Number	Problem Name: Description	Status of the problem?	Additional Information (if available)
R	CC_01	84th Street East Pipeline Replacement	No	This has been partially completed per Basin Plan recommendation. The 24" pipe has been replaced with 36", however the 12" cross culvert conveying drainage north to south has not been up sized.
R	CC_02	Clear Creek at 88th Street E Culvert	Yes	Problem may exist downstream of the 18” culvert. Flooding is still an issue in this area.
R	CC_03	Canyon Creek Property Acquisition at 5600 block of 104th Street E	No	In the last 5 years, there has been one request for action (RFA) for potential flooding due to flooding. Culverts have been cleared.
R	CC_04	58th Avenue East Setback Levee from Canyon Creek	Yes	There has been one RFA for flooding in this area in the last 5 years.
R	CC_05	Acquire property in the floodplain	No	This is now in the City of Puyallup jurisdiction and has been acquired by the City.
R	CC_06	Replace 24" culvert w/ 30" for flooding	Yes	There has been one RFA for flooding in this area in the last 5 years.

R	CC_07	Install berm and ditch for flooding	Yes	Road Operations has done some ditch work near the 12100 block.
R	CC_08	Install berm and ditch for flooding	No	This is now in the City of Puyallup jurisdiction. Inside the City of Puyallup's limits, no longer a Pierce County issue
R	CC_09	2 regional detention ponds to reduce flooding near 112 and Woodland Ave	Yes	Project was previously evaluated, and the recommended solution was to raise the road. However, the cost to benefit of this solution was going to be high. There are still continued capacity issues in this area.
R	CC_10	Purchase 58 properties in repetitive loss area	Yes	Pierce County has purchased properties in the repetitive loss area
G Groundwater	R Riverine	U Urban	C Coastal	

Additional information for the Clear-Clarks basin plan, can be found at the following link:
[Archive Center • Pierce County, WA • CivicEngage (piercecountywa.gov)]

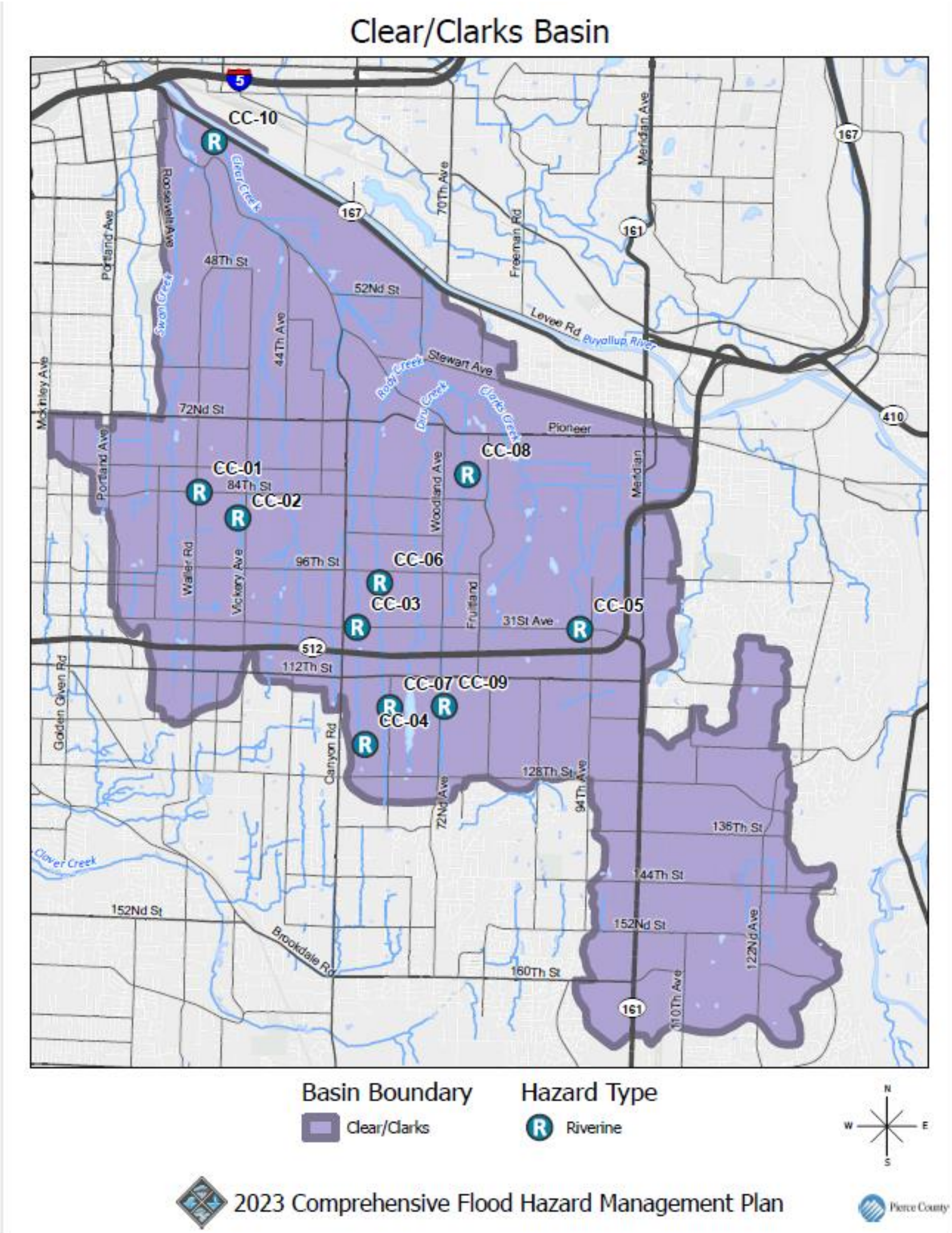


Figure 2 Locations of flood problems Clear/Clarks Basin

Gig Harbor Basin Plan

Basin Description:

The 42.4-square-mile Gig Harbor Basin is located on a peninsula extending southward into Puget Sound. It is bounded on the west by Carr Inlet and Henderson Passage, on the east by the Narrows, and on the south by Hale Passage. Several drainage divides that are located close to the Pierce/Kitsap county line form the northern boundary of the basin. The watershed contains approximately 101,000 acres or 158 square miles of land and 144 miles of shoreline. It is composed of two large peninsulas and many islands. The three largest islands are Fox, McNeil (state-owned), and Anderson. There are a number of smaller islands, including Raft, Herron, Cutts, Eagle, Gertrude, Tanglewood, and Ketron. Gig Harbor is the main commercial center and the only incorporated city. The remainder of the basin lies within unincorporated Pierce County, except for a small area at the northern edge of the basin that lies within Kitsap County.

In 2003, the Gig Harbor Basin plan was adopted by the Pierce County Council. This plan serves as a comprehensive guide to surface water management in the portions of the Gig Harbor Basin that are under Pierce County's jurisdiction.

Flood problems in the basin:

Most storm water runoff in the Gig Harbor Basin is routed to streams that flow to Puget Sound. Natural drainage patterns remain largely unaltered, although many culverts have been built to carry stream flow under roads and driveways. Curbs, gutters, and underground storm drains exist only in the more densely developed areas. Storm water runoff in older rural communities and suburban neighborhoods is typically routed to roadside ditches and then into natural streams. Many streams flow through fairly narrow canyons where streamside properties are generally located a considerable distance above the water level. Where the flood plain is broader, wetlands often exist, and are a deterrent to development. Several methods were used to identify historical flooding problems in the Gig Harbor Basin.

Almost all flooding problems that occur under existing conditions are localized and relatively minor. There has only been one recent report of flooding that caused serious damage. It occurred when a hillside above several homes was logged, and no measures were taken to control storm runoff from the denuded slope. This problem was addressed by installing a detention basin. Several individuals have noted that water from Crescent Creek overflows on to Crescent Valley Road at times. But, in general, the existing system appears to have sufficient capacity to carry storm water away from structures at the current level of urban development. Most of the reported problems are likely the result of debris accumulating in culverts and ditches and probably could be solved by improved maintenance. A few problems may be attributed to deficiencies in the engineered drainage systems associated with residential subdivisions.

<u>Identified flood problems in the Gig Harbor Basin:</u>

Table 3 lists the flood problems that were identified during the development of this basin plan. A status update for each flood problem has been provided below along with information on the type of flood hazard the problem is associated with (riverine, urban, groundwater, and coastal). Figure 3 provides the location of each identified flood problem.

Table 3: Gig Harbor Basin Plan Flood Problems

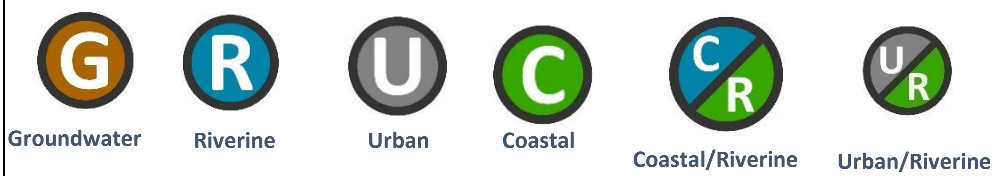
Type of Flooding	Project Number	Problem Name: Description	Status of the problem?	Additional Information (if available)
C/R	GH_01	Goodnough State Route 302: Replace culvert for flood & fish	Not Started	WSDOT injunction barrier. Rated as impassable but its a partial barrier.
R	GH_02	Goodnough Drive: Replace culvert for flood & fish	Not Started	Pierce County is working on a culvert replacement program for identified projects such as this.
R	GH_03	Goodnough State Route 16: Replace culvert for flood & fish	Not Started	WSDOT injunction barrier
U/R	GH_04	Goodnough 54th Ave: Replace culvert for flood, fish, & Water Quality	Not Started	Pierce County is working on a culvert replacement program for identified projects such as this.

U R	GH_05	Goodnough 144th St Ct & 51st Ave Ct: Replace culvert for flood & fish	Not Started	Pierce County is working on a culvert replacement program for identified projects such as this.
U R	GH_06	Goodnough 141st Ct NW & 52nd Ave: Replace culvert for flood & fish	Not Started	Pierce County is working on a culvert replacement program for identified projects such as this.
C	GH_07	Nelyaly Creek 82nd St.: Replace culvert for flood & fish	Not Started	Pierce County is working on a culvert replacement program for identified projects such as this.
R	GH_08	Muri Creek Ford Dr: Replace culvert for flooding	Not Started	Ditch work in this area was completed in 2017.
U R	GH_09	Wollochet Hunt St.: Replace culvert for flooding and fish	Not Started	There have been no Request for Action (RFA) in this area in the last 20 years.
U R	GH_10	Wollochet 57th St.: Replace culvert to reduce flooding and fish passage	Not Started	There has been no RFA's or maintenanc

				e Connection work orders found for this culvert.
	GH_11	Murphy Creek East Bay Dr.: Replace culvert for flooding	Not Started	Pierce County is working on a culvert replacement program for identified projects such as this.
	GH_12	Sullivan Gulch East Bay Dr.: Replace culvert for flooding & fish	Not Started	Pierce County is working on a culvert replacement program for identified projects such as this.
	GH_13	Sullivan Gulch Sullivan Dr.: Replace culvert for flooding & fish	Not Started	Pierce County is working on a culvert replacement program for identified projects such as this.
	GH_14	Doc Weathers County Park: Replace culvert for flood & fish	Not Started	Washington State Department of Fish and Wildlife barrier inventory says it was replaced in 2016

C	GH_15	Donkey Harborview Dr. & N. Harborview Dr.: Replace culvert for flood & fish	Not Started	This barrier belongs to Gig Harbor
C	GH_16	Donkey: Harborview Dr.: Replace culvert for flood & fish	Complete	This barrier belongs to Gig Harbor
C	GH_17	Donkey: Harborview/Burnham Dr: Replace culvert for flood & fish	Not Started	This barrier belongs to Gig Harbor
R	GH_18	Mark Dickson: 71st St Ct. home near Sylvia Lake: Resolve flooding & WQ in Sylvia Lake	Completed	Road Operations did some major ditch work in this area in 2018. Since the work was completed, there has not been any reports of water over the roadway.
R	GH_19	Mark Dickson: 82nd Ave. NW: Raise road to reduce flooding	Completed	Road Operations did some major ditch work in this area in 2018. Since the work was completed, there has not been any reports of water

				over the roadway.
	GH_21	Mark Dickson: Install vaults & replace culvert for flooding & Water Quality	Not Started	There has been no RFA's or Maintenance Connection work orders found for this culvert.



Additional information for the Gig Harbor basin plan, can be found at the following link: [Archive Center • Pierce County, WA • CivicEngage (piercecountywa.gov)]

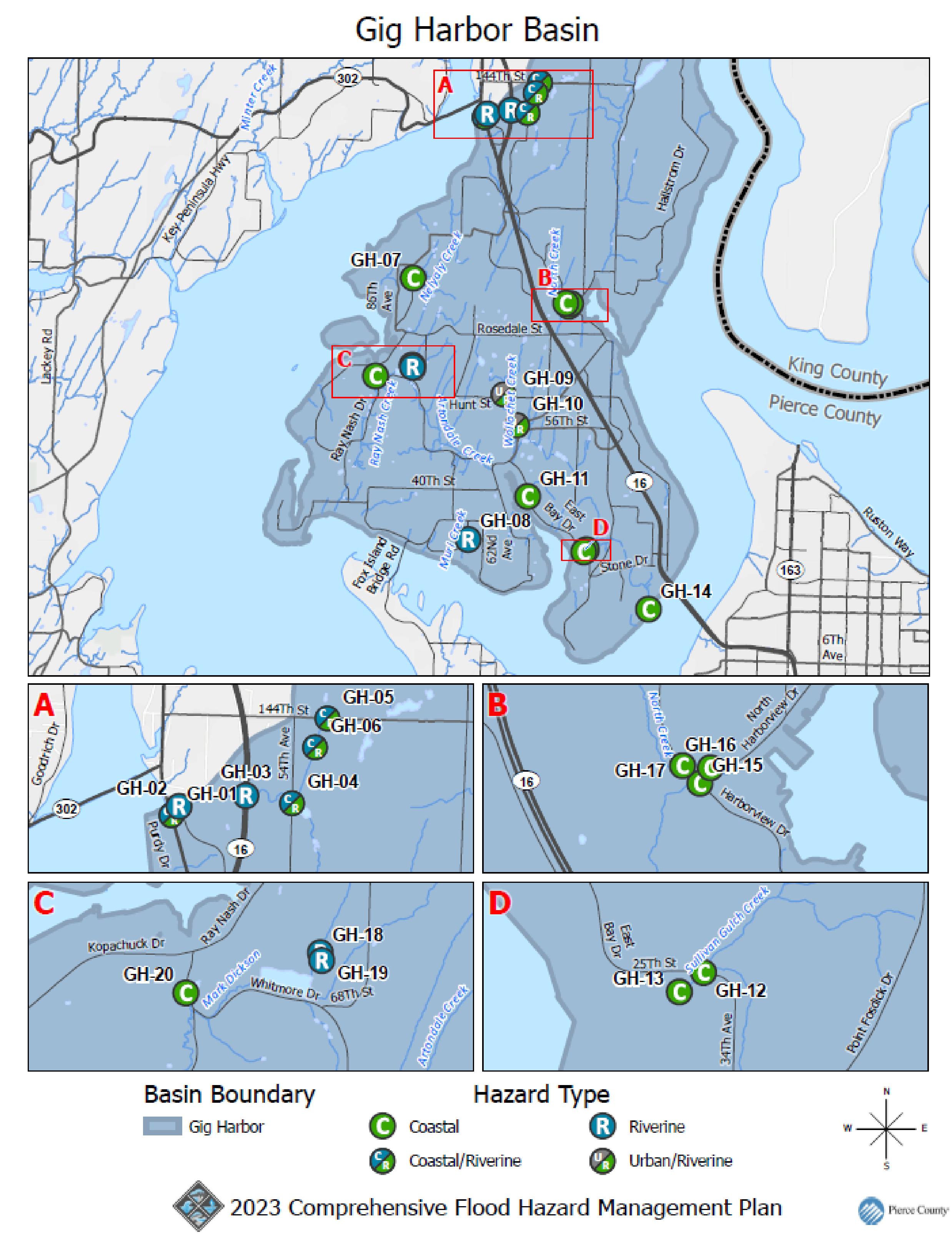


Figure 3. Locations of flood problems in the Gig Harbor Basin

Hylebos Browns-Dash Point Basin Plan

Basin Description:

The Browns-Dash Point Basin and Hylebos Basin are both located in the northeast corner of Pierce County and are within the Puyallup Water Resource Inventory Area (WRIA) 10. The Hylebos Basin covers 29 square miles (sq. mi.) (18,625 acres), and the Browns-Dash Point Basin covers 15 sq. mi. (9,589 acres). Both basins straddle the Pierce/King County boundary. Because of incorporations by the cities of Tacoma, Fife and Edgewood there is relatively little area of each basin that is unincorporated Pierce County. Within the Browns-Dash Point Basin, 758 acres (7.9 percent of the basin area) are in unincorporated Pierce County. Within the Hylebos Basin, 950 acres (5.1 percent of the basin area) are located in unincorporated Pierce County. The Hylebos Browns-Dash Point Basin contains Hylebos Creek and its tributaries and a "peninsula-like" feature northeast of the City of Tacoma with several smaller drainages that discharge directly to Puget Sound. Browns-Dash Point Basin Area: Flows into Puget Sound Hylebos Creek Basin: East Fork West Fork Surprise Lake Tributary Lower Hylebos Creek.

In 2006, the Hylebos Browns-Dash Point basin plan was adopted by the Pierce County Council. This plan serves as a comprehensive guide to surface water management in the portions of the Hylebos Browns-Dash Point Basin that are under Pierce County's jurisdiction.

Flood problems in the basin:

The Browns-Dash Point Basin has a mapped "A Zone" flood hazard area along the Commencement Bay and Hylebos Waterway shoreline that illustrates areas of potential coastal flooding.

The Hylebos Basin has a large mapped 100-year floodplain associated with the lower Hylebos, downstream of the confluence of the West and East Fork. Flood hazard areas have been updated by FEMA. Mapped flood hazard areas have been expanded to include more lands within the incorporated Pierce County area of the Basin. The most significant flooding on lower Hylebos Creek occurs where the channel makes its turn to the northwest and comes close to and crosses under I-5 and Hwy 99. During the 1996 and 1997 flood events, floodwaters encroached into the outer lanes of I-5 at this location. At this location, Hylebos Creek is confined to a narrow channel lined with ecology blocks and is forced to make a series of sharp degree turns. East of I-5, large fields and some houses were flooded during the 1996 and 1997 events. This flooding followed the Surprise Lake drainage path downstream to the confluence with the Hylebos main stem west of I-5.

Identified flood problems in the Hylebos Browns-Dash Point Basin:

Table 4 lists the flood problems that were identified during the development of this basin plan. A status update for each flood problem has been provided below along with information on the type of flood hazard the problem is associated with (riverine, urban, groundwater, and coastal). Figure 4 provides the location of each identified flood problem.

Table 4: Hylebos Browns-Dash Point Basin Plan Flood Problems

Type of Flooding	Project Number	Problem Name: Description	Status of the problem	Additional Information (if available)
U	HY-01	Spring Street: Replace open channel w/ 200' pipe	The culvert near 6602 Spring St NE was jet-rod due to a drainage issue at a nearby residence.	
U	HY-02	Dry Gulch & Varco Rd.: Improve drainage system w/ pipes and reconstructed channel	Drainage improvements were done in 2005 near 5220 Varco Rd NE	
U	HY-03	Hyada Blvd. at Wan-I-Da Ave. & La Hal Da Ave. NE: Install new larger capacity pipe	The ditch has been cleaned and reshaped due to standing water along Hyanda Blvd between Wana Wana Pl NE and Tulalip St. NE.	
U	HY-04	Tok-A-Lou Ave. near Ton-A-Wan-Da (5000 Blk): Replace pipe; construct new outfall w/ dissipater	Not started	
U	HY-05	Layman Terrence: Install culvert & reconstruct channel	Ditch cleared and driveway tile jet rodded to alleviate water backing up and flowing onto the road near 4508 Layman Terrace NE.	

U	HY-06	Wa-Tau-Ga Ave. NE: Install pipe & reconstruct channel	Not started	
U	HY-07	Northwood: Replace existing pipe w/ HDPE tightline over bluff; new outfall w/ dissipater; trash racks	Not started	
U	HY-08	1st St. Ct NE & 66th Ave NW: Install pipe in steep gully	Not started	There have been drainage repairs near 215 66^{th} Ave NE.
U	HY-09	8th St. E. & 66th St.: Storm drain replacement	Not started	Driveway tiles near 6502 8th St E jet rodded and ditch cleaned and reshaped
U	HY-10	Hylebos Creek Restoration: Restoration of up to 1000' of riparian habitat	In progress	First phase of Lower Hylebos has been completed. This project has been prioritized through regional conversations with tribes
G Groundwater	R Riverine	U Urban	C Coastal	

Additional information for the Hylebos Browns-Dash Point basin plan, can be found at the following link : Archive Center • Pierce County, WA • CivicEngage (piercecountywa.gov)

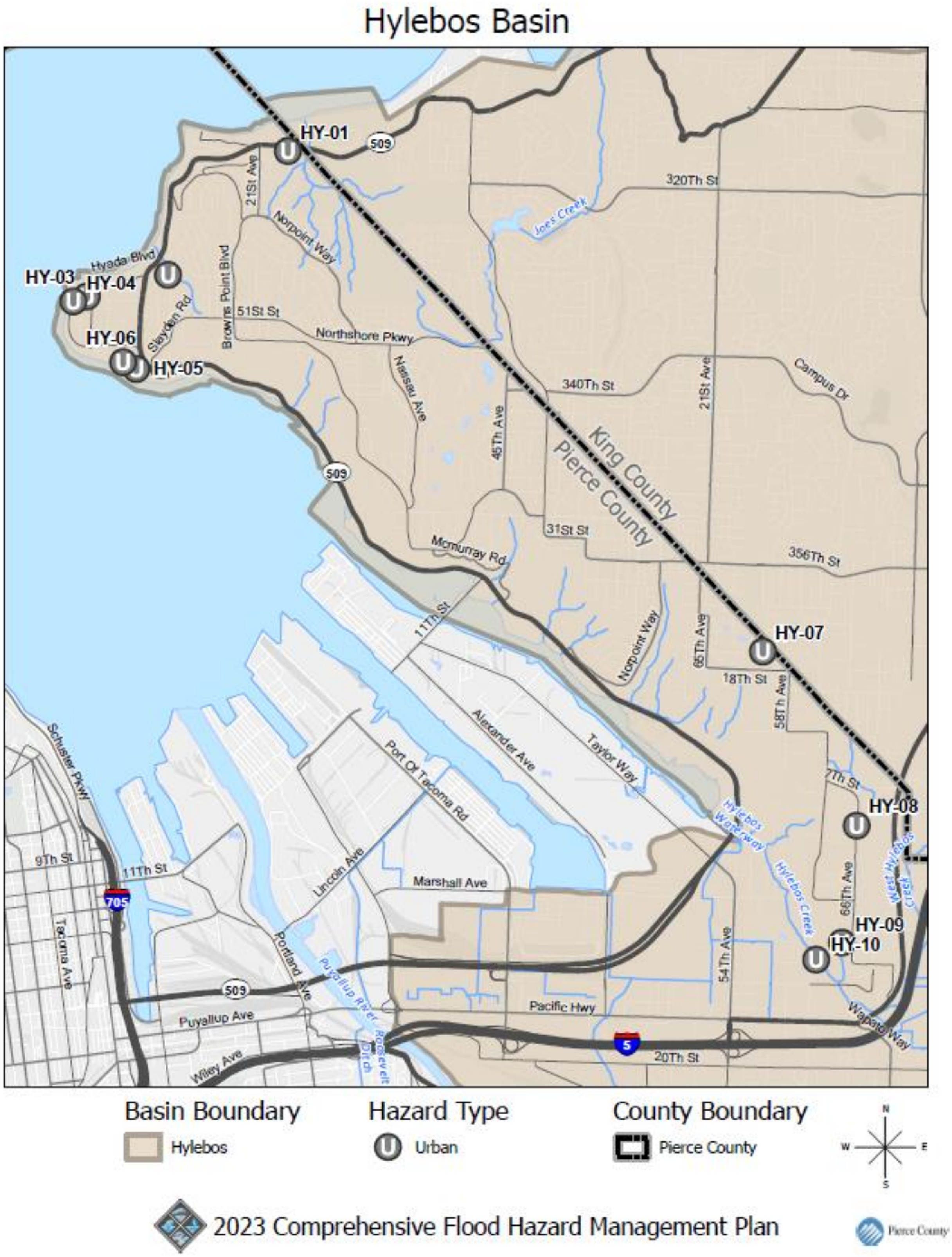


Figure 4. Locations of flood problems in the Hylebos Basin

Key Peninsula-Islands Basin Plan

Basin Description:

The Key Peninsula-Islands (KI) Basin is an agglomeration of four separate surface basins identified by at one time was called Pierce County Water Programs which is now Pierce County Surface Water Management. These are the Key Peninsula Basin, the Islands Basin, the Burley–Minter Basin, and the Fox Island Basin. Combined, these basins have an area of approximately 114 square miles. The Key Peninsula extends southward into Puget Sound and is bounded on the west by Case Inlet and on the east by Carr Inlet. Islands surrounding the Key Peninsula Basin and include: Fox, Raft, Cutts, Ketron, Anderson, and Herron Islands. McNeil Island and small area of Mason County are not included in this plan. Several drainages located along Pierce/Kitsap County line form the northern boundary of the KI Basin. Much of the peninsula consists of rolling, rather flat-topped hills and ridges. Bluffs drop to the waters of Puget Sound on all three sides of the peninsula and on the islands. There are approximately 57 streams in this Basin. The climate of the KI Basin is mild. It receives between 50 and 55 inches of precipitation annually, including approximately 5 inches of snow on average.

In 2006, the Key Peninsula- Islands Basin plan was adopted by the Pierce County Council. This plan serves as a comprehensive guide to surface water management in the portions of the Key Peninsula Islands that are under Pierce County's jurisdiction.

Flood problems in the basin:

Most stormwater runoff in the KI Basin is routed to streams that flow to Puget Sound, with a few lakes interrupting flows in a couple of subbasins. Natural drainage patterns remain largely unaltered, although many culverts have been built to carry stream flow under roads, driveways and private culverts. As a largely rural basin, there are few curbs, gutters, and underground storm drainage systems. Stormwater runoff in rural communities is typically routed to roadside ditches and then into natural streams. Some streams flow through well-defined ravines where streamside properties are generally located a considerable distance above the water level. Others flow through flatter terrain where the flood plain is broader. Wetlands often exist within the floodplain and have served as a deterrent to development. There has been history of flooding in the last couple of decades at Huge Creek at 160th making it dangerous to pass through the area. In general, the existing drainage system appears to have sufficient capacity to carry stormwater away from structures at the current level of urban development. Most of the reported problems are the result of undersized culverts and debris accumulation. This could be solved by improved maintenance in the area.

Identified flood problems in the Key Peninsula-Islands Basin:

Table 5 lists the flood problems that were identified during the development of this basin plan. A status update for each flood problem has been included to address whether the identified problems are still issues or not. Figure 5 provides the location of each identified flood problem.

Table 5: Key Peninsula-Islands Basin Plan Flood Problems				
Type of Flooding	Project Number	Problem Name: Description	Status of the problem?	Additional Information
R	KP_01	Lackey Road Culvert Replacement: Replace culvert w/ box culvert for flooding & fish passage	Not started	Culvert replacement program
R	KP_02	Driveway E. of 70th Avenue: Replace 2 culverts for fish passage and flooding	Not started	Private barrier that needs to be addressed.
R	KP_03	Huge Creek at 160th: Replace culvert w/ box culvert to reduce flooding	In progress	This project was completed in 2021.
C	KP_04	Purdy Creek/144th St. Culvert replacement: Replace culverts to reduce flooding; fish passage & WQ concerns	In progress	Pierce County SWM is working on this project. A feasibility study has been completed for this area
R	KP_05	Purdy Creek at 160th St. Culvert Replacement: Replace culvert w/ box culvert for fish passage and flooding	In progress	Pierce County SWM is working on this project.
R	KP_06	Mahnke Rd./SE of Reeves Rd./158th Ave. Culvert Replacement: Replace culvert w/ box culvert for fish passage and potential flooding	Not started	

R	KP_07	S. of 56th St. Culvert Replacement: Replace culvert for fish passage/possible flooding	Not started	
R	KP_08	Sanberg Rd. / Amsterdam Bay Culvert Replacement: Replace culverts with bridge for flooding	Completed	There was a fish passage project completed on Sandberg Rd on Schoolhouse Creek by the South Puget Sound Salmon Enhancement Group in 2000.
R	KP_09	McFadden Road Culvert Replacement: Replace culvert with bridge for flooding and possible fish passage	Not started	Culvert replacement program
G Groundwater	R Riverine	U Urban	C Coastal	

Additional information for the Key Peninsula basin plan, can be found at the following link: [Archive Center • Pierce County, WA • CivicEngage (piercecountywa.gov)]

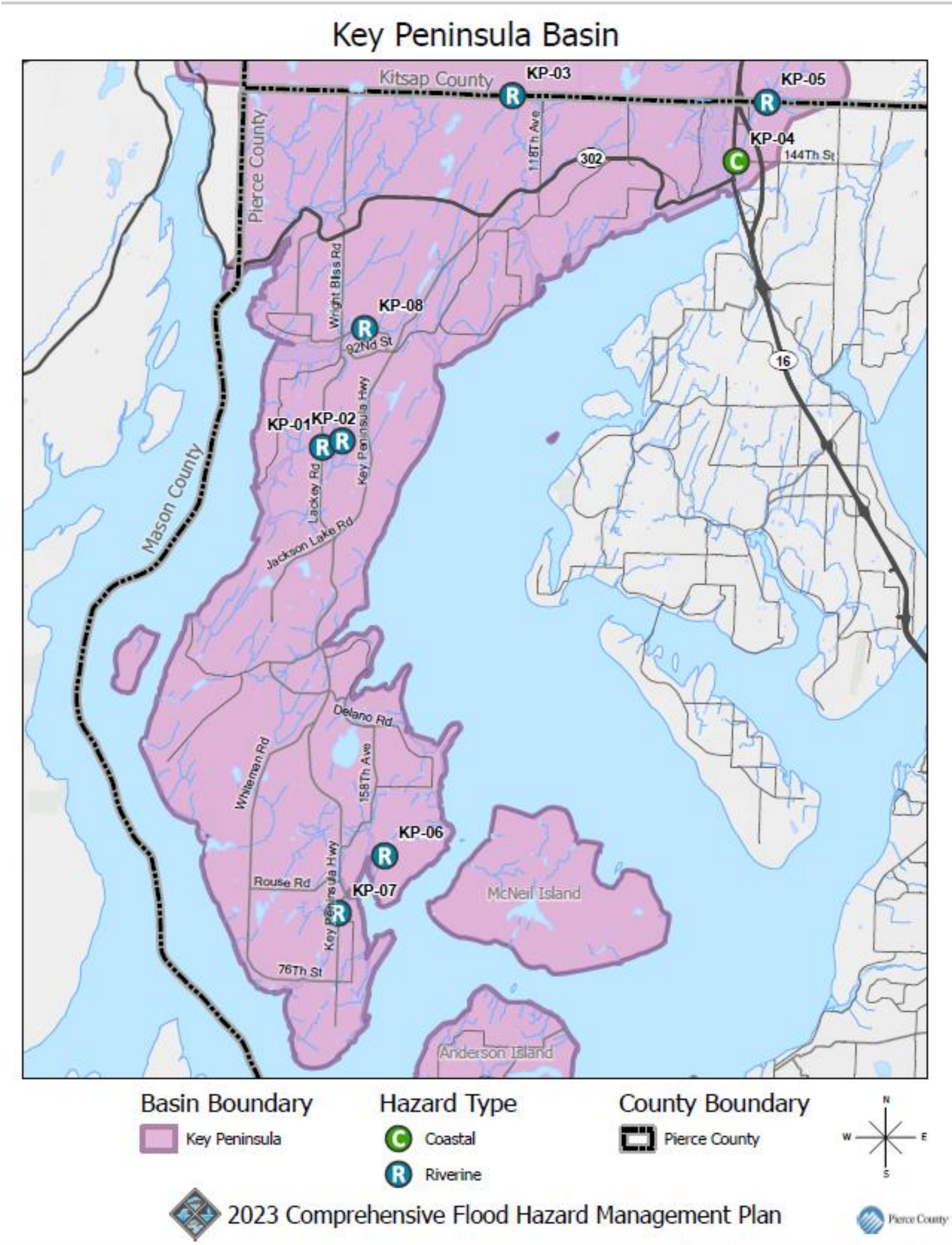


Figure 5. Locations of flood problems in the Key Peninsula-Islands Basin

Mid-Puyallup Basin Plan

Basin Description:

The Mid-Puyallup Basin comprises the drainage areas of tributaries to the Puyallup River between river mile (RM) 7 and RM 26.5. It excludes the Carbon River and White River drainages and the main stem of the Puyallup River. The main stem of the Puyallup River is covered in other plans. The entire Mid-Puyallup planning area encompasses 57.6 square miles (36,333 acres), of which 41.8 square miles (74%) is within unincorporated Pierce County. The remaining 15.8 square miles (26%) are within areas incorporated by various cities; Bonney Lake, Fife, Orting, Puyallup, and Sumner.

The Mid-Puyallup Basin is part of "Washington State Water Resource Inventory Area"(WRIA) 10, the Puyallup-White River Basin. Mid-Puyallup Basin contains six primary tributaries:

- Alderton Creek, tributary 0399, confluence at Puyallup RM 12.2
- Van Ogles Creek, tributary 0400, confluence at Puyallup RM 13.1
- Ball Creek, tributary 0405, confluence at Puyallup RM 14.9
- Fennel Creek, tributary 0406, confluence at Puyallup RM 15.5
- Canyon Falls Creek, tributary 0410, confluence at Puyallup RM 16.2
- Horsehaven Creek, tributary 0589, confluence at Puyallup RM 20.2

In addition, 18 square miles (11,560 acres) drain directly to the Puyallup River and are not associated with the creeks.

In 2005, the Mid-Puyallup Basin plan was adopted by the Pierce County Council. This plan serves as a comprehensive guide to surface water management in the portions of the Mid-Puyallup Basin that are under Pierce County's jurisdiction.

Flood problems in the basin:

Flooding issues range from streamside to residential flooding within the upland contributing basins. Flooding concerns also occur along the main stem of the Puyallup River, which are a result of Puyallup River flows rather than flows from Mid-Puyallup Basin tributaries. Problems have greater justification for developing CIPs due to their relative significance in meeting the program objectives such as protection against flooding or prevention of resource degradation. There are a few flood problems that occur on private property - the most significant problems were found within the tributary basin areas of Ball Creek, Fennel Creek, and Horsehaven Creek. Ball Creek has several minor flooding problems in the neighborhoods that comprise its headwaters and one culvert on the downstream reach. In 2018, Surface Water Management removed three culverts in lower Ball Creek and replaced a culvert with a fish passable culvert and restored habitat in the lower reach, allowing for more flood capacity in this vicinity. Fennel Creek has a variety of flooding problems throughout the Basin. The most significant problem is a stormwater pond that is too small and needs an improved overflow path. Horsehaven Creek is similar to Ball Creek in that it has some minor flooding problems in the upper Basin area and on downstream culverts that will likely need to be replaced. Water overtopping the roadway is also a recurring issue in the vicinity of Horsehaven Creek. Pierce County is working on two culvert replacement projects located at 150th St and 188th St that replace undersized culverts with fish-passable culverts, also allowing for more capacity for water to flow through.

<u>Identified flood problems in the Mid-Puyallup Basin:</u>
Table 6 lists the flood problems that were identified during the development of this basin plan. A status update for each flood problem has been provided below along with information on the type of flood hazard the problem is associated with (riverine, urban, groundwater, and coastal). Figure 6 provides the location of each identified flood problem.

Table 6: Mid-Puyallup Basin Plan Flood Problems

Type of Flooding	Problem Number	Problem Name: Description	Status of the problem?	Additional Information (if available)
R	MP-01	Railroad Culvert Replacement; N Military Rd: Replace 2 culverts w/ box culvert for flooding and fish passage	Not started	Problem is being moved to the Culvert Replacement program.
R	MP-02	McCutcheon Road Bridge Replacement: Replace bridge at Fennel Creek to reduce flooding	Not started	An updated bridge analysis is needed for this project.
R	MP-03	Kelly Lake Road Bridge Replacement: Replace bridge at Fennel Creek to reduce flooding	Not started	An updated bridge analysis is needed for this project.
R	MP-04	188th St E Culvert Replacement: Replace culvert for flooding and fish passage	Completed	constructed in 2022
R	MP-05	150th Ave Culvert Replacement: Replace	In progress	3

		culvert for flooding and fish passage		
R	MP-06	Flooded Property Acquisition on 149th Ave E: Acquire 2 properties & remove homes	Not started	
G Groundwater R Riverine U Urban C Coastal				

Additional information for the Mid-Puyallup basin plan, can be found at the following link:
[Archive Center • Pierce County, WA • CivicEngage (piercecountywa.gov)]

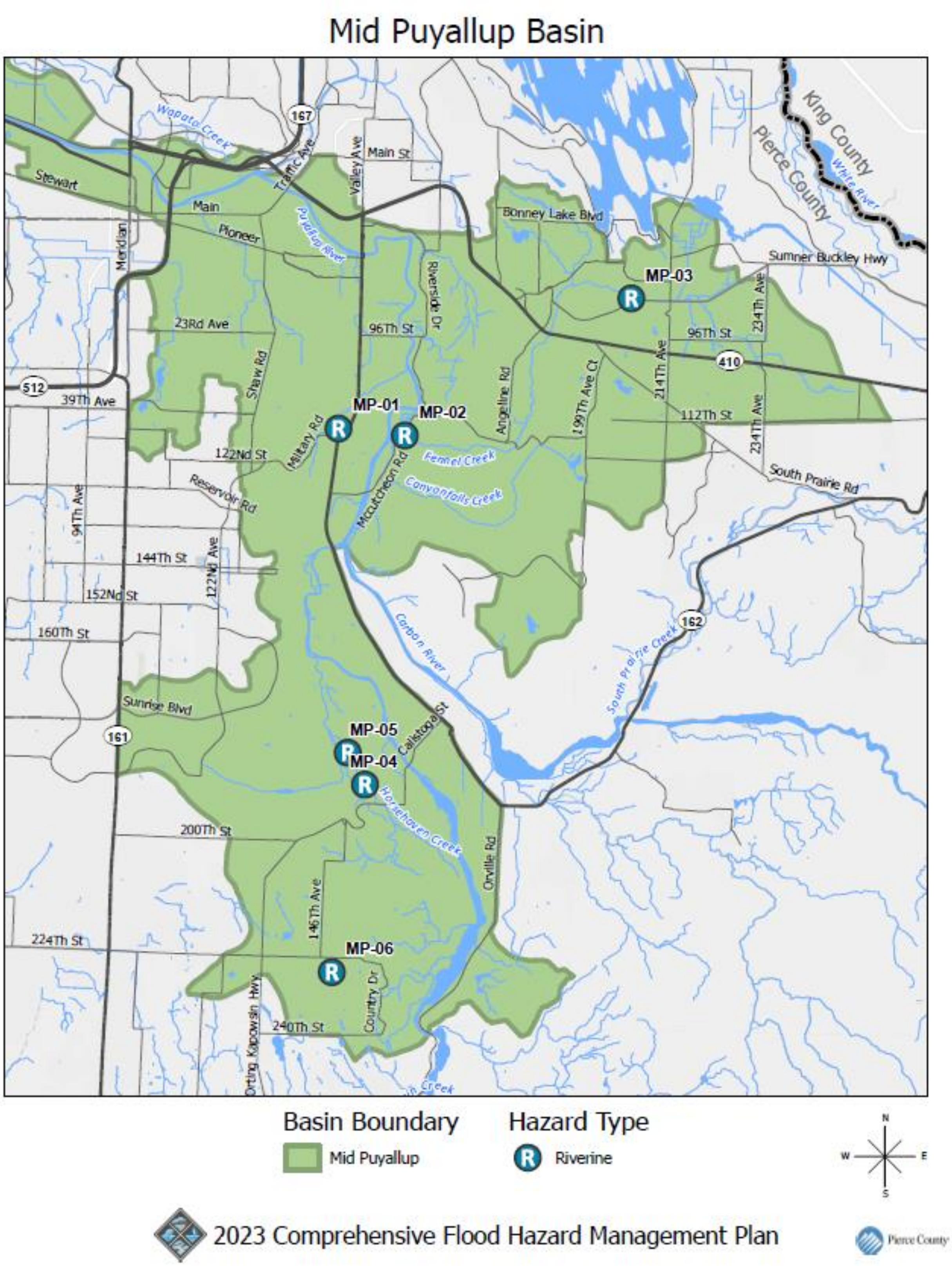


Figure 6. Locations of flood problems in the Mid Puyallup Basin

Muck Creek Basin Plan

Basin Description:

Located in southwest Pierce County, the Muck Creek Basin is the largest tributary in size in the Nisqually River Watershed. The Basin includes Muck Creek and three significant tributaries: Lacamas Creek, the North Fork of Muck Creek and the South Fork of Muck Creek (also known as South Creek). The Muck Creek Basin is approximately 93 square miles in size with elevations ranging from 140 to 960 feet. The topography of the Basin is generally flat to moderately rolling hill terrain. The only substantial relief in the Basin is the hills along the upper portion of the North Fork of Muck Creek and the canyon formed by the lower stretch of the creek as it flows into the Nisqually River. The creek flows across broad natural prairies with native grasses, oaks and through local second-growth coniferous and hardwood-forested riparian habitats. The majority of the Muck Creek Basin is rural in nature. It is characterized by agricultural, forest, pasture and prairie areas with low-density residential development. The largest population center is the unincorporated Graham area in the northeast portion of the Basin. The only incorporated city in the Basin is the City of Roy. Much of the Basin is a patchwork of small (hobby) farms and ranches, interspersed with larger working cattle ranches and timber lots. Fort Lewis occupies a large percentage of the northwestern portion of the basin. Much of the stream channel of the South Fork and the main stem of Muck Creek goes dry during the summer and early fall months. This appears to be a natural condition and is primarily due to the highly infiltrative glacial deposits that cover the middle portion of the Basin. The few long-term groundwater records that exist for the Basin show no declining or increasing trend in groundwater levels.

In 2003, the Muck Creek Basin plan was adopted by the Pierce County Council. This plan serves as a comprehensive guide to surface water management for the Muck Creek Basin.

Flood problems in the basin:

The Muck Creek Basin is generally rural in nature. Impervious area within the Muck Creek Basin averages only 6-11 percent. Most of the flooding problems stem from development which has diverted runoff, causing downstream problems, or development within the flood prone areas, particularly local depressions. Two types of flooding problems exist in the Basin; public flooding problems which are generally flooding of public roads or facilities, and private flooding problems occurring on private property. All major storm events in Pierce County in combination with antecedent conditions caused a number of drainage complaints from Pierce County residents. Several roads were overtopped where culverts underneath the roads were not able to pass the high flow rate of stormwater runoff, or the roads were not high enough to stay above the water surface. In addition, private property was flooded, and property was damaged.

Identified flood problems for the Muck Creek Basin:

Table 7 lists the flood problems that were identified during the development of this basin plan. A status update for each flood problem has been provided below along with information on the type of flood hazard the problem is associated with (riverine, urban, groundwater, and coastal). Figure 7 provides the location of each identified flood problem.

Table 7: Muck Creek Basin Plan Flood Problems

Type of Flooding	Project number	Problem Name/Description	Status	Additional information (if available)
R	MC-01	252nd St. E Conveyance Improvements: Install culvert to reduce flooding	Not Started	Wetlands on both sides of road. Beavers are making dams inside the cross culvert which cause flooding problems. Ops goes out to clean out beaver dams when needed. No beaver deceiver installed yet. Potential road raise, larger culvert, or stick with beaver deceiver however this is in a very low area and previous road raises under similar conditions have led the beavers to just build up.
R	MC-02	336th St S Grade Change: Raise road to reduce flooding	Completed	The road has been raised and there is no known flooding.

Additional information for the Muck Creek basin plan, can be found at the following link:
[Archive Center • Pierce County, WA • CivicEngage (piercecountywa.gov)]

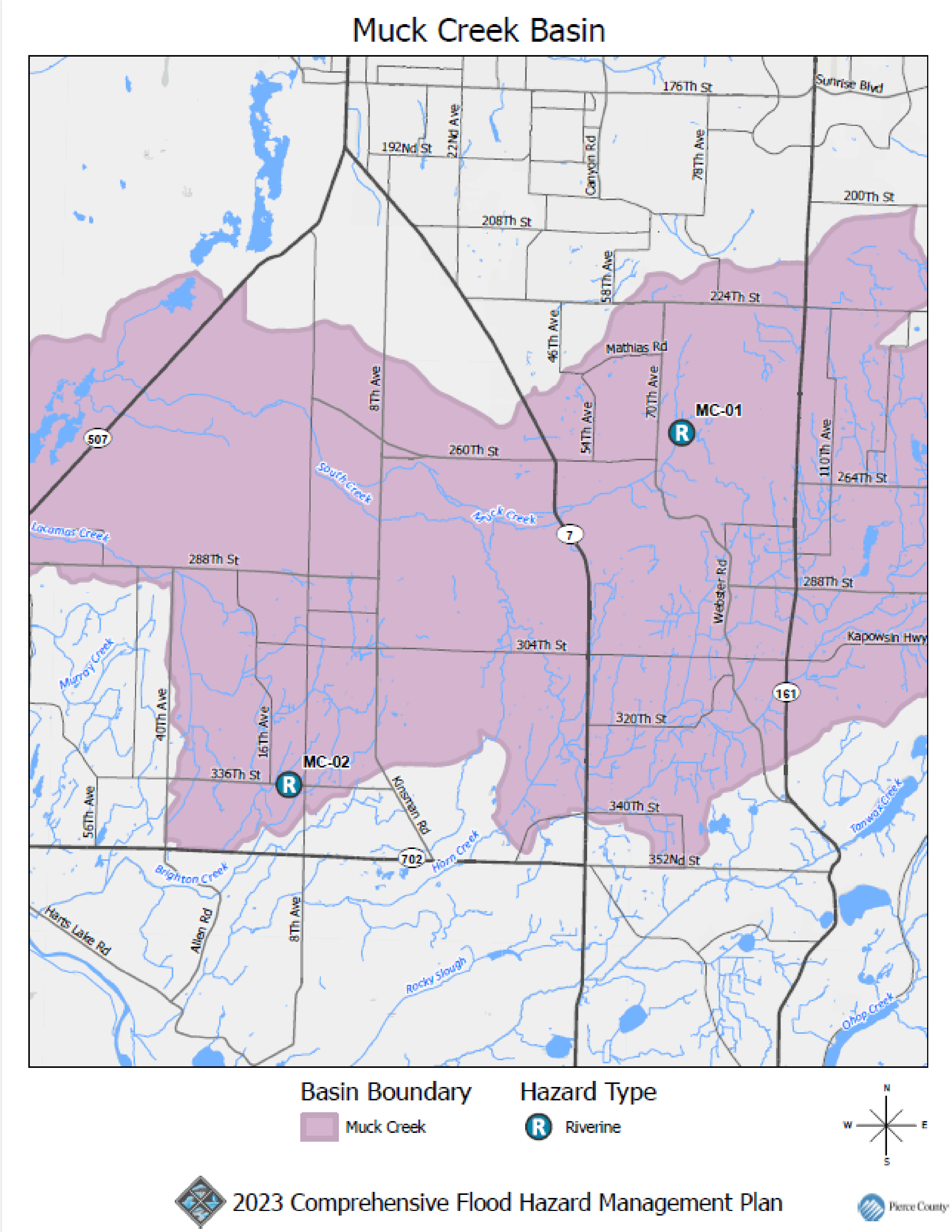


Figure 7. Locations of flood problems in the Muck Creek Basin

Nisqually River Basin Plan

Basin Description:

The Nisqually River originates on Mount Rainier and flows approximately 78 miles before discharging into the Puget Sound. In 2014 the Nisqually River Basin plan was adopted by the Pierce County Council. This plan served as a comprehensive guide to surface water management in unincorporated areas of the Nisqually River Basin. The planning area includes the unincorporated Pierce County portion of WRIA 11, exclusive of the Muck Creek basin. Moreover, this basin plan does not cover areas of the basin that lie within other jurisdictions, such as incorporated towns and cities, commercial timber lands regulated by the state Department of Natural Resources, Thurston and Lewis counties, and federal lands, except where activities in these areas may contribute to surface water management problems in unincorporated Pierce County. However, the planning area does encompass approximately 240 square miles within the 760-square mile Nisqually River Watershed. The planning area is more than five times larger than the next largest planning area and includes more than 500 miles of streams and encompasses more than 16 lakes.

Flood problems in the basin:

Major floods in the Nisqually River Basin occurred in 1933, 1965, 1974, 1975, 1977, 1996, 1997, November 2006, January 2009, and Dec 2015. According to FEMA's 1987 Flood Insurance Study, major floods typically occur between October and March as a result of rainstorms, sometimes augmented by melting snow. Channel aggradation may be contributing to flooding along the upper Nisqually River. The upper Nisqually River can transport large amounts of sediment and debris during high flow events. High sediment loads have caused substantial channel aggradation near the Mount Rainier National Park boundary. Retreat of the headwater glaciers, which exposes more unconsolidated sediment to erosion, could be contributing to this increased sediment loading trend. Channel aggradation can significantly affect flood elevations and inundation areas. Types of observed flooding within the Nisqually River Basin are:

- Mainstem Flooding
- Tributary Flooding
- Lake Flooding
- Roadway Flooding

Most of the local flooding problems identified in the Nisqually River Basin Plan were related to roadway flooding. For example, 60 out of the 89 flooding problems that were identified are related to roadway flooding. Beaver activity and debris accumulations cause a number of the problems as well on the Nisqually River. The following paragraphs summarizes the drainage/flooding problems that were identified for this basin plan.

- The most significant flooding problem area is located on the mainstem of the Nisqually River near the community of McKenna. Approximately 80 parcels in this area have been inundated by more than three feet of water during the past decade. In February 1996, a large flood event occurred on the river that flooded a significant number of properties and homes. This area is still vulnerable and at risk to such flooding impacts. In the late 1990s, Pierce County purchased 17 of these parcels at a cost of approximately $2.5 million.
- Other locations along the Nisqually mainstem that have incurred flood damages include the Wilcox Flats area and some areas upstream of Lake Alder.
- Murray Creek, Brighton Creek, Horn Creek, Tanwax Creek, Kreger Creek, and Ohop Creek have extensive flood hazard areas in low-lying regions and around lakes
- Minor flooding problems have been reported on a number of tributaries including Murray Creek, Kreger Creek, Horn Creek, upper Tanwax Creek, Ohop Creek, and Lynch Creek.
- Flooding problems were reported on Cranberry Lake, Rapjohn Lake, Tanwax Lake, Whitman Lake, Ohop Lake, and Clear Lake.
- More than 50 roadway flooding problems were identified. Most of these were located in the Murray Creek, upper Tanwax Creek, Brighton Creek, Horn Creek, upper Ohop and Kreger Creek subbasins.
- Beaver dams are a common cause of minor flooding in this area.

Identified flood problems in the Nisqually River Basin:

Table 8 lists the flood problems that were identified during the development of this basin plan. A status update for each flood problem has been provided below along with information on the type of flood hazard the problem is associated with (riverine, urban, groundwater, and coastal). Figure 8 provides the location of each identified flood problem.

Table 8: Nisqually River Basin Plan Flood Problems				
Type of Flooding	Project Number	Problem Name: Description	Status of the problem?	Additional Information (if available)
R	NI-01	Nisqually River Mainstem Acquisition Phase 2: Purchase ~ 100 acres along river	In Progress	This work is ongoing. Nisqually Land Trust has actively been working on this. Identified in the WRIA 11 TAG docs as priority projects.
R	NI-02	Tisch Road South Culvert Replacement: Replace culvert to reduce flooding	Not Started	In 2014, Maintenance and Operations installed a beaver deceiver that is currently operational. However, flooding still occurs from beaver activity.
R	NI-03	Upper Brighton Creek Culvert Replacements: Replace 5 culverts to reduce flooding	Not Started	
R	NI-04	364th Street East Culvert Replacement: Replace culvert to reduce flooding	Not Started	This is a private culvert.
R	NI-05	Wilcox Flats Repetitive Loss Acquisition: Purchase repetitive loss properties	In Progress	Ongoing. Nisqually Land Trust has actively been working on this. Identified in the WRIA 11 TAG docs as priority projects.
R	NI-06	Hart's Lake Loop Road Culvert Replacement: Replace culvert to reduce flooding	In Progress	Nothing in RFA to suggest ongoing flooding concerns

R	NI-07	Culvert Replacement at 365th Street East: Replace 18" culvert w/box culvert to reduce flooding	Not Started	
R	NI-08	Silver Lake Culvert Replacement: Replace culvert to reduce flooding	Not Started	Culverts appear to be clear with no visible flow restrictions. Pictures for the Road files indicate survey work may have been completed for this area.
R	NI-09	Culvert Replacement at Thomas Road: Replace culvert w/ box culvert to reduce flooding	Not Started	
R	NI-10	Webster Road Culvert Replacement: Replace 18" culvert w/box culvert to reduce flooding	Not Started	
R	NI-11	Ohop Creek Repetitive Loss Property Acquisition: Purchase properties along Ohop	In Progress	
R	NI-12	Mashel Small Properties Acquisition: Purchase ~80 acres of small properties	In Progress	

R	NI-13	Culvert Replacement at 278th Avenue East: Replace culvert box culvert to reduce flooding	Not Started	
R	NI-14	Dean Kreger Road Culvert Replacement and Slope Stabilization: Replace culverts to stabilize slope & reduce flooding	Completed	
G Groundwater	R Riverine	U Urban	C Coastal	

Additional information for the Nisqually River basin plan, can be found at the following link:
[Archive Center • Pierce County, WA • CivicEngage (piercecountywa.gov)]

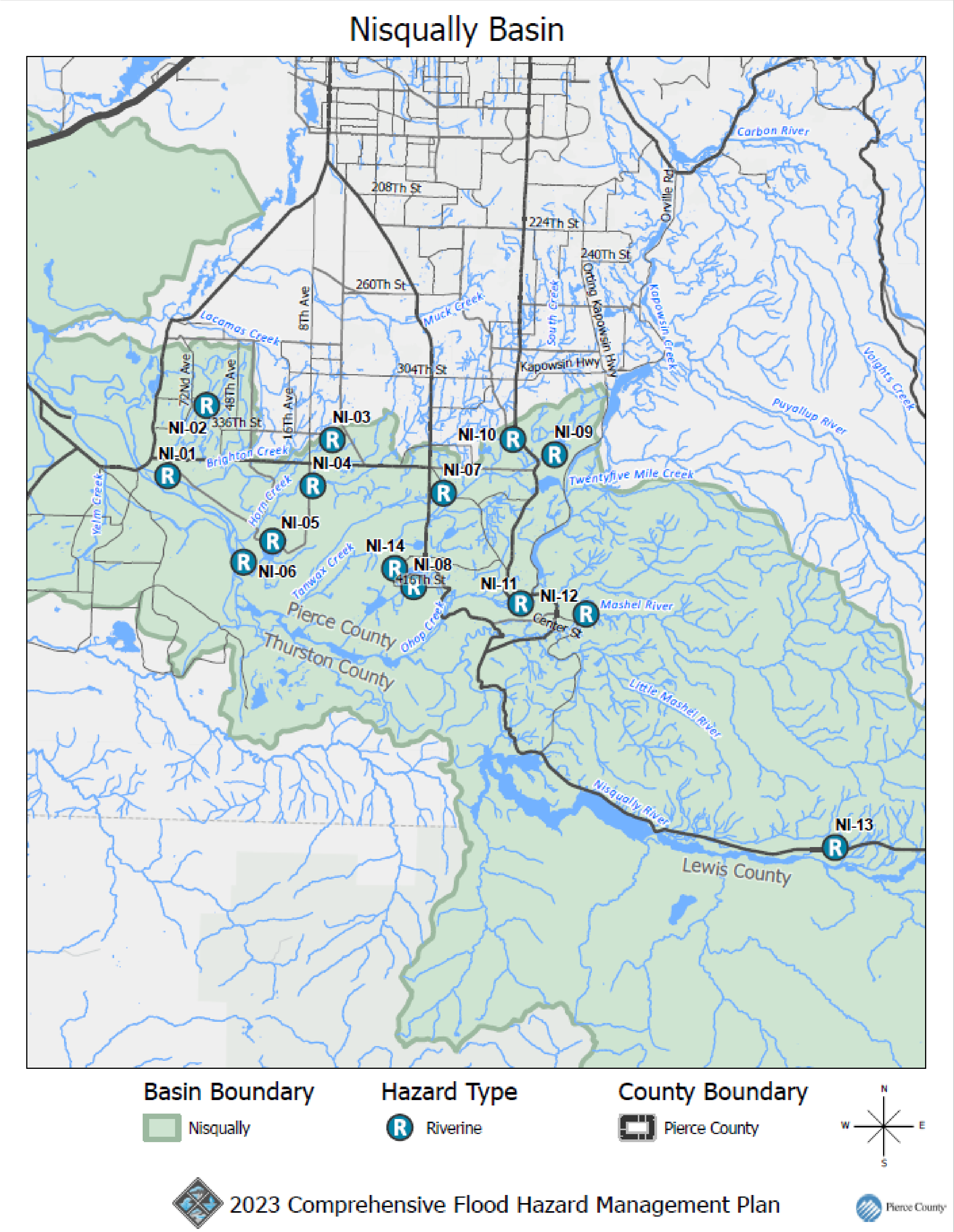


Figure 8. Locations of flood problems in the Nisqually Basin

White River Basin Plan

Basin Description:

The White River basin planning area is comprised of three planning areas, Upper White River, Lower White River, and Mud Mountain basins. These planning areas are collectively referred to as the White River Basin that encompass approximately 496 square miles. The basin planning area encompasses approximately 34 square miles of the 496 square mile White River watershed. Approximately 75% of the White River Basin is within Pierce County; the remainder is in King County.

The White River Basin Plan focuses on the unincorporated, non-federal portions of the watershed that are under Pierce County's jurisdiction. Much of the upper basin lies within National Forest lands or Mount Rainier National Park.

In 2013, the White River Basin plan was adopted by the Pierce County Council. This plan serves as a comprehensive guide to surface water management in the portions of the White River Basin that are under Pierce County's jurisdiction.

Flood problems in the basin:

Flooding and drainage problems were categorized into two general types of flooding: riverine and stormwater (minor stormwater drainage failures and roadway/driveway flooding). Riverine flooding in the Lower White River Basin is a natural phenomenon that has been mitigated by means of engineered structures (dams and levees), including Mud Mountain Dam. Under the original water control plan, channel capacity of the White River downstream of Mud Mountain Dam was estimated to be at least 20,000 cubic feet per second. However, flooding has occurred downstream of the dam at discharges well below the original estimated channel capacity. The reduced flood capacity of the river was attributed to multiple factors including encroachment of development along the channel, channel aggradation, and limitations on channel dredging (U.S. Army Corps of Engineers, 2002). Flood hazard reduction for the White River Basin focused on the floodplain property acquisition program. Multiple jurisdictions are working on projects to address White River flood hazards. King County's proposed Pacific Right Bank Flood Protection project includes a setback levee and pump station in the City of Pacific. The City of Sumner's White River Restoration project includes the replacement of the Stewart Bridge, property acquisition, setback levee and habitat improvement including the addition of an anastomosing channel and wetlands to provide a large storage area for floodwaters. Pierce County is assessing solutions for flooding problems along Butte Avenue. These projects will replace flood control levee installed in the early 1900s.

Stormwater flooding problems in the White River Basin planning area consist of minor roadway/driveway flooding. After problem sites were visited, the problems were screened and separated for analysis. Most problems were eliminated from further analysis because they were considered maintenance issues, located on private property or private roads, located in incorporated areas, or because additional information was required. The following paragraphs summarizes the drainage/flooding problems that were identified for this basin plan.

- Pierce County Water Programs' River Improvement Division maintains nearly 30,000 linear feet of flood control levees along the White River. According to Water Programs' 2005 Capital Improvement Program (CIP), six percent of the White River levee system is currently rated "adequate" (i.e., provides protection for a 100-year recurrence interval flood).

- The Mud Mountain Dam is the primary flood control structure on the White River. An informal agreement between the U.S. Army Corps of Engineers (USACE), the Muckleshoot Tribe, and Pierce and King Counties limits the rate of water release from the dam to 12,000 cfs, when feasible.

- The impervious surface estimates for current land use in the planning area range from 0 to 14 percent. The Upper White River, Lake Tapps, and Lower White River sub-basins have the highest impervious surface percentages with 8, 10, and 14 percent, respectively. The remaining sub-basins range from 0 to 4 percent impervious. Based on the current zoning, impervious surface areas in the planning area may range from 0 to 20 percent at full build-out. The greatest increases in impervious surface area are expected to occur in the Lower White River sub-basin.

- Lake Tapps is the only significant lake in the White River Basin. Lake Tapps was built more than 90 years ago to provide water storage for a hydroelectric facility. The lake was created by building approximately 2.5 miles of earthen dikes and embankments around four small natural lakes. A dam on the White River near Buckley diverts water to the lake via a canal. The lake discharges water back into the White River via a tailrace that enters the river near Sumner. Puget Sound Energy (PSE) owns the lake and its associated facilities. PSE has ceased hydropower generation at Lake Tapps and is currently in negotiations to sell the lake (and the associated water rights). In the future, the lake may be used for recreation and municipal water supply rather than hydropower.

Identified flood problems in the White River Basin:

Table 9 lists the flood problems that were identified during the development of this basin plan. A status update for each flood problem has been provided below along with information on the type of flood hazard the problem is associated with (riverine, urban, groundwater, and coastal). Figure 9 provides the location of each identified flood problem.

Table 9: White River Basin Plan Flood Problems				
Type of Floodin g	Project Number	Problem Name: Description	Status of the problem?	Additional Information (if available)
R	WR-01	Acquire Property Adjacent to White River for Floodplain Preservation and Water Quality Protection: Purchase property adjacent to river for floodplain and Water Quality	Not started	Muckleshoot Tribe and Puget Sound Energy will most likely be the lead for this project.
R	WR-02	Crystal River Ranch Estates Drainage Improvements: Install new cross culverts and driveway culvert to reduce flooding	Not started	Planning and Public Works and Maintenance & Operations has inspected and observed all the culverts along Alpine Dr E, Birch Way E, and Mountain Side Dr E. It appears that under most conditions the existing culverts have capacity for the flows received. But under heavy rainfall or snow/ice conditions, if any culvert gets blocked it causes flooding. Maintenance of the road side ditches along Mountain Side Dr E is at times critical to reduce the impacts of flooding.
G Groundwater	R Riverine	U Urban	C Coastal	

Additional information for the White River basin plan, can be found at the following link:
[Archive Center • Pierce County, WA • CivicEngage (piercecountywa.gov)](piercecountywa.gov)

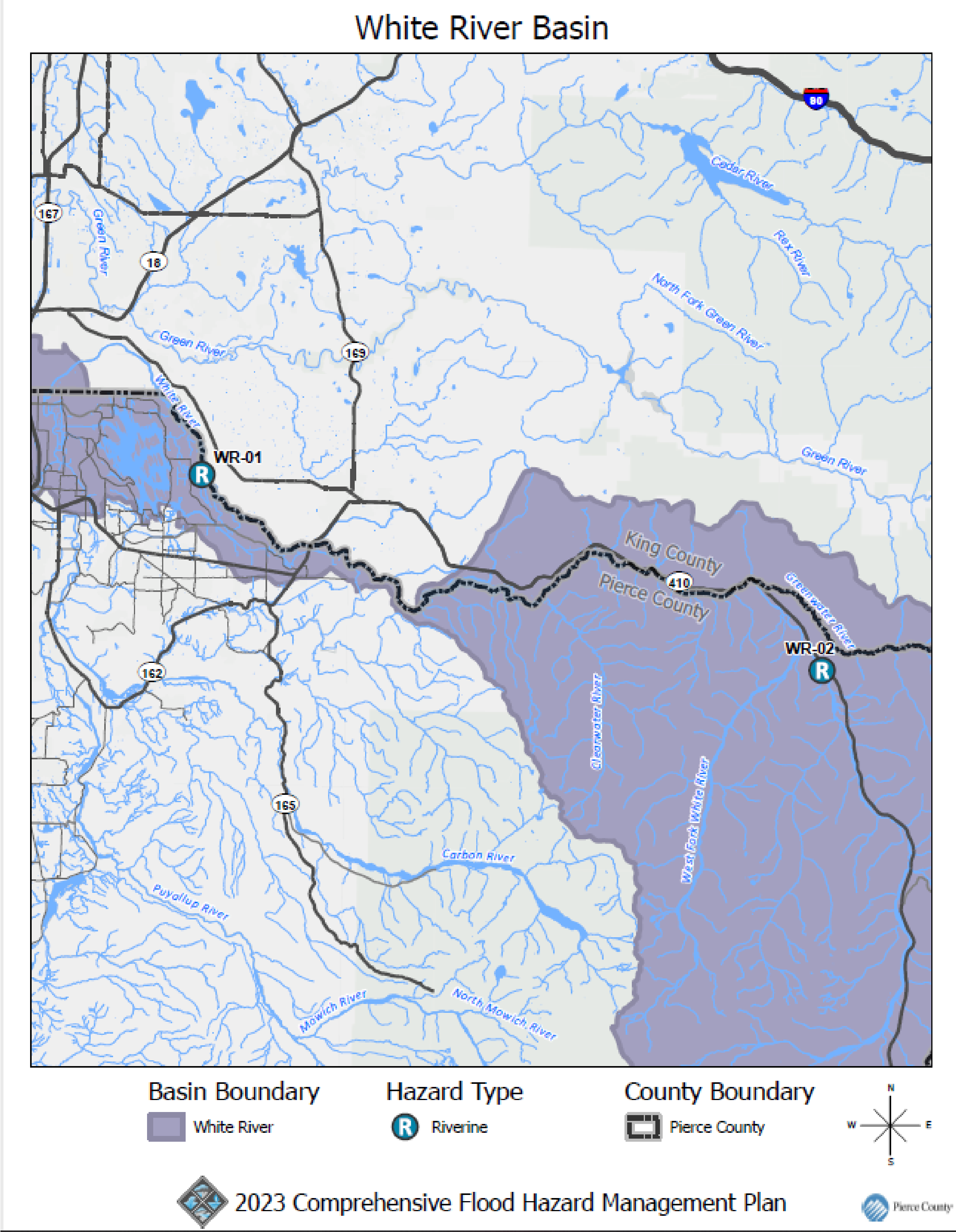


Figure 9. Locations of flood problems in the White River Basin

Appendix B

LEGAL AGREEMENTS

Settlement Agreement between the Puyallup Tribe of Indians and the Federal Government, State of Washington, Local Governments of Pierce County and Private Interests

Implications of the Puyallup Settlement Agreement to the Comprehensive Flood Hazard Management Plan

The Settlement Agreement has clear implications for the Comprehensive Flood Hazard Management Plan in terms of any actions proposed in the Lower Puyallup River in the area under jurisdiction of the Puyallup Tribe (between RM1.4 and RM 7.2). All actions in this area need approval of the Puyallup Tribe. The Agreement also specifically affects vegetation management, gravel removal, and flood control activities to the extent to which they affect fisheries habitat. The Agreement calls for the partners and stakeholders involved in development of the plan to work closely with the Puyallup Tribe of Indians to ensure that the draft and final recommendations of the plan are consistent with the Agreement.

Overview

In 1990, Congress passed a Settlement Agreement between the Puyallup Tribe of Indians, local governments in Pierce County (cities of Tacoma, Fife and Puyallup and Pierce County), the State of Washington, the United States of America, Port of Tacoma, and certain private property owners (Union Pacific Railroad, Burlington Northern, the Commencement Bay Tideland Owners Committee and Riverbed Owners Committee). This was the second largest negotiated settlement of Indian land and jurisdictional claims in the nation's history.

Key provisions of this agreement that affect flood hazard management planning, include: (1) numerous additions to the tribe's land base (including the submerged lands (riverbed) within the Puyallup River within the 1873 survey area, below the ordinary high water mark from approximately RM 1.4 to RM 7.2); (2) provisions for substantial restoration of the fishery resource, allowing for future development while lessening impacts on fisheries, (3) resolution of conflicts over governmental jurisdiction; and (4) establishment of a consultation process.

Specific to the Puyallup River ownership, the Puyallup Tribe confirmed all existing rights-of-way across the riverbed and the right to maintain the rights-of-way. The Tribe agreed to not deny, condition, or impose any charge for discharges of wastewater, storm water, or sanitary waters when discharges comply with applicable federal water standards and do not interfere with the Tribe's treaty protected fishing rights. Within three years of the effective date of the agreement, the Tribe, State, Federal Government and Pierce County agreed to plan for flood control, including addressing the location, amount, and timing of necessary gravel removal, vegetation control, and the roles and responsibilities of the Tribe, State, County and Federal Government in plan development and implementation. [The 1991 Puyallup River Basin Comprehensive Flood Control Management Plan was completed to address this provision].

The goal of the fisheries portion of the Agreement is to enhance the fisheries resource, including the protection of necessary habitat, while allowing construction and development to occur. A variety of fisheries enhancement programs and fisheries protection efforts, including habitat restoration, were part of the Agreement. More specifically, the Agreement called for local government actions to address the Tribe's goal of increased salmon and steelhead production, including protection of necessary habitat, while providing for residential, commercial, industrial and other development, natural resource use, and protection of lives and property from flooding.

The Agreement indicates that these goals shall be recognized by the local governments which are parties to this Agreement and after review they may adopt or modify as needed: (1) watershed action plans, (2) shoreline master plans, (3) land and resource use plans and regulations, and (4) environmental protection regulations. In addition, the local government parties, in consultation with the Tribe, will develop procedures for land use matters as part of this Agreement.

In terms of implementation, the Agreement specifies that appropriate local governments will take the following actions as needed to implement the goals:

1. Prepare action plans for drainage basins in Water Resource Inventory Area 10 (Puyallup River and Commencement Bay drainage basins);
2. Develop and implement a County wetland management program, in consultation with the Tribe;
3. Provide regulations to preserve or provide streamside vegetation for the purpose of maintaining water temperature, minimizing erosion and sedimentation, providing food, and retaining protection from predation;
4. Modify flood control activities to offer increased protection to the fisheries habitat;
5. Expand or modify County Basin Flood Control Study to evaluate alternative measures for flood control benefits and impacts; provide the Tribe with copies of County Hydraulic Permit applications on request; work with Tribe to carry out gravel removal in a manner which takes into account protection of fisheries habitat;
6. Develop culvert and floodgate designs and installation, maintenance and inspection guidelines and programs for improved fish passage; and
7. Dechlorinate treated sewage discharges to fresh water if necessary to protect the fisheries resources.

In addition, the Tribe is authorized to review existing land use plans, regulations, and policies and consider whether changes are needed to afford greater protection of the fisheries resource. Local governments are required to provide the Tribe with access to necessary information to accomplish such review. The local government shall consider any recommendation from the Tribe regarding fisheries habitat concerns and provide a written response to the Tribe.

Vegetation Management Agreement with Puyallup Tribe of Indians

Applicability of Vegetation Management Agreement to Comprehensive Flood Hazard Management Plan

Adopted in 1985, the Puyallup River Vegetation Management Program was an agreement between Pierce County and the Puyallup Tribe to settle a legal dispute about vegetation on the County's flood control facilities. The United States District Court issued a stipulation that acknowledged the vegetation management program and enabled the lawsuit to be cancelled. The agreement specifies allowable vegetation removal for maintenance activities, sediment berm and gravel removal, and levee and revetment reconstruction in the Puyallup River Basin. Recommendations in the Pierce County Rivers Flood Plan must be consistent with this agreement or recommend specific changes to this agreement for consideration by the two parties to the agreement.

Overview

In 1985, the Puyallup Tribe of Indians and Pierce County entered into an agreement setting out how vegetation would be maintained on revetments and levees adjacent to the Puyallup, Carbon, and White Rivers upstream of River Mile 3.0 of the Puyallup River. The goal of the Puyallup River Management Program was "to provide for the riparian vegetation habitat requirements of the fish and wildlife resources in conjunction with the basic requirements entrusted to Pierce County of revetment integrity and inspection, emergency revetment repairs, river channel capacity, and County road maintenance along tributary streams."

The agreement allows for variation in vegetation management due to differences in stream morphology and the physical structure of adjacent levees and revetments. It identifies five reaches as follows : (1) Puyallup River from RM 3.0-10.4; (2) Puyallup River from the White River confluence to Calistoga Bridge (RM 10.4-22.2) and Carbon River from the mouth to SR-162 (RM 0-6.1); (3) Puyallup River upstream of RM 22.2 and Carbon River upstream of RM 6.1; (4) White River from the mouth to the Muckleshoot Indian Tribe reservation (RM 0-8.9); and (5) White River above RM 15.5.

The agreement specifies that Pierce County evaluate the need for riparian vegetation removal on an annual basis and coordinate site evaluations with the Puyallup Tribe. Except in emergencies (defined as when a revetment is threatening to fail or overtop), vegetation removal will take place only after site evaluations.

For all reaches, guideline standards address: (1) riparian vegetation along mainstem levees and revetments; (2) riparian vegetation growing on proposed gravel/sediment removal areas within mainstem rivers; (3) riparian vegetation growing on revetment reconstruction areas; and (4) use of herbicides. The guidelines address issues such as maintenance of access roads, removal of blackberry vines. It limits vegetation removal to 20% of each mile length in any given year, maintaining a five-foot buffer of vegetation along the water's edge at gravel removal sites, and guidance on use of herbicides. The requirements for vegetation growing on "revetment reconstruction areas" specify that the riverward slope of all reconstructed revetments shall be replanted with vegetation consistent with surrounding sites, as soon as practicable. The County is specifically allowed to maintain concrete slab revetments "clean" of all vegetation, including root systems.

In addition to the guideline standards, the vegetation management program contains specific limitations for the individual five reaches. These standards govern issues such as mowing, selective removal and thinning of woody vegetation (e.g., vegetation over 30 feet in height on sediment berms in Reach 1 or vegetation with a diameter over six inches where required for levee integrity along the lower two-thirds of the levee slope in Reaches 2 and 4). The standards also cover sediment berm removal in Reach 1.

Removal of gravel and vegetation within the Puyallup River Basin is also regulated pursuant to RCW 75.20.100 and other Washington Administrative Code requirements (e.g., application and approval of a hydraulic permit from the Washington Department of Fish and Wildlife). In addition to these requirements, the County and Tribe have agreed that the County shall notify the Tribe of its intent to remove gravel or vegetation, before the County submits an application for hydraulic permit, giving the location of the vegetation removal and proposed timing.

U.S. Army Corps of Engineers Mud Mountain Dam Operational Agreement

Implications of Corps of Engineers Federally Authorized Projects on Comprehensive Flood Hazard Management Plan

The MMD and its operations (through the Water Control Manual) and the levees on the Lower three miles of the Puyallup River are maintained and controlled by the U.S. Army Corps of Engineers. Any proposed changes to operations of MMD need to go through extensive negotiations with the USACE, similar to those resulting in the 2004 changes to the Water Control Manual. Similarly, modifications to or changes related to maintenance of the levees in the Lower Puyallup River requires discussions with and approval from the Corps of Engineers. Modifications to this levee have been previously approved by the USACE, such as for the restoration of the Go-Gle-Hi-Tee habitat project (on the right bank between SR509 and the Lincoln Avenue Bridge).

The Puyallup River General Investigation, being pursued by Pierce County and its local partners with the Corps of Engineers, is the venue for discussions related to these three federally authorized projects. Maintenance and operation of bank protection near Orting is carried out by Pierce County. Proposed changes to these river management facilities should consider implications for ongoing federal support under the PL84-99 program and broader flood hazard management and habitat-related objectives.

Overview

Three federally authorized projects have been constructed in the Puyallup River Basin with a purpose of flood risk management: (1) Mud Mountain Dam, located at River Mile 29.6 on the White River; (2) a channel conveyance project on approximately 2.2 miles of the Lower Puyallup River on the left and right banks from about River Mile 0.75 to 2.9; and (3) a bank protection project along the Puyallup River near the town of Orting, covering a distance of about 10 miles.

Mud Mountain Dam

The primary control on the magnitude of flood flows in the Lower Puyallup and Lower White Rivers is the Mud Mountain Dam (MMD), completed in 1948, at RM 29.6 on the White River. The MMD Flood Control Project was authorized by an act of Congress in 1936. The authorized project purpose of MMD is to prevent flood damages in the Lower Puyallup River Valley below the mouth of the White River. MMD is somewhat unique in that it was developed for the single purpose of flood storage to reduce downstream flooding, and it is otherwise operated as a run-of-river facility. A run-of-river facility allows the river to flow freely during normal non-flood conditions. Most other federal dams are multi-purpose, with a permanent pool for irrigation or conservation flows (to support instream flows downstream).

The MMD is operated by the U.S. Army Corps of Engineers and provides storage of up to 106,000 acre-feet of floodwaters. It was originally operated to maintain flows on the Lower Puyallup River below 45,000 cubic feet per second (cfs) at the Puyallup River gage in Puyallup (#12101500). Under the initial water control plan, water stored in MMD was discharged to the White River at up to 17,600 cfs (USACE 2002). Channel capacity of the White River downstream of MMD was estimated to be at least 20,000 cfs. However, field observations made in the 1970s indicated that flooding in the White River downstream of MMD was occurring at discharges as low as 12,000 cfs. The reduced flood carrying capacity of the river was attributed to multiple factors including encroachment of development along the channel, accretion of sediments in the channel, and limitations on channel dredging (USACE 2002).

The Water Control Manual for the MMD was updated in 2004 to reflect a revised operating procedure (USACE 2004). The primary objective is still to keep flood discharges in the Lower Puyallup to 45,000 cfs, but a new secondary objective is to limit dam discharges to 12,000 cfs, when feasible.

Lower Puyallup River Channel Conveyance Project

The Flood Control Act of 1938 provided for the construction and maintenance of a channel conveyance project on the lower three miles of the Lower Puyallup River between River Mile 0.75 and 2.9 on both the left and right banks (USACE 2009). The project straightened the channel, constructed levees, and changed bridges to provide a channel capacity of 50,000 cfs. The project started at the East 11th Street bridge (RM 0.75) and extended upstream to about River Lane along River Road (RM 2.9), near the Tacoma City limits. The project was completed in 1950. Ongoing maintenance activities include brushing, fence repair, grading of roadways and levee tops, noxious weed control, erosion repair, and flood damage repair.

Bank Protection near the City of Orting

A federal project, adopted in June 1936, provided for bank protection and construction of revetments at critical points along the Puyallup River, above and below the City of Orting, Pierce County, for a distance of 10 miles (USACE 2009). Construction was completed in 1936 as a Works Projects Administration (WPA) project under the direction of the Corps of Engineers. Maintenance responsibility was transferred to Pierce County after construction.

References

U. S. Army Corps of Engineers (USACE). 2002. Section 905(b) Analysis, General Investigation Reconnaissance Study, Puyallup/White River Watershed, Washington, prepared by HDR.

U. S. Army Corps of Engineers (USACE). 2004. Water Control Manual, Mud Mountain Dam, White River, Washington, USACE, Seattle District, September 2004.

U. S. Army Corps of Engineers (USACE). 2009. Section 905(b) (WRDA 86) Analysis, General Investigation Reconnaissance Study, Puyallup River, Washington, USACE, Seattle District, March 2009.

Tacoma Power Agreement on Alder and LaGrande Dams

Implications of Tacoma Power's Nisqually Hydropower Dams on the Comprehensive Flood Hazard Management Plan

Tacoma Power's Alder and LaGrande dams on the Nisqually River at River Miles 44.2 and 42.4 generate hydropower, provide conservation and instream flows for the Nisqually River, and support recreation at Alder Lake. The dams do provide some incidental attenuation of flood flows, however, there are no flood control requirements included in the operating agreement. Proposed changes to the operation of the dams to address flood control are highly unlikely and would need the approval of Tacoma Power, the Federal Energy Regulatory Commission, and the Nisqually River Coordinating Committee.

Overview

Tacoma Power began generating electricity from the water of the Nisqually River nearly 100 years ago. The original diversion dam, completed in 1912, was replaced in 1945 with the Alder and LaGrande Dams. The Alder Dam, located at RM 44.2, is 285 feet high and has a storage capacity of 231,900 acre-feet. The dam impoundment, Alder Lake, and its associated parks are heavily used for recreation. The LaGrande Dam, located at RM 42.4 is 192 feet high and has a small storage capacity of 2700 acre-feet. The two dams are part of the Nisqually hydroelectric project, owned and operated by Tacoma Power.

The Nisqually Hydroelectric Project is operated under a license issued by the Federal Energy Regulatory Commission (FERC). The 40-year FERC licencse (No. 1862) was issued on March 7, 1997. The license contains articles pertaining to operational requirements, including minimum instream flow, lake levels for recreation and ramping rate requirements. There are no requirements for flood control or flood storage. According to Tacoma Power, operator of the dams, the dams provide some incidental attenuation of flood flows, however, there are no flood control requirements in the operating agreement (Nisqually Basin Plan, 2008). When possible and consistent with the federal mandate, Tacoma Power voluntarily uses the available storage to help reduce the downstream crest of the flood. However, Tacoma Power will do so only when these operations remain consistent with prudent operation of the project and the requirements of its federal license (personal communication with Todd Lloyd, Tacoma Power, October 2006).

Articles 402 and 403 of the operating agreement require minimum instream flows to be met downstream of the LaGrande powerhouse and LaGrande Canyon, respectively. The Nisqually River Coordinating Committee (NRCC) made up of the Nisqually Tribe, Washington Department of Fish and Wildlife, and Tacoma Public Utilities establish these instream flows to support fisheries. Article 404 addresses required reservoir water levels for Alder Lake and maximum conservation releases from LaGrande dam and powerhouse. Finally, Article 405 specifies allowable down ramping rates, or the rate at which discharges from the dam are reduced. There are no known operations at the dam to manage sediment transport through the reservoirs. Most of the sediment load (all except fine suspended sediment) originating from the upper reaches of the Nisqually River is trapped in Alder Lake (Nisqually Basin Plan 2008).

References

Pierce County Planning and Public Works, Surface Water Management Division. 2008. Nisqually River Basin Plan, Volumes 1 and 2. Pierce County, Washington.

Lake Tapps Agreement

Implications of the Agreement between Cascade Water Alliance and the Lake Tapps Community

Lake Tapps was built by Puget Power Electric (now Puget Sound Energy, referred to here as PSE) in 1911 for hydroelectric power generation. Water is diverted from the White River near Buckley and conveyed in a canal to Lake Tapps. The lake discharges through a tailrace that enters the White River near Dieringer, just upstream from the confluence with the Puyallup River.

PSE has historically managed the lake as a reservoir. During the "Normal Full Pool" the water levels are maintained between 541.3 and 543 msl from April 15 through October 31 during periods of normal operations. This allows recreational use of the lake. In late fall, the lake is drawn down for the winter to reduce the potential for waves from winter storms overtopping the levees around the lake, to allow maintenance activities on the levees and to prevent growth of milfoil and other aquatic plants. This is accomplished by releasing more water from the lake than is diverted from the White River. The lowest water elevation reached is below 530 ft. In the spring less water is released and the lake is gradually refilled.

PSE ceased hydropower operations at Lake Tapps in 2004. In 2006, PSE agreed to sell the Lake Tapps facilities to the Cascade Water Alliance (CWA), contingent on PSE obtaining a municipal water right for the project, among other things. The CWA is a coalition that includes Bellevue, Issaquah, Kirkland, Redmond, Tukwila, Covington, the Sammamish Plateau, and Skyway Water Districts. CWA would use Lake Tapps as a source of potable water while continuing to support recreation uses of the lake. CWA plans to construct a water treatment plant and delivery systems to transport the treated water to CWA members.

Cascade Water Alliance will continue to manage the lake water levels seasonally.

On May 13th, 2009 a private agreement was finalized between the Lake Tapps Community and the Cascade Water Alliance regarding maintenance of Lake Tapps with regard to the use of Lake Tapps as a municipal water supply resource. (Elevations are expressed in relation to NGVD rather than msl as in previous agreements with PSE.) Water levels will be similar to historic levels, but will be subject to compliance with provision of minimum instream flows in the White River for habitat, provision of recreational lake levels and provision of municipal water supply, in that order of priority. Changes to the agreement may be negotiated as necessary. Pierce County is not a signatory to the agreement.

Flood Storage Opportunity

Lake Tapps has a surface area of 2700 acres and for dam break analysis purposes has a total storage capacity of 69,700 acre-feet. Historically, by agreement between the lake owner and Lake Tapps Homeowners the lake is gradually drawn down for maintenance between the end of October and the beginning of April. If the lake is ultimately drawn down to elevation 515'(the outlet elevation) there would be approximately 23,000 acre-feet of water remaining in the lake, leaving potential capacity for 46,700 acre-feet of storage. The flume between the White River and Lake Tapps was originally constructed with a capacity of 2000 cfs. In order to protect against dike failure at Printz Basin the diversion rate has typically been held to 900-1000 cfs. At this reduced rate it would take 30-40 days to fill the lake to capacity.

Water diversions from the river to the lake are restricted by the capacity of existing infrastructure. They are also restricted by negotiated agreements between the water rights owners and the Puyallup and Muckleshoot Indian tribes and related permit restrictions imposed by the Department of Ecology.

References:

November 24, 2009 conversation with Bob Barnes, PSE. (JMR)

TIM 7 White River Basin Plan (Draft), Dam Break Analysis

2009 Agreement Regarding Lake Tapps between Cascade Water Alliance and the Lake Tapps Community

Mount Rainier National Park Service Agreement on the Nisqually River Flood Control Structure Operation and Maintenance

Implications of the of National Park Service Agreement on the Operation and Maintenance of the County Flood Control Structure

Any modifications to, or maintenance of, the flood control structure on Park property requires that specific provisions detailed below be met. In discussing "levels of service" for flood hazard management or channel migration protection, it is necessary to consult and reach agreement with the National Park Service on any proposed changes.

Overview

In 2009, Pierce County reached an agreement with the Federal Government to operate and maintain Pierce County's existing flood control structure on the Nisqually River within the boundaries of Mount Rainier National Park. A right-of-way for such a public utility or service for domestic, public, or other beneficial uses is allowable if it is deemed to not be incompatible with the public interest. The flood control structure is on Park land for a distance of approximately 1,754 feet, near the entrance of the Park. The purpose and intent of the flood control structure is to provide protection to park employees working within the Nisqually Entrance developed area, and to residents of private property adjoining the park's west boundary along the Nisqually River, State Route 706, and to protect historic resources within the Mount Rainier National Historic Landmark District.

The operation and maintenance of the flood control structure is subject to the following key terms and conditions of the agreement:

1. The County will use only the approved right-of-way (90 feet in width, lying 50 feet on the southerly riverward side and 40 feet on the northerly landward side of the centerline) for operation and maintenance of the facility.
2. In the event of an emergency, the flood control structure is damaged to such an extent that it cannot be placed back in its pre-damaged location, representatives from the County and the Park will meet to determine the course of action needed and mutually agree upon the location for the repair.
3. The County shall comply with all local, State and Federal laws, including compliance under SEPA and NEPA, and applicable regulations promulgated thereunder in the operation and maintenance of the flood control structure.
4. Copies of all required permit applications prepared by the County must be submitted to National Park for environmental review by park resources staff before the County forwards the applications to the appropriate agencies.
5. Routine maintenance or repair by the County may include, but is not limited to, clearing selected vegetation, repair sloughing and scoured areas, undercuts, adding or replacing toe and face rock, and grading the access road in the right-of-way. However, any maintenance actions proposed by the County, including those listed above, must be reviewed by appropriate park staff for their potential resource impacts and cumulative effects as required under NEPA and National Park Service policy.

Appendix C. Climate Change Projections for Pierce County

Climate change in the Pacific Northwest is predicted to have significant effects on flooding and channel migration within Pierce County river systems. More precipitation is expected to fall as rain instead of snow, which could increase the magnitude of fall and winter flooding along the major rivers. As a result, flood events may be more frequent and longer in duration. It is necessary to account for these changes as part of project and program implementation throughout the county.

As mentioned in Chapter 1, Pierce County completed a Climate Change Resilience Strategy for Pierce County SWM along with other departments. For continued updates on this planning effort, please visit [Climate Change Resilience Plan | Pierce County, WA - Official Website (piercecountywa.gov).]()

C.1 How Climate Change will Affect Flooding in Pierce County

Summary

Floods in the Puget Sound region are becoming larger and more frequent due to the combined effects of declining snowpack, intensifying rain events, and rising sea levels. For example, one recent study projects a 25 percent to 44 percent increase in the volume of the 100-year flood by the 2080s for the lower Puyallup River (on average, for a low and a high greenhouse gas scenario, respectively; Chegwidden et al. 2019).

Given that the FEMA calculation of the 100-year flood discharge in the lower Puyallup River was 48,000 cfs and as of 2022 the calculated discharge (based on observations) is now 59,500 cfs, the estimated discharge of 60,000 to 69,000 cfs for the future 100-year flood in the 2080s appears understated. These discharge estimates represent dramatic changes in flooding, especially given the severe consequences of major floods under current conditions. Additional flooding impacts, such as potential consequences of groundwater flooding, wildfire, and channel aggradation in response to higher sediment loads, could be important but have not yet been sufficiently studied.

This section provides a concise summary of climate change impacts on flooding and related risks in Pierce County. The following subsections briefly summarize the science related to the primary climate change topics that affect flooding in Pierce County.

Background on Climate Projections

To estimate future climate change and its impacts, scientists use global climate models (GCMs) driven by greenhouse gas scenarios. GCMs are designed to represent the processes controlling Earth's climate. These models incorporate the state-of-the-art in climate science, and different groups around the world have developed GCMs that can be used to estimate future conditions. Simulations

> **GCM** are designed to represent the process controlling Earth's climate

from these different GCMs are periodically gathered in a set of coordinated simulations referred to as the Coupled Model Intercomparison Project (CMIP), which is an initiative of the World Climate Research Programme. In each new CMIP experiment, dozens of different GCMs are combined with a range of possible greenhouse gas emissions, to provide many different estimates of future changes in climate.

Greenhouse gas emissions are determined by factors ranging from geopolitics to technological innovations to population growth. Since these factors are impossible to predict, scientists use greenhouse gas scenarios to represent a range of different future conditions. These "what if" scenarios are used as input to GCM simulations to make projections of future climate.

By using multiple distinct models, as in the CMIP experiments, we can better capture the uncertainty associated with modeling climate change. Similarly, by considering different greenhouse gas scenarios, we can capture the uncertainty associated with emissions. By providing multiple estimates of the future, the CMIP experiments help paint a more reliable picture of what climate might look like based on varying emissions scenarios.

The most recent Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report (AR6, https://www.ipcc.ch/assessment-report/ar6/), published in 2021 was based on the CMIP6 projections. However, there are no impact studies for the region based on these latest projections, since it takes time to apply the new projections in impacts assessments. As a result, this report is focused primarily on relatively recent published studies using climate change projections generated by the CMIP3 and CMIP5 projections, which were used in the IPCC Fourth (AR4) and Fifth (AR5) Assessment Reports, respectively. The CMIP3 studies in the Skagit basin are based on a low-end ("B1") and moderate ("A1B") greenhouse gas scenario. The CMIP5 studies in the region are based on a different set of scenarios, referred to as the "Representative Concentration Pathways", or RCPs. These include a low-end ("RCP 4.5") and a high-end ("RCP 8.5") scenario. Additional information on these scenarios can be found in Section 1 of Mauger et al. (2015).

Although the CMIP3 and CMIP5 projections are somewhat different from each other, due both to differences in the GCMs and greenhouse gas scenarios, results from both sets of projections show consistent results for the Pacific Northwest. Specifically, all projections consistently show substantial warming, and the majority of models project a decrease in summer precipitation. Cool season (October through March) precipitation projections are less clear cut, but generally indicate wetter conditions in winter. As described below, projections from CMIP6 are broadly comparable to those from CMIP5. New IPCC reports and CMIP results can be expected every 6 to 7 years.

Given their complexity, GCMs cannot simulate the entire globe at a fine spatial resolution. Typical resolutions for GCMs range from about 30 to 100 miles between grid cells. Most climate change impacts cannot be assessed at these coarse spatial scales. "Downscaling" refers to techniques used to translate from the coarse GCM scales to finer scales needed to assess the impacts of climate change. These can be broadly split into two categories: statistical downscaling, and dynamical downscaling. In statistical downscaling, empirical relationships between weather observations and GCMs are used to estimate local-scale changes in the future. Dynamical downscaling, in contrast, uses a physical model – often referred to as a regional climate model, or RCM – to represent the weather processes at local scales, driven with boundary conditions from a GCM. Most studies to date have relied on statistical downscaling. Although this approach may be adequate in many situations, recent research has shown that statistical downscaling does not adequately capture changes in heavy rain events (Salathé et al. 2014). This means that dynamically downscaling is the best approach for assessing changes in flood risk.

Warming Air

Temperatures are rising in Pierce County and are projected to rise significantly more over the next century.

What this means: As a result of warming temperatures, Pierce County will experience reduced snowpack as snow-dominant and mixed rain and snow basins transition to predominantly rain-dominant conditions in Pierce County watersheds. Stream and river water temperatures are also expected to rise in response to higher ambient air temperatures throughout the year.

Past Trends

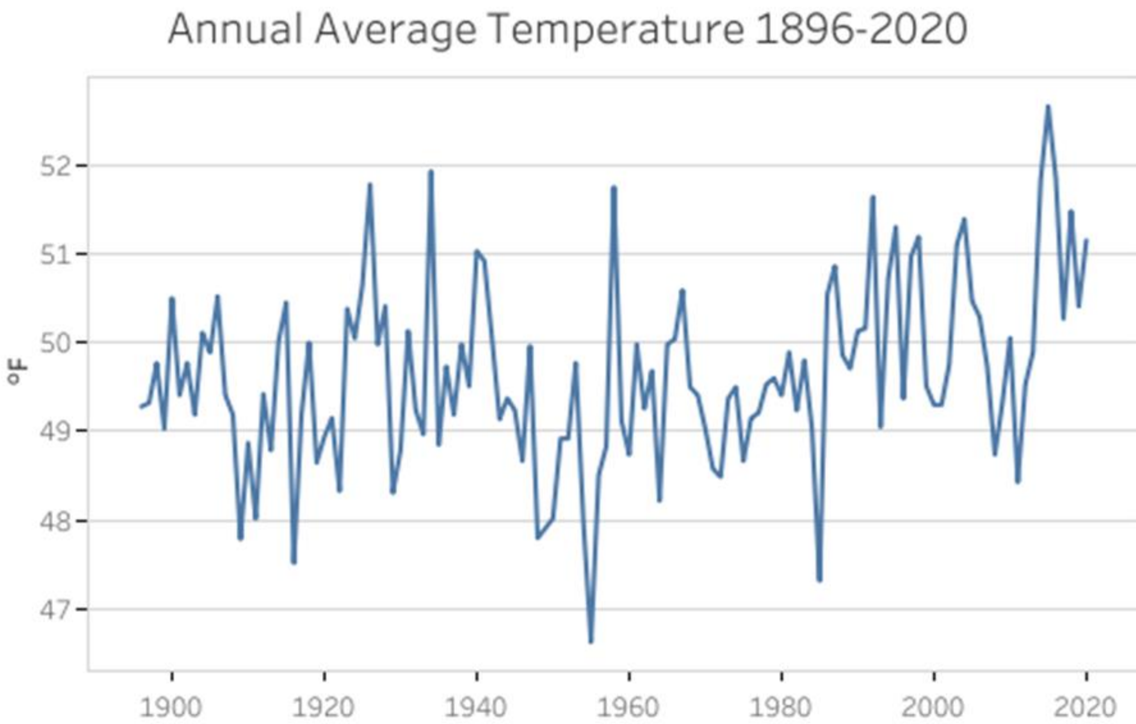
The Puget Sound region warmed by +1.3°F (range: +0.7°F to +1.9°F) between 1895 and 2014 (Vose et al. 2014). All but six of the years from 1980 to 2014 were warmer than the 20th century average. This is the change in annual average temperature, averaged across the lowlands of Puget Sound. At the McMillin Reservoir weather station, in Pierce County, temperatures rose by about 1°F from 1900 to 2020 (https://climate.washington.edu/climate-data/trendanalysisapp/). Changes in seasonal average temperatures, extremes, or the growing season generally also show increases, consistent with observed warming across the globe.

Projected Changes

All models project warming for all greenhouse gas scenarios. Differences among greenhouse gas scenarios are minor until after mid-century, at which point they can diverge significantly. Figures C.1 and C.2 show the historical and projected change in temperature, averaged over the state of Washington (Frankson et al. 2022, based on the CMIP5 GCM projections). These show that the warming of the last century is small compared to the projected changes for the coming decades.

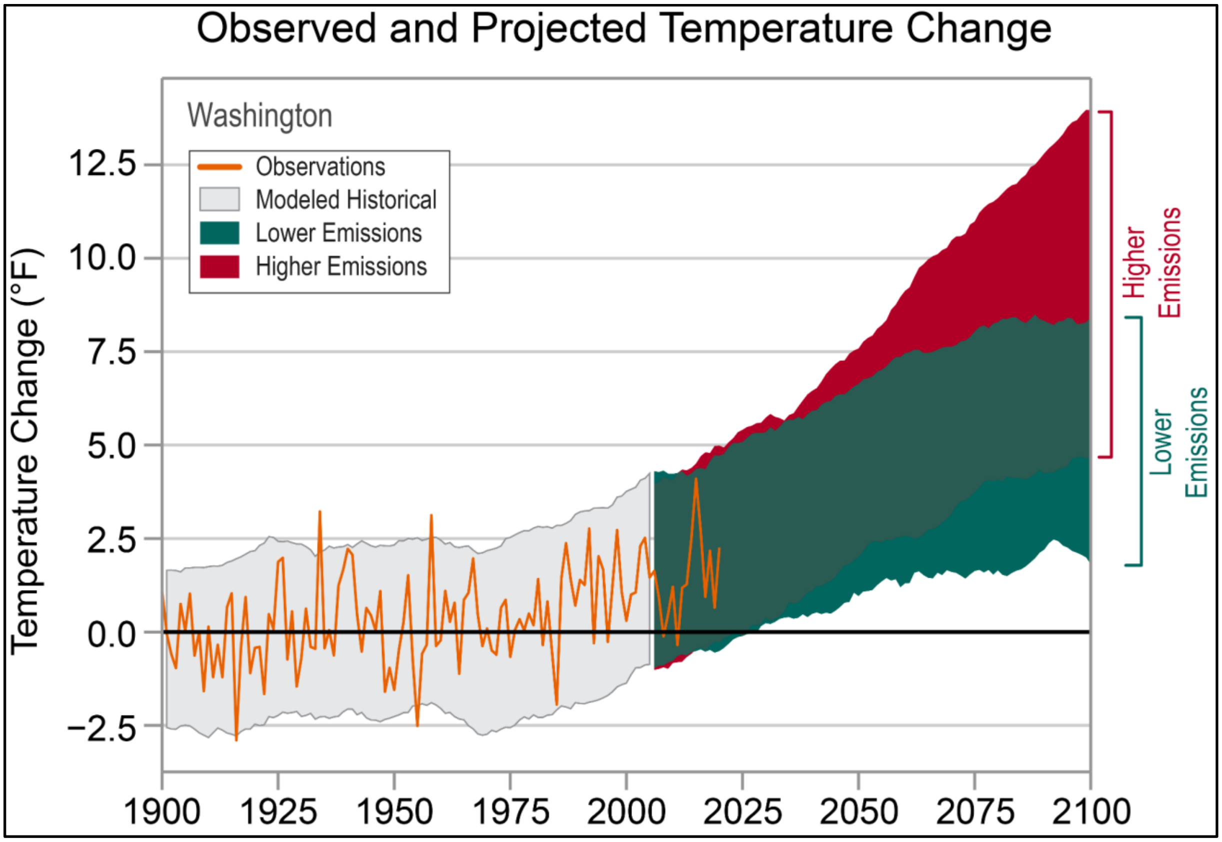
Warming is also projected to vary by season. Figure C.3 shows three screenshots of the Pacific Northwest Climate Projection tool, with side-by-side results for different generations of GCM projections, comparing annual average warming to the projections for summer (Jun-Aug) and winter (Dec-Feb). While warming is projected for all seasons, summer temperatures are projected to rise more than winter temperatures.

Figure C.1. State of Washington Annual Average Temperature, 1896-2020



Note: Since 1900, average temperature has risen by about 1°F at McMillin Reservoir, between South Hill and Orting. Plot shows annual average temperature for each year from 1896-2021. Source: https://climate.washington.edu/climate-data/trendanalysisapp/

Figure C.2. State of Washington Observed and Projected Temperature Change



Note: Models project warming to continue and accelerate through the 21st century. The figure shows average temperature for the state of Washington, relative to the average temperature for 1901-1960. Results are shown for both observed and modeled historical temperatures and projected future temperature for both a low (RCP 4.5) and a high (RCP 8.5) greenhouse gas scenario. Source: Frankson et al. (2022).

Figure C.3 Warming is projected for all seasons, but summer temperatures are projected to rise more than winter temperatures.

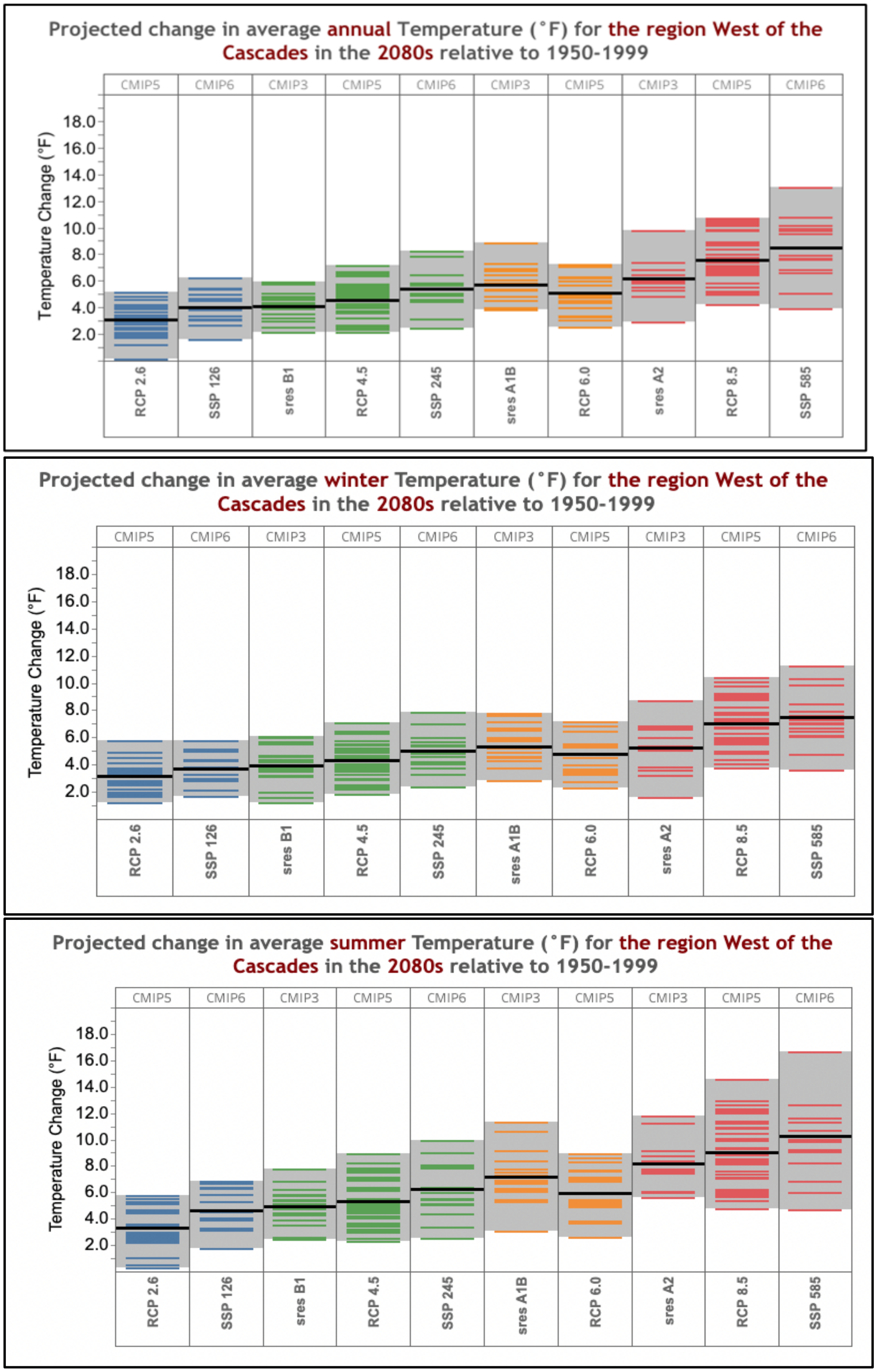


Figure shows the projected change in annual (top), winter (middle), and summer (bottom) average temperature (°F), by the 2080s, for the region west of the Cascade crest. Source: https://cig.uw.edu/resources/analysis-tools/pacific-northwest-climate-projection-tool/

Precipitation Changes

Although there are few statistically significant trends in historical precipitation in Washington, models project a clear increase in heavy precipitation events and a strong tendency toward decreasing precipitation in summer. Changes for annual and winter precipitation are less clear cut, but generally indicate wetter conditions in the future.

Past Trends

There are few statistically significant trends in annual and seasonal precipitation for the region (see Figure C.4). Even where trends are present, long-term changes are much smaller than year-to-year variability.

Modest increases in heavy rainfall have been documented in Western Washington in the last 122 years of measurements. Most studies find increases in both the frequency and intensity of heavy precipitation (such as Madsen and Figdor 2007; Mass et al. 2011; Rosenberg et al. 2010). Not all trends are statistically significant – results depend on the dates and methods of the analysis.

What this means: Heavier precipitation events will bring larger and more frequent floods, while also exacerbating stormwater management challenges. Decreasing summer precipitation will further lead to lower streamflows, and the associated water supply consequences, in summer. Both changes could affect rates of groundwater recharge and associated groundwater levels.

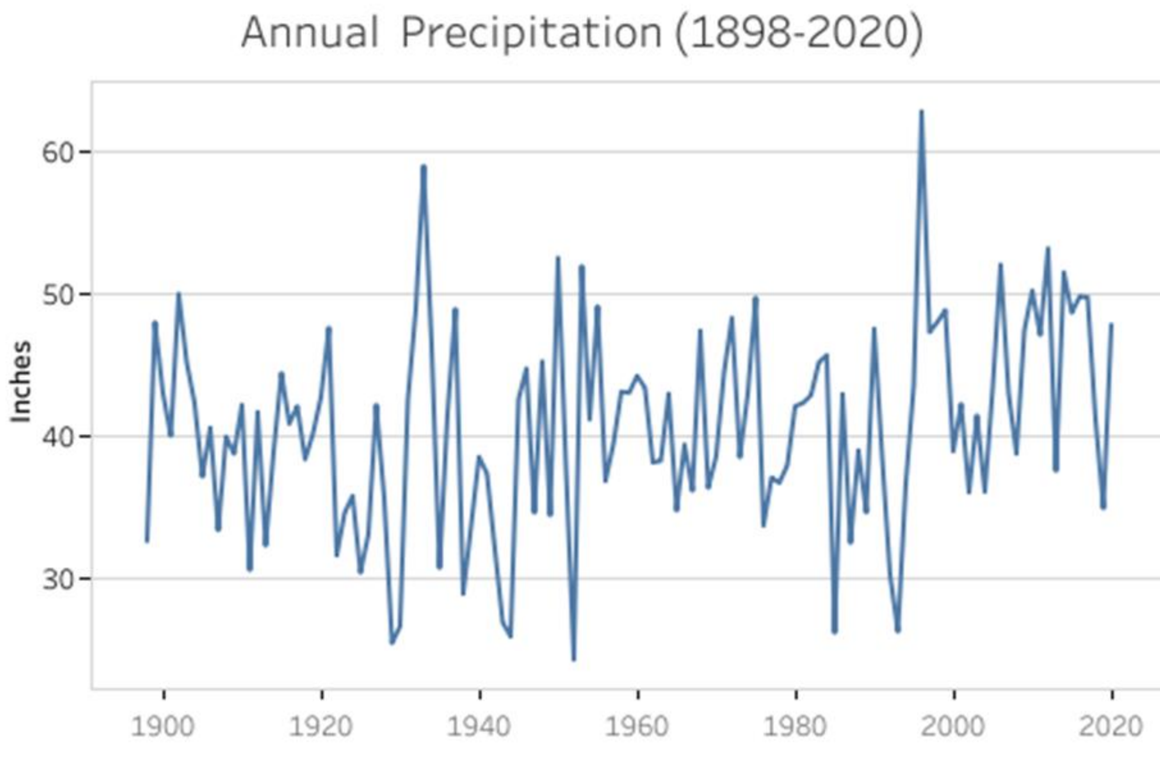
Projected Changes

Changes in annual and seasonal precipitation in western Washington are projected by various models to be generally small, despite some large fluctuations year to year. However, precipitation is projected to decrease the most in summer, which would see the greatest change compared to the other seasons (see Figure C.5).

Based on clear evidence, climate change is expected to lead to more intense heavy rain events in western Washington in the future, primarily because climate change would increase the amount of water supplied to winter storms (Warner et al. 2015). Figure C.6 shows the average projected change in precipitation extremes for the Puyallup River watershed for the 2080s and a high (RCP 8.5) scenario. These show large increases in precipitation intensity for all six durations analyzed, with larger increases for shorter durations. For example, for the 1-hour duration, models project an increase of +30% (range: +15 to +44%). All models project increases for every duration except 72 hours, indicating high certainty in future increases. The patterns of change are similar for other return intervals, indicating that heavy precipitation intensity will increase for events ranging from the very rare (e.g., 100-year event) to the more routine (e.g., 2-year event).

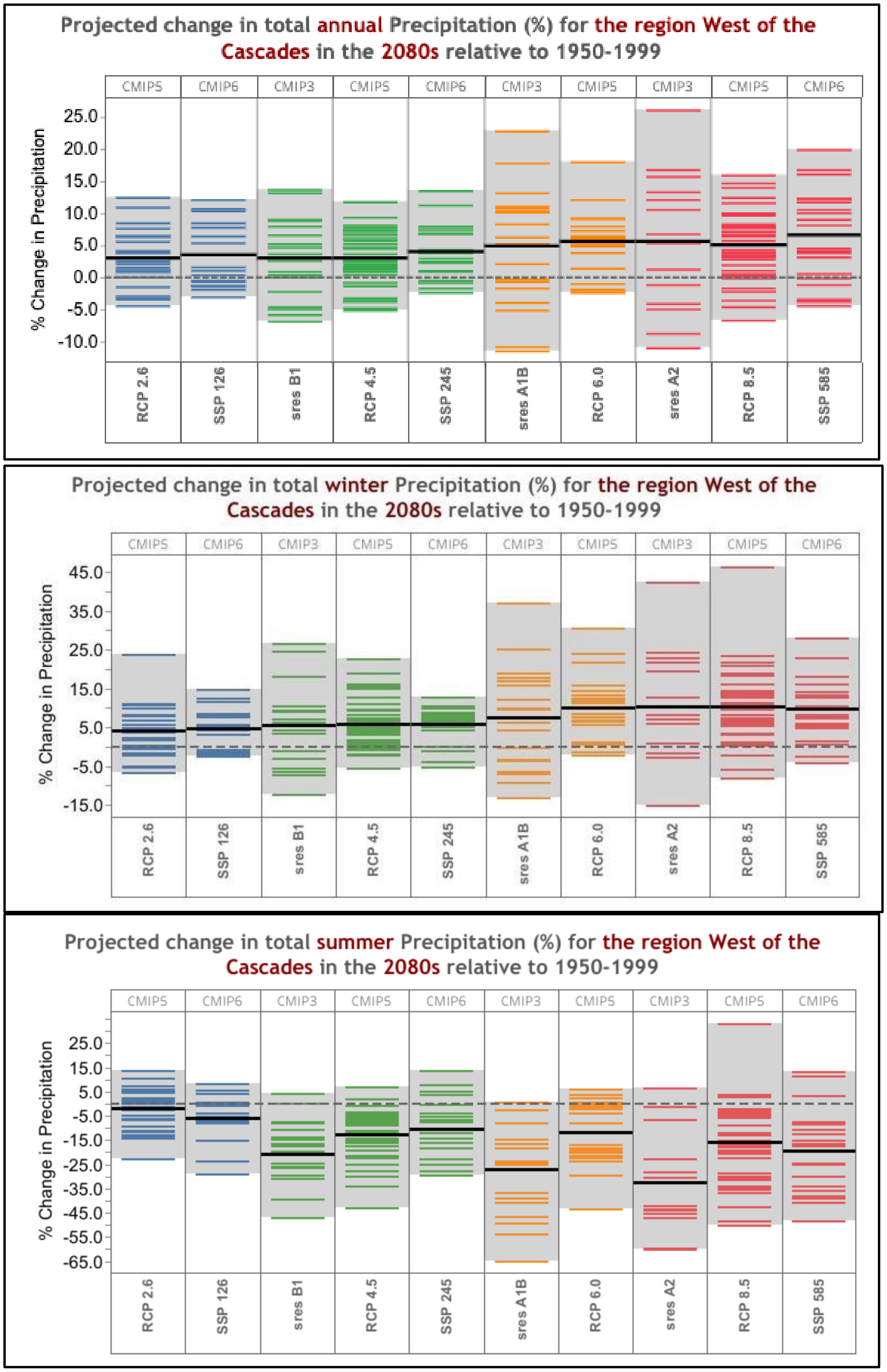
Modeling studies have begun to evaluate the implications of these changes for river flood risk in the future; these are discussed in the subsections below. Other potential impacts have not been explored for the region, including erosion and landslide risks, implications for groundwater recharge, and stormwater impacts.

Figure C.4. Washington State Annual Precipitation, 1898 to 2020



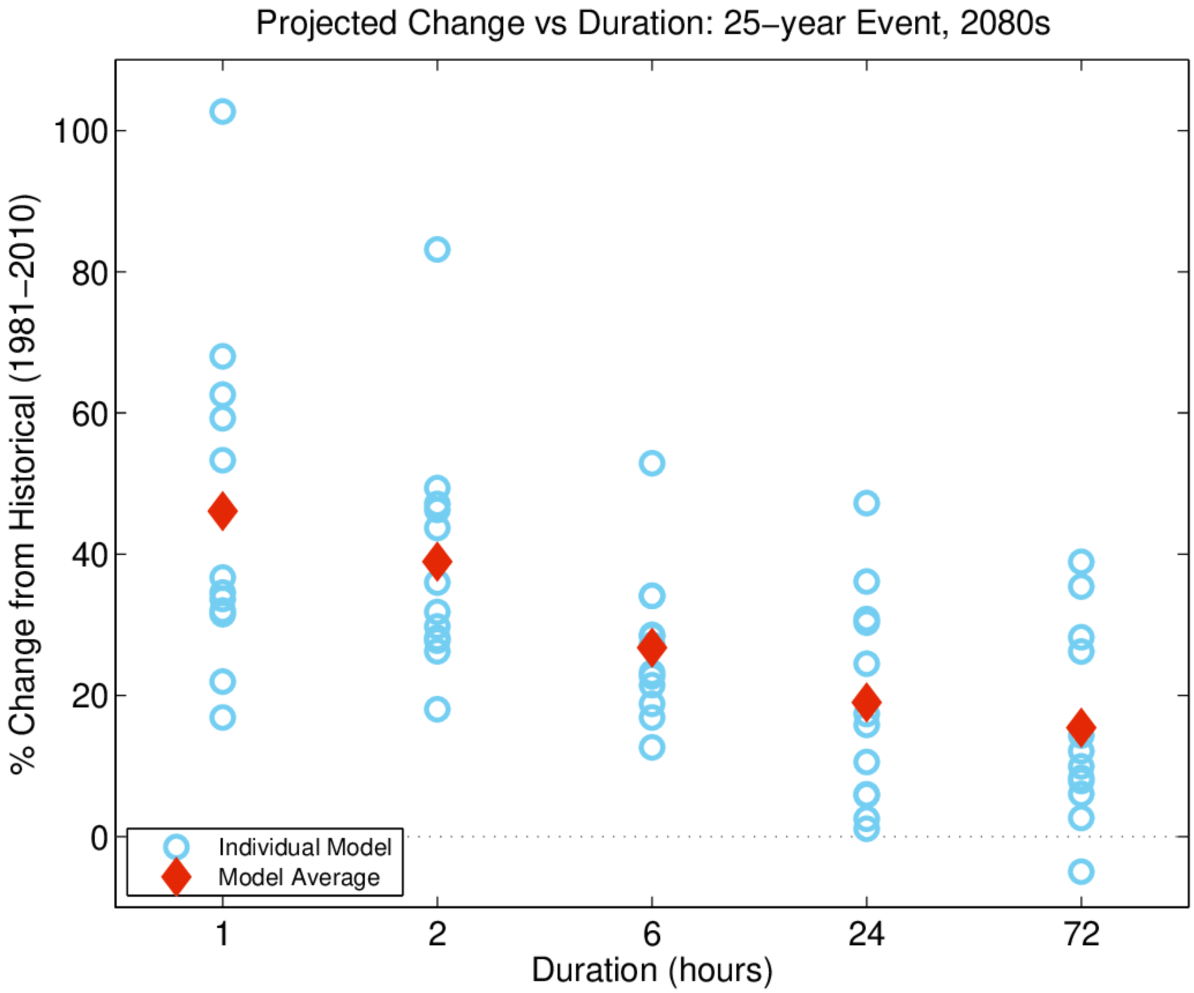
Note: Since 1900, annual precipitation has increased by about 6 inches at McMillin Reservoir, between South Hill and Orting. Plot shows annual total precipitation for each year from 1896-2021. Source: https://climate.washington.edu/climate-data/trendanalysisapp/.

Figure C.5. Projected Annual, Winter, and Summer Changes in Total Precipitation West of the Cascades, 2080s



Note: Projected changes in annual and seasonal precipitation are generally small compared to the range among models. Figure shows the projected change in annual (top), winter (middle), and summer (bottom) precipitation (%), by the 2080s, for the region west of the Cascade crest. Source: https://cig.uw.edu/resources/analysis-tools/pacific-northwest-climate-projection-tool/

Figure C.6. Average Projected Change in Precipitation Extremes for the Puyallup River Watershed, 2080s



Note: More intense heavy precipitation; shortest durations are projected to increase the most. Projected change in heavy precipitation, averaged over the Puyallup watershed. The plot shows the percent change in the 25-year event for the 2080s (2070-2099, relative to 1981-2010) and a high (RCP 8.5) greenhouse gas scenario, for six event durations: 1 hour, 2 hours, 6 hours, 24 hours, and 72 hours. Projections are based on dynamical downscaling, which research has shown to more accurately represent changes in precipitation extremes. Source: https://cig.uw.edu/projects/heavy-precipitation-projections-for-use-in-stormwater-planning/

Shrinking Snow and Glaciers

Spring snowpack and glacier volumes have declined significantly since observations began in the twentieth century, and models project accelerated declines over the coming decades. Accompanying trends include a higher snowline, shorter snow season, and higher proportion of precipitation falling as rain.

What this means: Warmer temperatures than what used to be snow will fall as rain, meaning a greater potential for flooding. Declining snowpack also means less snowmelt in spring and summer, leading to lower flows in rivers and drier conditions across the landscape. This could lead to an increased risk of wildfire in the future.

Past Trends

Across the western U.S., April 1 snowpack has declined by 15 to 30 percent since the middle of the twentieth century (Mote et al. 2018) (Figure C7). Considering the western U.S. as a whole, this corresponds to a loss of water equivalent to the volume of Lake Mead, the West's largest reservoir. Changes at Paradise on Mount Rainier are less pronounced than the regional average, showing a 10 percent decline since 1940. This is because Paradise is a cold location on the slopes of Mount Rainier—even with warming, the area remains well below freezing for much of the year.

Most glaciers that feed into Puget Sound are also in decline. On Mount Rainier, Riedel et al. (2020) estimated that the Emmons glacier had lost over 13 m (42.6 feet) of water, averaged across the entire glacier, from 2003 to 2019. While the 2020 study did not provide volume estimates, a previous study (Riedel and Larrabee 2015) estimated that the volume of the Emmons glacier declined by 89.4 million cubic meters (about 72,500 acre-feet) from 2002 to 2011.

Although on balance the majority of glaciers are receding, some show increases in some years and declines in others, in part because their response time is so long. For example, Sisson et al. (2011) found increases in some Mount Rainier glaciers between 1970 and 2007, even though on balance they estimated a 14 percent decline in glacier volume over that time frame.

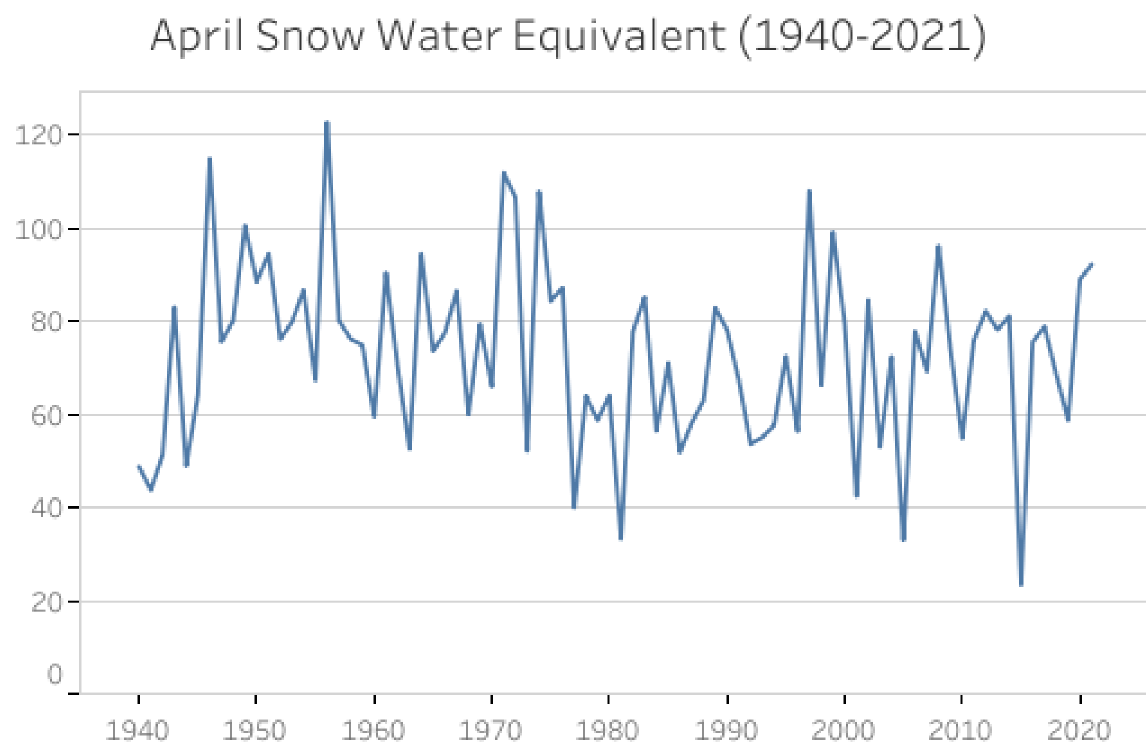
Glacier melt provides an important boost to streamflow in summer, especially when flows are lowest after most of the snowpack has melted. Riedel et al. (2020) estimate that glacial melt contributes on average about 20 percent of streamflow on the White River for May to September.

Projected Changes

Average spring snowpack in the Puget Sound region is projected to decline by 42 percent to 55 percent by the 2080s (2070 through 2099, relative to 1970 through 1999), on average, for a low (B1) and a moderate (A1B) greenhouse gas scenario, respectively. This will result in a shift to higher streamflow in winter, an earlier peak in spring snowmelt, and lower flows in summer (Figure C.8).

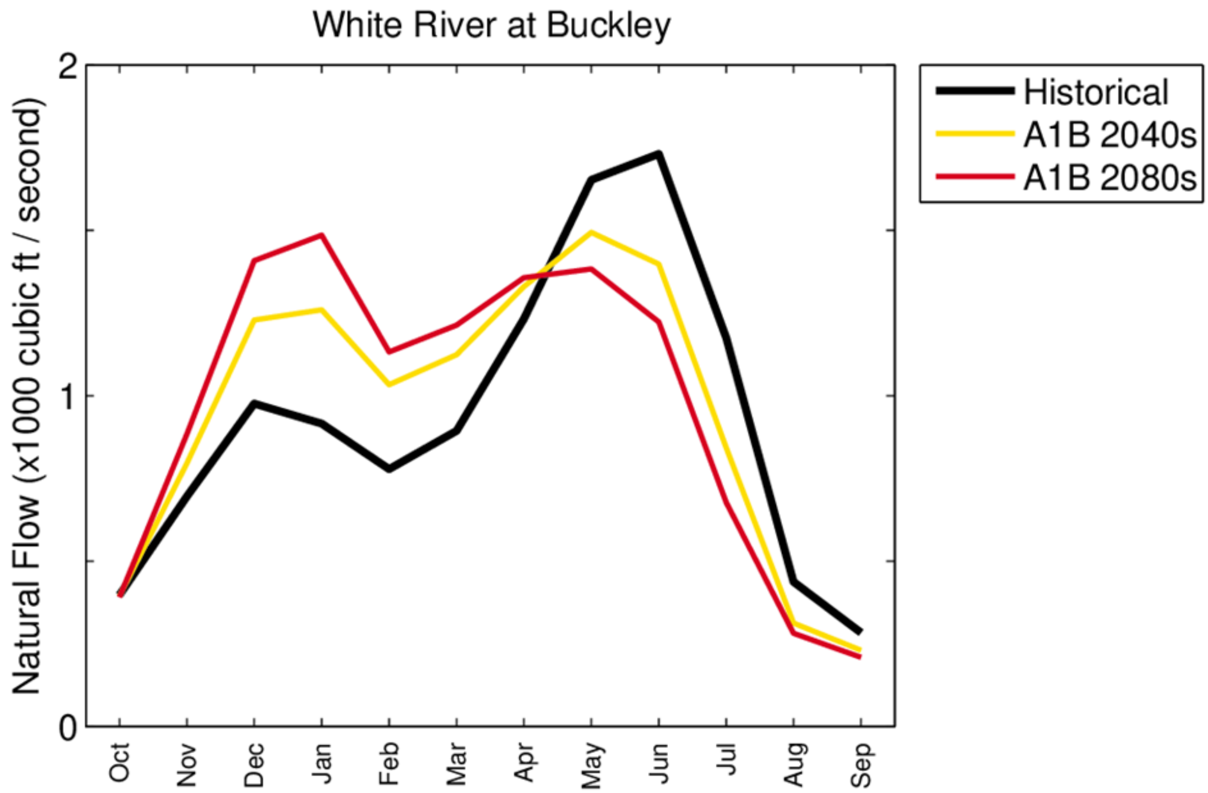
Few studies have modeled future changes for Mount Rainier glaciers. Frans et al. (2018) modeled the Nisqually glacier, finding that glacier area will remain stable through about 2050, then decline rapidly thereafter. Their modeling projects about a 25% decline for a low (RCP 4.5) greenhouse gas scenario and more than a 60% decline in area for a high (RCP 8.5) greenhouse gas scenario, by 2100, relative to 1960 (Figure C.9). Accelerated glacial melt could contribute to an increase in streamflow initially, followed by a rapid decline as glaciers recede more substantially. Frans et al. (2018) find that glacial melt from the Nisqually glacier will follow this pattern: increasing through about 2060, then decreasing thereafter. As noted above, glacial melt is only an important contributor to streamflow in summer, and so is not directly relevant to flooding.

Figure C.7. April Snowpack Declines since 1940 at Paradise on Mount Rainier



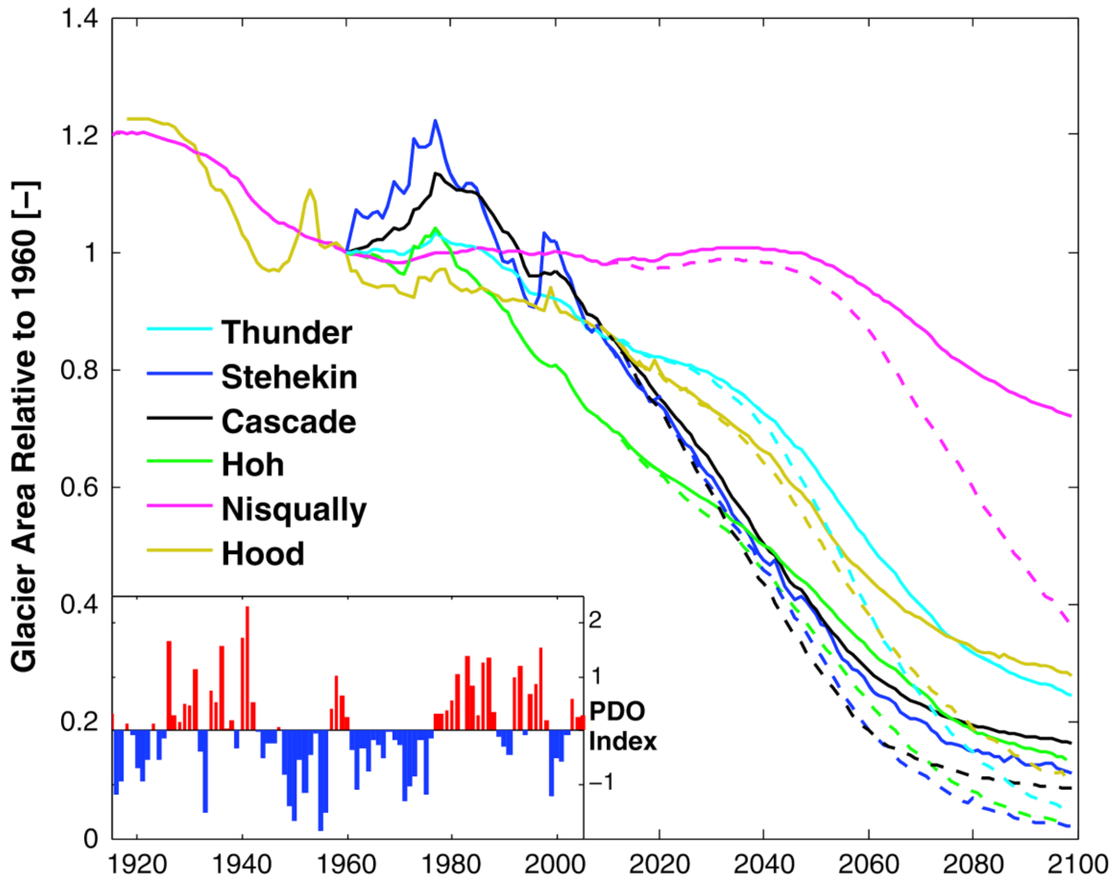
Note: Changes at Paradise are less than the regional average because it is cold enough that it stays well below freezing for much of the year. Plot shows the April 1 Snow Water Equivalent (SWE) for the Paradise SNOTEL station on Mt Rainier, for each year from 1940-2021. Source: https://climate.washington.edu/climate-data/trendanalysisapp/

Figure C.8. Projected Reduced Future Snowpack Compared to Historical Snowpack



Note: Plot shows monthly average streamflow for the water year (Oct-Sep), for the White River at Buckley, for the past (1970-1999), mid-century (2030-2059), and end of century (2070-2099). Future projections are based on the average of 10 GCM projections and a moderate (A1B) greenhouse gas scenario. For these simulations, the primary driver of change is the reduction in snowpack associated with warming. Source: Hamlet et al. (2013), http://warm.atmos.washington.edu/2860/

Figure C.9 Projected Glacier Receding across the Pacific Northwest



Note: Plot shows the modeled glacier area relative to 1960 for a selection of Pacific Northwest glaciers, including the Nisqually glacier on Mount Rainier. Future projections are based on the average of 10 GCM projections. Solid lines show the projections for a low (RCP 4.5) greenhouse gas scenario, and dashed lines show the projections for a high (RCP 8.5) greenhouse gas scenario. A time series of the Pacific Decadal Oscillation (PDO) index for the period 1915–2005 is provided on the inset. Given the long response time of glaciers, these oscillations could affect the modeled glacier variations in the modeled 21st century projections. Source: Frans et al. 2018

Sea Level Rise

Sea level has risen over the last century and is projected to rise more rapidly in the coming decades. In addition to higher high tides, rising sea levels increase the likelihood and reach of coastal flooding.

What this means: Sea level rise in Pierce County will result in more frequent coastal flooding during high tidal and storm events. Higher sea levels will also push back against river flows, leading to greater flood risk in the lower Puyallup River and potentially leading to more sediment deposition, which would further exacerbate flood risk. An increase in saltwater intrusion, both in the river and potentially via groundwater, is also a risk as sea level rises.

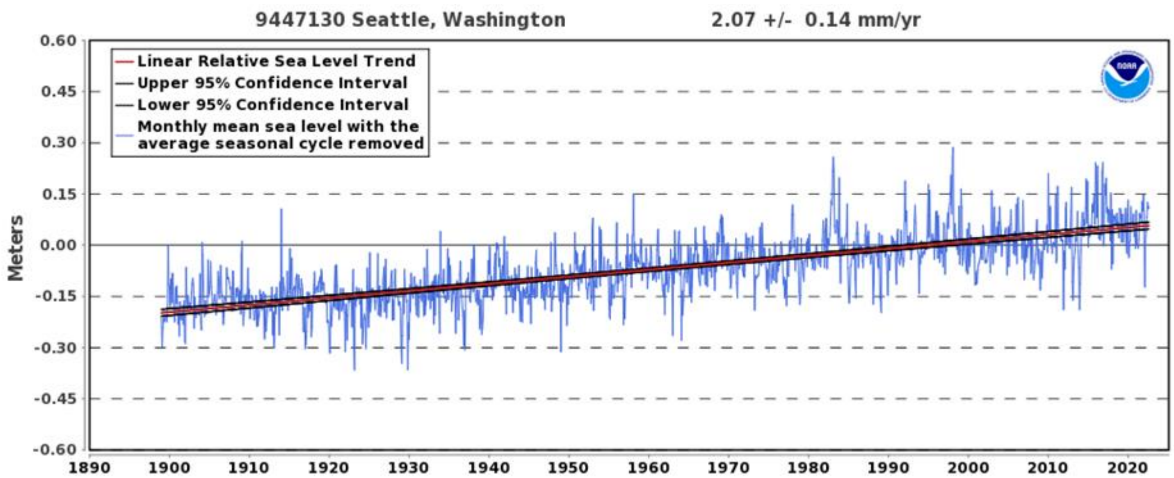
Past Trends

Since 1900, sea level has risen by about 10 inches at the Seattle tide gauge (https://tidesandcurrents.noaa.gov/, Figure C.10). This is similar to the global estimate of sea level rise over that same time period; the IPCC estimates a rise of about 8 inches from 1901 to 2018 (IPCC 2021).

Sea level is a measure of the relative height of the ocean and land surface. Climate change affects only the change in sea level. However, in our tectonically active region, land motion can be important. For Seattle, a bit less than half of the historical rise is due to land subsidence, and the same is roughly true for Pierce County (Newton et al. 2021). While important for understanding past changes in sea level, this effect will become less important as sea level rises more rapidly in the future.

Sea level varies with the tides, of course, but also with seasons and due to passing storms. Average sea level in winter is about 6 inches higher than in summer. Individual storms can also elevate sea level due as a result of lower surface pressure, winds, and ocean currents. Miller et al. (2019), for example, estimate that for Puget Sound the 100-year storm surge can raise sea levels by 3.2 feet. Studies do not find evidence for a long-term trend in surge, though sea level rise can lead to increased impacts even if the amount of surge itself is not changing

Figure C.10. Trend in Sea Level Rise, 1900 - 2020



Note: Sea Level has risen by about 10 inches (25 cm) at the Seattle tide gauge since 1900. Plot shows the monthly mean sea level at the Seattle tide gauge from 1900-2021, after the seasonal cycle has been removed (removing the seasonal cycle makes it easier to focus on the long-term trend). Source: https://tidesandcurrents.noaa.gov/

Projected Changes

Sea level is projected to rise more rapidly in the coming decades. For Commencement Bay, the latest study projects a rise of 2.1 feet (likely range: 1.5–2.7 feet) for a low (RCP 4.5) greenhouse gas scenario and 2.5 feet (likely range: 1.9–3.3 feet) for a high (RCP 8.5) greenhouse gas scenario by 2100, relative to 2000 (Figure C.11; Miller et al. 2018). The rate of rise is projected to accelerate throughout the 21st century, with the largest changes occurring after 2050.

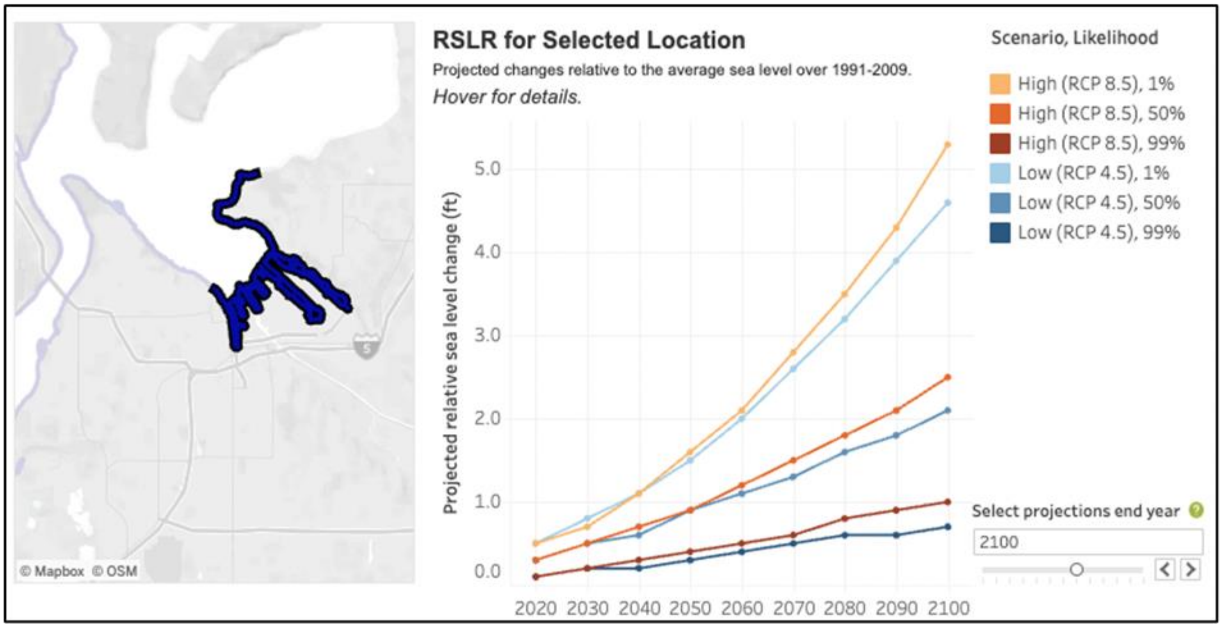
These projections are probabilistic, given the likelihood that sea level rise will rise above a certain level. This lends itself to a risk-based approach to planning for coastal floods. The feet level rise quoted above give the likely range (17-83% probability), but the uncertainty range can expand beyond that. This is illustrated in Figure C.11, which shows results for the 99%, 50%, and 1% likelihood projections for each greenhouse gas scenario.

The probabilistic approach can also be used to look at the likelihood of a fixed amount of sea level rise by a particular year. For example, Figure C. 12 shows the likelihood of at least 1 foot of sea level rise. Projections show that by 2060, the chance of an additional 1 ft of sea level rise is 62% for a low (RCP 4.5) greenhouse gas scenario and 73% for a high (RCP 8.5) greenhouse gas scenario.

The science is inconclusive about the potential for a change in storm surge or wave heights (Miller et al. 2019). However, a rise in sea level will increase the reach of coastal floods even in the absence of a change in surge and wave heights. This means that coastal flood elevations should be expected to rise in tandem with sea level rise.

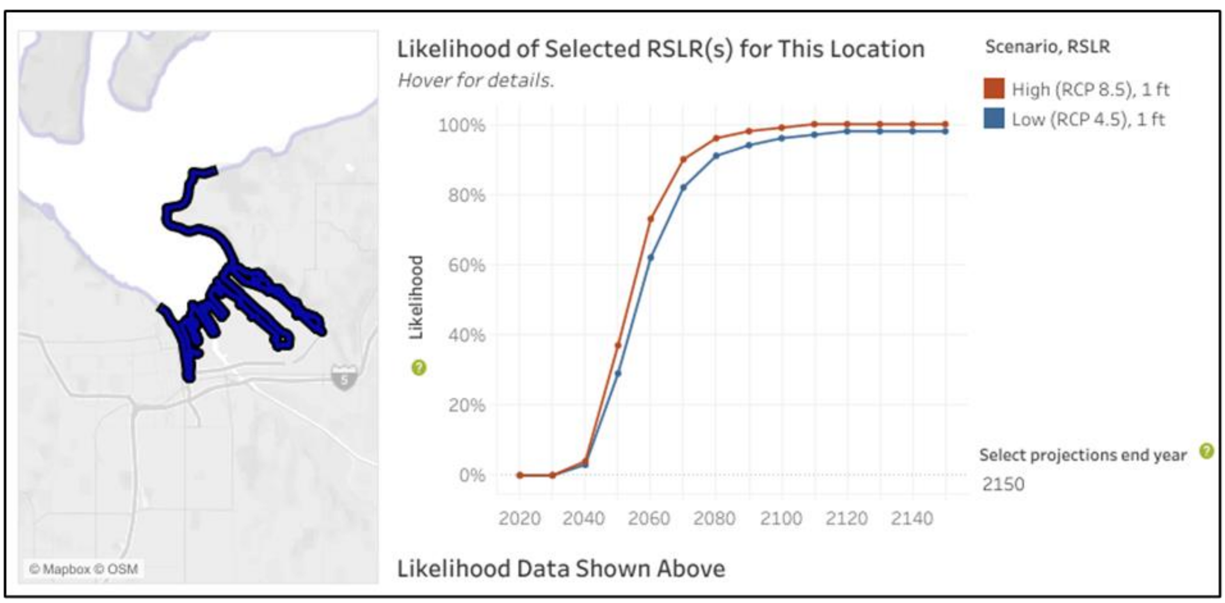
Higher sea level can also increase the risk of saltwater intrusion, both via groundwater and in the lower Puyallup River. Horner-Devine and Mauger (2022) recently evaluated the extent of saltwater intrusion in the lower Puyallup River. They estimate that climate change could more than double the frequency of saltwater intrusion above the Clear Creek inlet.

Figure C.11 Likelihood of Rapid Sea level Rise for Commencement Bay



Note: There is large uncertainty for rapid sea level rise for Commencement Bay. Lines show the low (99% chance of exceedance), median (50%) and high (1%) estimates of future sea level rise for both a low (RCP 4.5) and high (RCP 8.5) greenhouse gas scenario. Source: Miller et al. 2018, https://cig.uw.edu/projects/interactive-sea-level-rise-data-visualizations/

Figure C.11. Likelihood of 1 Foot Rapid Sea Level Rise for Commencement Bay



Note: High likelihood of 1 ft additional foot of sea level rise. Projected likelihood of 1 ft of sea level rise for both a low (RCP 4.5) and high (RCP 8.5) greenhouse gas scenario. The tool can be used to explore a range of possible increases in sea level, from 0 to 10 ft. Source: Miller et al. 2018, https://cig.uw.edu/projects/interactive-sea-level-rise-data-visualizations/

Groundwater Flooding

Groundwater flooding in Pierce County could occur more in the future due to either rising sea levels or heavier precipitation events, depending on the location. Very few studies assess potential impacts of climate change on groundwater flooding.

What this means: Potential increases in the frequency and duration of groundwater flooding could put infrastructure, residential and commercial development, and farmland at risk of inundation, particularly during more frequent storm events. Groundwater flooding also increases the amount of standing water on agricultural lands, which can negatively impact crop yields and delay spring cultivation.

Past Trends

Limited studies have been done to evaluate past trends in groundwater flooding.

Projected Changes

Climate change is expected to contribute to increased groundwater flooding in coastal areas due to higher sea levels. Heavier precipitation events are also expected to increase the risk of groundwater flooding.

River Flooding

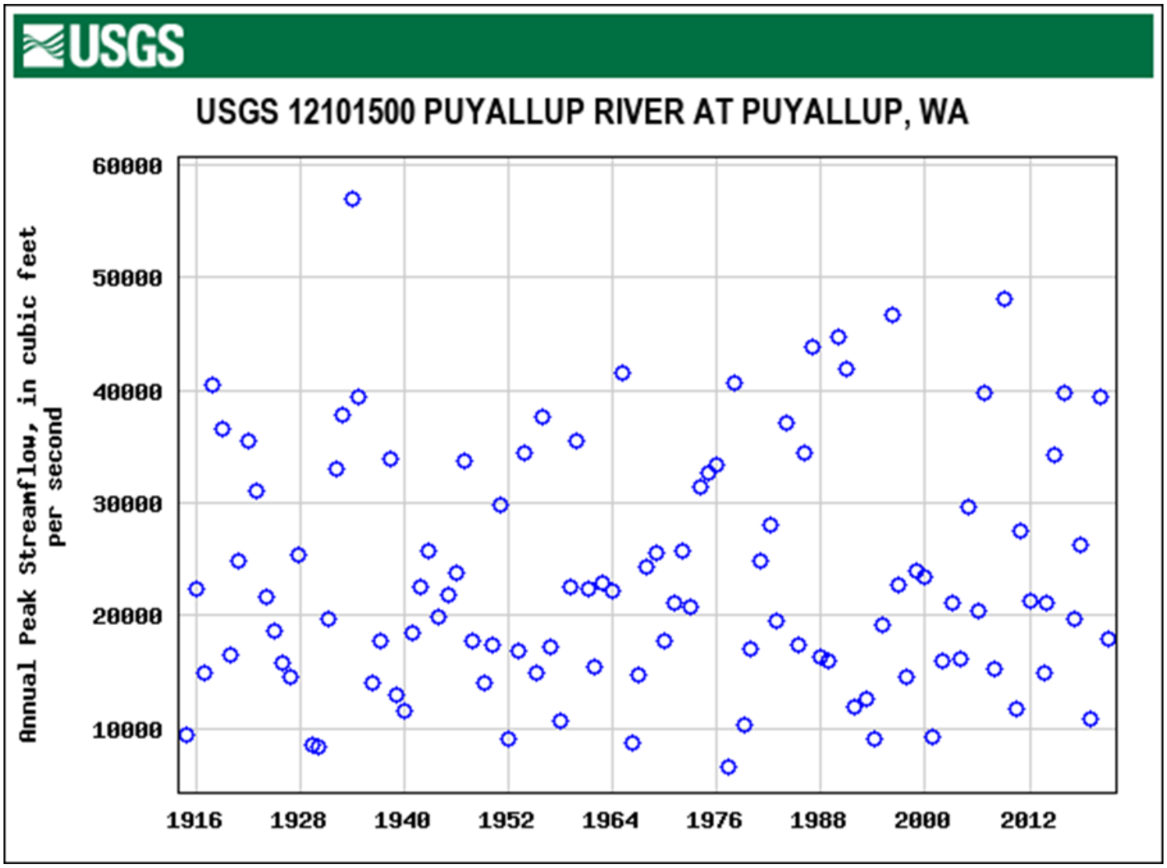
River floods in Pierce County are projected to become larger and more frequent due to receding snowpack, heavier rain events, and higher sea level. Other climate-related factors could further exacerbate flood risk, in particular the potential for increased sedimentation and an increased risk of wildfire.

What this means: Larger and more frequent floods would result in more frequent overbank flooding, including a higher risk of catastrophic flooding within Pierce County's watersheds. This could impact public safety and infrastructure, as well as riverine ecosystems and agriculture.

Past Trends

No study has specifically evaluated past trends in peak flows for the Puyallup River watershed. However, a visual inspection of the peak flow time series for the USGS Puyallup at Puyallup flow gauge suggests there is no long-term trend (Figure C.13). Further investigation would be needed because the observed flows are affected by reservoir operations at Mud Mountain Dam on the White River, which could obscure a trend.

Figure C.13. Annual Peak Flow in Puyallup River, 1916 to 2020



No long-term trend in peak instantaneous flows for the Puyallup at Puyallup gauge. Plot shows the annual peak in instantaneous (15-min average) streamflow for the USGS Puyallup River at Puyallup gauge. Source: https://waterdata.usgs.gov/

Projected Changes

New streamflow projections, which are currently in development for the Puyallup River watershed, are expected to be released in 2023. In the meantime, two previous studies produced estimates of future peak flows for this watershed:

- Hamlet et al. (2013). This older dataset included projections for the Whiter River near Buckley (USGS #12100000).
- Chegwidden et al. (2019). This dataset is more recent and provided projections for multiple locations, including the White River near Buckley (USGS #12100000) and the Puyallup River at Puyallup (USGS #12101500).

The percent changes in flow at each location are listed in Figure C.14, for both datasets. For example, for the Puyallup River at Puyallup gauge, projected changes for the 2080s (relative to 1970–1999) range from 25%, on average, for a low (RCP 4.5) greenhouse gas scenario to 44%, on average, for a high (RCP 8.5) greenhouse gas scenario.

Figure C.14. Percent Change in 100-year Flood for Buckley and Puyallup

GHG Scenario		Low (B1)[1]	Low (RCP 4.5)[2]	Moderate (A1B)[1]	High (RCP 8.5)[2]
Buckley	2040s	39% (-14-85%)	42% (-16-110%)	56% (22-115%)	28% (-20-95%)
	2080s	69% (28-118%)	32% (2-86%)	78% (40-145%)	53% (3-150%)
Puyallup	2040s	–	38% (-9-97%)	–	26% (-3-72%)
	2080s	–	25% (-3-75%)	–	44% (16-110%)

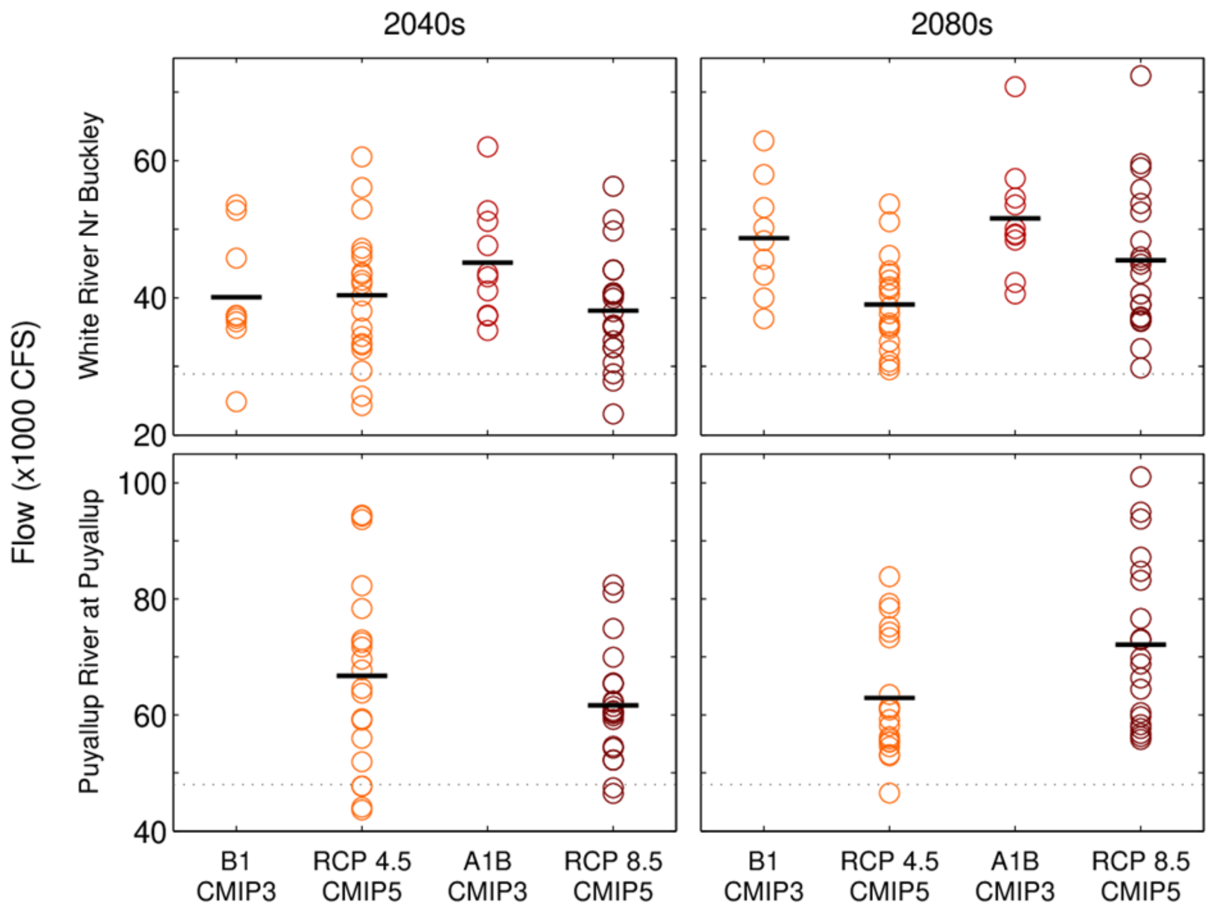
Note: Large increases are projected in the 100-year flood. Figure shows the percent change in the 100-year flood for two recent studies: Hamlet et al. (2013) and Chegwidden et al. (2019). Percent changes are provided for the average among models, with the range in parentheses, for both the 2040s (2030-2059) and 2080s (2070-2099), relative to 1970-1999. The two datasets use different generations of climate models and greenhouse gas scenarios, as well as other differences in the hydrologic modeling approach.

1 Source: Hamlet et al. (2013)
2 Source: Chegwidden et al. (2019)

Figure C.15 shows how the percent change projections translate to absolute flow magnitudes in the future. Absolute flows were estimated by scaling the percent changes in Figure C.15, using the following historical 100-year flow estimates from FEMA (2017):

- 28,900 cfs for the White River at its confluence with the Greenwater River (upstream of Mud Mountain Dam)
- 48,000 cfs for the Puyallup River at Puyallup

Figure C.15. Magnitude of Projected 100-year Flood for Puyallup and White Rivers in 2040s and 2080s



Note: Floods are projected to become larger and more frequent. Plots show the magnitude of the projected 100-year flood for the 2040s and 2080s (relative to 1970-1999), for the White River near Buckley and Puyallup River at Puyallup gauge locations. Results are shown for two studies that estimate future flows on the river: Hamlet et al. (2013) and Chegwidden et al. (2019). The Hamlet et al. (2013) dataset did not include projections for the Puyallup River at Puyallup. Absolute flow estimates were obtained by scaling the FEMA (2002) estimates for the 100-year flow magnitudes for each location, using the peak flow changes listed in Table 1. Source: Hamlet et al. (2017, http://warm.atmos.washington.edu/2860/) and Chegwidden et al. (2019, https://www.hydro.washington.edu/CRCC/).

The uncertainty around these estimates is large, in part because it is difficult to estimate changes in an event size as rare as the 100-year event. The uncertainty is less, for example, for changes in the 2-year flood event.

Neither of the above datasets accounts for the effects of flow regulation at Mud Mountain Dam. It is not clear if the percent changes would be smaller with the dam, since it is possible that future flood events could overwhelm its capacity to retain flood waters. An additional study would be needed to quantify future regulated flows by accounting for the impact of potential reservoir operations.

Both the Hamlet et al. (2013) and Chegwidden et al. (2019) datasets are based on coarse-scale hydrologic modeling and only provide flow projections for a few locations across the watershed. In addition, these efforts are based on statistical downscaling, which recent research has shown does not adequately capture changes in heavy rain events (Salathé et al. 2014; see discussion of "downscaling" in Background section above). A new study is currently underway that is based on fine-scale hydrologic modeling, will provide results for numerous streamflow sites across the watershed, and uses dynamical downscaling to estimate future conditions. The new projections will also account for the effect of current reservoir operations at Mud Mountain Dam. These results are planned for release in 2023.

Another pathway for climate change impacts on flooding is sediment. Higher sediment loads are expected in the future due to receding snowpack and glaciers, heavy rain events, higher and more erosive river flows, and possible increases in the frequency and size of both landslides and wildfire. On the Skagit River, for example, Lee et al. (2016) projected more than a fourfold increase in the average suspended sediment discharge for December-February, and a 149% increase in the annual suspended sediment load, by the 2080s, relative to 1970-1999, for a moderate greenhouse gas scenario (A1B). This additional sediment transport could cause the streambed to rise ("aggrade") in places. Changes in riverbed elevation could be temporary, resulting from "pulses" of sediment that slowly migrate down river, or could be chronic, reflecting a long-term trend in aggradation. No study has estimated future sediment transport or aggradation on the Puyallup River, in part because of a lack of available data from which to assess current trends.

Projected increases in peak flows, rain intensity, and sea level, along with the likely increase in sediment aggradation could all combine to dramatically increase both frequency and magnitude of damaging flood events in Pierce County. Existing studies (e.g., NHC 2007) have evaluated the depth and extent of current floods, however none have evaluated how this will change in the future. In an ongoing project, Pierce County is developing hydraulic model simulations to estimate future changes in the extent and depth of flooding on the Puyallup River. Results from this study are planned for release in 2023.

Few studies have evaluated the potential efficacy of flood risk management efforts, and whether these actions measure up to the risks that we are facing today and in the future. For example, NSD (2022) recently estimated that existing proposals for setback levees, while beneficial, would not significantly decrease the volume of the 100-year flood in the Puyallup River. This suggests that other strategies may be needed in addition to levee setbacks, in order to adequately respond to present and future flood risks.

C.4 References

Chegwidden, O. S., Nijssen, B., Rupp, D. E., Arnold, J. R., Clark, M. P., Hamman, J. J., ... & Xiao, M. (2019). How do modeling decisions affect the spread among hydrologic climate change projections? Exploring a large ensemble of simulations across a diversity of hydroclimates. Earth's Future, 7(6), 623-637.

FEMA, 2017. Flood Insurance Study: Pierce County, Washington and Incorporated Areas. Federal Emergency Management Agency. Flood Insurance Study Number: 53053CV001A. Volume 1 of 5. Effective: March 7, 2017.

Hamlet, A.F. et al. 2013. An overview of the Columbia Basin Climate Change Scenarios Project: Approach, methods, and summary of key results. Atmosphere-Ocean 51(4): 392-415. doi: 10.1080/07055900.2013.819555.

Horner-Devine, A.R. and G.S. Mauger, 2022. Salt intrusion in the lower Puyallup River under current and future conditions. Report prepared for Pierce County. Civil and Environmental Engineering and Climate Impacts Group, University of Washington.

IPCC, 2021: Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 3−32, doi:10.1017/9781009157896.001

Madsen, T., & E. Figdor, 2007. When it rains, it pours: global warming and the rising frequency of extreme precipitation in the United States. Report prepared for Environment California Research and Policy Center. 47pp.

Mass, C. et al., 2011. Extreme Precipitation over the West Coast of North America: Is There a Trend?. Journal of Hydrometeorology, 12(2), 310-318.

Mauger, G.S.,J.H. Casola,H.A. Morgan, R.L. Strauch, B. Jones, B. Curry, T.M. Busch Isaksen, L. Whitely Binder, M.B. Krosby, and A.K. Snover, 2015. State of Knowledge: Climate Change in Puget Sound. Report prepared for the Puget Sound Partnership and the National Oceanic and Atmospheric Administration. Climate Impacts Group, University of Washington, Seattle. doi:10.7915/CIG93777D

Miller, I.M., Morgan, H., Mauger, G., Newton, T., Weldon, R., Schmidt, D., Welch, M., Grossman, E. 2018. Projected Sea Level Rise for Washington State – A 2018 Assessment. A collaboration of Washington Sea Grant, University of Washington Climate Impacts Group, University of Oregon, University of Washington, and US Geological Survey. Prepared for the Washington Coastal Resilience Project. Updated July 2019.

Miller, I.M., Yang, Z., VanArendonk, N., Grossman, E., Mauger, G. S., Morgan, H., 2019. Extreme Coastal Water Level in Washington State: Guidelines to Support Sea Level Rise Planning. A collaboration of Washington Sea Grant, University of Washington Climate Impacts Group, Oregon State University, University of Washington, Pacific Northwest National Laboratory and U.S. Geological Survey. Prepared for the Washington Coastal Resilience Project.

Mote, P. W., Li, S., Lettenmaier, D. P., Xiao, M., & Engel, R. 2018. Dramatic declines in snowpack in the western US. Npj Climate and Atmospheric Science, 1(1), 1-6.

Natural Systems Design. 2022. Puyallup River Watershed Flood Storage Assessment.

Newton, T. J., Weldon, R., Miller, I. M., Schmidt, D., Mauger, G., Morgan, H., & Grossman, E. 2021. An Assessment of Vertical Land Movement to Support Coastal Hazards Planning in Washington State. Water, 13(3), 281.

Riedel, J. and M.A. Larrabee. 2015. Mount Rainier National Park glacier mass balance monitoring annual report, water year 2011: North Coast and Cascades Network. Natural Resource Data Series. NPS/NCCN/NRDS—2015/752. National Park Service. Fort Collins, Colorado. https://irma.nps.gov/DataStore/Reference/Profile/2219351.

Riedel, J., M. A. Larrabee, and K. L. Ladig. 2020. Mount Rainier National Park glacier mass balance monitoring report, water years 2012-2019: North Coast and Cascades Network. Natural Resource Data Series NPS/NCCN/NRDS—2020/XXXX. National Park Service, Fort Collins, Colorado.

Rosenberg, E. A. et al. 2010. Precipitation extremes and the impacts of climate change on stormwater infrastructure in Washington State. Climatic Change, 102(1-2), 319-349.

Salathé, E. P., Hamlet, A. F., Mass, C. F., Lee, S. Y., Stumbaugh, M., & Steed, R. 2014. Estimates of twenty-first-century flood risk in the Pacific Northwest based on regional climate model simulations. Journal of Hydrometeorology, 15(5), 1881-1899.

Sisson, T. W., J. E. Robinson, and D. D. Swinney. 2011. Whole edifice ice volume change A.D. 2970 to 2007/2008 at Mount Rainier, Washington, based on LiDAR surveying. Geology 39(7):639-642.

Vose, R. S. et al., 2014. Improved historical temperature and precipitation time series for US climate divisions. Journal of Applied Meteorology and Climatology, 53(5), 1232-1251.

Warner, M.D., et al. 2015. Changes in Winter Atmospheric Rivers along the North American West Coast in CMIP5 Climate Models. J. Hydrometeor, 16, 118–128. doi: http://dx.doi.org/10.1175/JHM-D-14-0080.1

Washington State Department of Ecology (Ecology). 2019. Stormwater Management Manual for Western Washington. Publication Number 19-10-021, July. 2019SWMMWW (wa.gov).

Wilhere, G., J. Atha, T. Quinn, L. Helbrecht, and I. Tohver. 2017. Incorporating Climate Change into the Design of Water Crossing Structures: Final Project Report. Washington Department of Fish and Wildlife. November.

Problem and Project Ranking Criteria

In October 2021 the cities/towns along with Pierce County worked to modify and update the problem/project ranking criteria that was in the 2013 Pierce County Rivers Flood Hazard Management plan. This work took place during two Disappearing Task Group meetings. Each city and town as well as the County used the updated problem/project ranking criteria to score their individual capital flood projects which is listed in Appendix D.

Jurisdiction Name: City of Bonney Lake

Problem Statement: *The City of Bonney Lake is an urban city experiencing urban flooding issues due to past land decisions.*

Floodplain Regulations Link: Chapter 16.26 BLMC https://www.codepublishing.com/WA/BonneyLake/#!/BonneyLake16/BonneyLake1626.html#16.26

Sub Planning Area: Middle Puyallup and White River Basin

Flood Projects

Project Description	Location	Type of Flooding	Potential Solution	Estimated Cost	1. Existing land use of affected area	2. Severity of potential flood or channel migration	3. Area of impact	4. Frequency of flood or channel migration occurrence impact	5. Project Effectiveness	6. Phasing and Sequencing of Projects	7. Multiple Projects benefits	8. Partnerships and Opportunity	9. Best Management Practices	Total
Significant flooding caused by natural occurring pothole with no outfall - occurred twice in last 20 years.	188th Ave E/62 St E (East Hill Pothole)	Urban	Propose installing a pressure main and pump to convey high water events to an outfall on Lake Tapps. System would include a pump at the eastern most pond area and conveyance of approximately 1,500 LF of 8" PVC pipe beneath 64th Street East. Proposed work solves flooding at Project 1-2 site as well.	$3,514,980	4	4	4	6	12	1	2	4	3	40
Reports state that culvert crossing at Kelly Lake Road is undersized in capacity and unable to meet stormwater requirements, resulting in overtopping of Kelly Lake Road.	Church Lake/Kelly Lake	Urban	There are several possible solutions are appropriate dependent upon further technical analysis. One option is to replace a culvert (70 LF) with revised inverts and excavation at inlet to increase head pressure at culvert inlet. An analysis of capacity of culverts at 2 driveways (25 LF each) downstream (located in Pierce County jurisdiction) will be required. Alternative solutions include replacement of Kelley Lake Road culvert only, a direct closed connection between Kelley Lake Road culvert and upstream culvert with structures and pipe, or a more robustly excavated sump area at culvert inlet	$67,200	6	4	4	8	7	3	0	3	3	38
Reports indicate that the Walmart parking basin to an existing storm system draining to a pond located immediately south of the Walmart building.	192nd Ave E/SR410 - Walmart Parking Lot	Urban	Propose the addition of a catch basin to an existing storm system draining to a pond located immediately south of the Walmart building.	$19,880	4	2	2	5	9	5	0	3	3	33

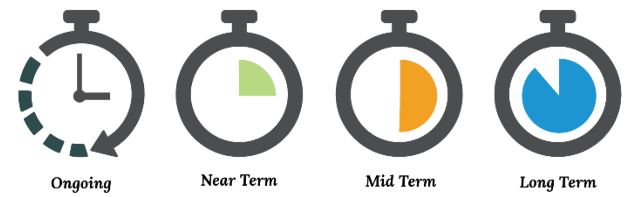
Stormwater conveyance system is surcharging near outfalls to Lake Tapps in two locations.	Cascade Dr E/North Island Drive E.	Urban	Propose to plug a lateral stormwater pipe beneath Island Drive at 4942 N Island Dr E and construct approximately 455 LF of 12" stormwater pipe and 6 new catch basins beginning at 4942 N Island Dr E and discharging to a proposed ditch. Extruded asphalt curb (with driveway cutouts) will direct stormwater into the proposed catch basins along Island Drive E. The proposed ditch is 235 LF and runs along the north side of Cascade Dr E to Lake Tapps. Finally, 55LF of 12" stormwater pipe will connect stormwater from the southeast quadrant of Cascade Dr E and N Island Dr E to the proposed system discharging to the proposed ditch along.	$254,475	5	3	2	4	9	5	0	3	3	34
Pothole located at the northeast corner of Locust Avenue and 82nd Street E fills with water during sustained storm events and floods 82nd Street.	Locust Avenue and 82nd Street	Urban	The city should purchase parcel 5640000200, modify the existing pond, and raise the roadway surface of 82nd Street E to increase the available storage capacity. Finally, cost of pump system and stormwater pipe required to convey excess pond water east along 82nd Street E to a stream connected to Lake Bonney outflow. Downstream analysis will be necessary to determine the impacts of this diversion.	$3,735,480	7	6	5	6	9	3	2	4	3	45

Flood Problems

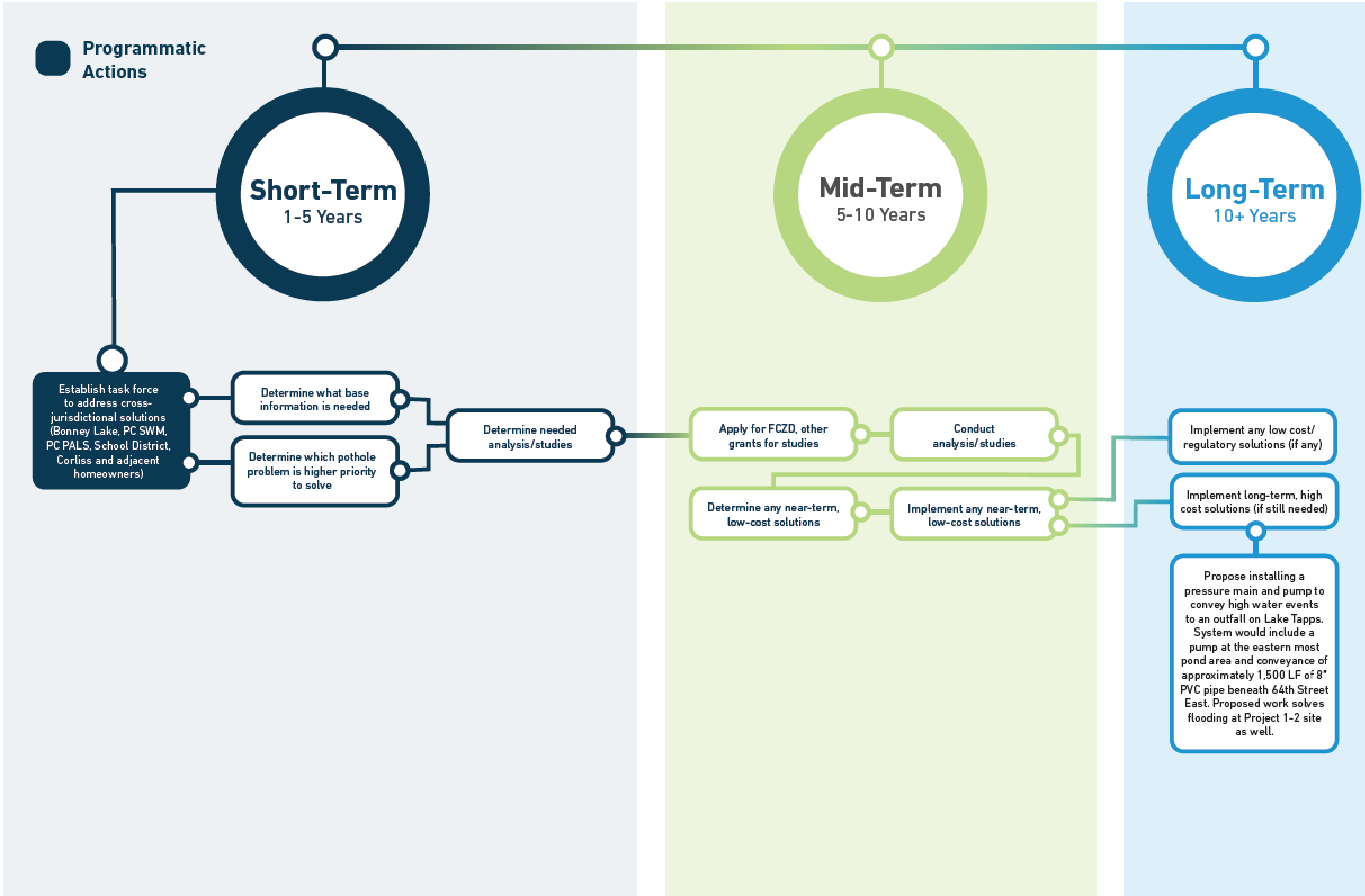
Problem Description	Location	Type of Flooding
Interflow issue that was revealed after the Legacy plat developed probably 10-15 years ago. Homeowner installed a French drain system. There are outwash soils that appear to accept stormwater readily but then it hits a hardpan situation that flows in the direction of the property down gradient. In the Legacy Park situation all the water in the plat was directed to the storm pond so a lot more water was funneled to an area that more than likely increased the interflow but that was not backed up by a study.	Bonney Lake Blvd & 181st Ave East	Groundwater

City Programmatic Recommendations

Timeline	Action	Lead Department	Partners	Progress
	Create a workgroup to discuss the pothole issue that is cross jurisdictional	Bonney Lake	Pierce County Stormwater and PALS, Private landowners, school district, whoever bought the Corliss property	



Bonney Lake Pot Hole
Urban Flood Hazards Pathway



Jurisdiction Name: City of Dupont

Problem Statement: The City of Dupont experiences urban flooding that restricts and delays access to residential areas and emergency services.

Floodplain Regulations Link: https://www.codepublishing.com/WA/DuPont/#!/html/DuPont23/DuPont2305.html

Sub Planning Area: Nisqually Basin

Flood Projects

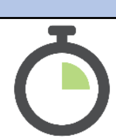
Project Description	Location	Type of Flooding	Potential Solution	Estimated Cost	1. Existing land use of affected area	2. Severity of potential flood or channel migration	3. Area of impact	4. Frequency of flood or channel migration occurrence impact	5. Project Effectiveness	6. Phasing and Sequencing of Projects	7. Multiple Projects benefits	8. Partnerships and Opportunity	9. Best Management Practices	Total
Forcite/Louviers Street flooding	Forcite/Louviers Street	Urban	Install infiltration trench and put in a drywell	$10,000	6	3	2	10	4	5	3	6	0	39
Haskell Street and Louviers Flooding	Haskell / Louviers	Urban	Catch Basin, basic treatment, infiltration trench	$77,400	6	2	2	4	9	3	8	3	0	37
Baskdale and Haskell Flooding	Barksdale / Haskell	Urban	Catch Basin, bioretention cell	$87,000	6	2	2	4	9	3	8	3	0	37
Barskdale and Penniman Street Flooding	Barksdale / Penniman	Urban	Catch Basin, basic treatment, infiltration trench	$133,100	6	2	2	4	9	5	8	3	0	39
Barksdale and Hopewell Flooding	Barksdale / Hopewell	Urban	Catch Basin, basic treatment, infiltration trench	$77,400	6	2	2	4	9	5	8	3	0	39
Louviers and Hercules Flooding	Louviers / Hercules	Urban	Catch Basin, basic treatment, infiltration trench	$84,400	6	2	2	4	9	5	8	3	0	39
Barksdale and Hercules Flooding	Barksdale / Hercules	Urban	Catch Basin, basic treatment, infiltration trench	$71,800	6	2	2	4	9	5	8	3	0	39
Louviers and Repauno Flooding	Louviers / Repauno	Urban	Catch Basin, basic treatment, infiltration trench	$87,000	6	2	2	4	9	3	8	3	0	37

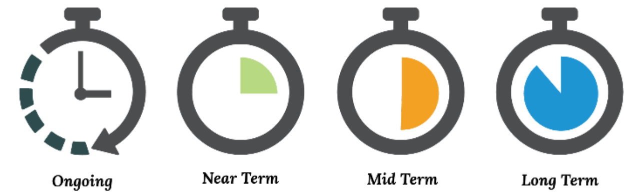
Repauno Flooding	Repauno	Urban	Catch Basin, basic treatment, infiltration trench	$110,000	6	2	2	4	9	3	8	3	0	37
Repauno and Barksdale Flooding	Repauno / Barksdale	Urban	Catch Basin, basic treatment, infiltration trench	$110,000	6	2	2	4	9	3	8	3	0	37
Santa Cruz and Brandywine Flooding	Santa Cruz / Brandywine	Urban	Catch Basin, basic treatment, infiltration trench	$110,000	6	2	2	4	9	3	8	3	0	37

Flood Problems

Problem Description	Location	Type of Flooding
Martin Street Flooding	Martin Street	Urban
McNeil by Center Drive flooding	McNeil by Center Drive	Urban
Flooding on Kittson Street	Kittson Street	Urban
Lake Sellars trail flooding	Between State farm and the Historic Village	Groundwater
Coastal and stream flooding	At mouth of Sequalitchew Creek	Coastal

City Programmatic Recommendations

Timeline	Action	Lead Department	Partners	Progress
	Work with other municipalities (in the County) and Pierce County to gather additional information on grant opportunities	Pierce County	Cities in Pierce County	


Ongoing
Near Term
Mid Term
Long Term

Jurisdiction Name: City of Edgewood

Problem Statement: *For being a community situated on a hill, the City of Edgewood has large areas of isolated drainage that result in regular flooding. There are few natural drainage courses that leave the city, limiting our ability to address these flooding areas without interagency coordination.*

Floodplain Regulations Link: https://www.codepublishing.com/WA/Edgewood/#!/Edgewood14/Edgewood1480.html#14.80

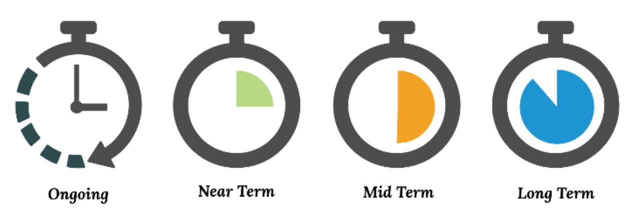
Sub Planning Area: White River and the Hylebos Basin

Flood Projects

Project Description	Location	Type of Flooding	Potential Solution	Estimated Cost	1. Existing land use of affected area	2. Severity of potential flood or channel migration	3. Area of impact	4. Frequency of flood or channel migration occurrence impact	5. Project Effectiveness	6. Phasing and Sequencing of Projects	7. Multiple Projects benefits	8. Partnerships and Opportunity	9. Best Management Practices	Total
Ponding water with reverse slope ditch across private property Severity - Overtops roadway	9100 block 34th St E	Urban	Install new piped conveyance in ROW	$150,000	5	3	1	10	11	3	4	3	5	45
Shallow ditch Severity - Overtops roadway at intersection	127th Ave E @ 48th St. E	Urban	Install new piped conveyance in ROW	$150,000	7	3	2	10	12	5	6	3	5	53
Ponding water with no outlet	112th Ave E @ 24th St. E	Urban	Install new piped conveyance in ROW	$150,000	7	4	3	10	12	5	6	5	5	57
Failing drywell system with no outlet	13100 block 56th E	Urban	Install new piped conveyance in ROW, improve downstream system into Sumner	$500,000	6	6	2	10	12	5	6	8	5	60

Flood Problems		
Problem Description	**Location**	**Type of Flooding**
Pothole Drainage Basins	Edgewood potholes	Urban
Valley Floor High Groundwater during wet season	Wapato/Simons Creek	Groundwater/Urban

City Programmatic Recommendations				
Timeline	**Action**	**Lead Department**	**Partners**	**Progress**
	Study and develop flood reductions plans for each of the city's pothole basins.	City of Edgewood	N/A	
	Begin to Coordinate efforts for surface water management conveyance, as needed following flood reduction plan development. Develop a workgroup	City of Edgewood	Sumner, Fife, Puyallup, Pierce County, Milton	
	Develop a workgroup to discuss Countyline Road flooding issue from Unincorporated King County	City of Edgewood	King County	



Jurisdiction Name: City of Fife

Problem Statement: *Almost all of Fife's 3,730 acres lies below 20 feet mean sea level except for a small portion east of Hylebos Creek. Thus, Fife acts as a basin to which many of the surrounding communities discharge stormwater. As such, the city experiences urban and riverine flooding on a regular basis. Commercial, residential, and industrial districts all experience the impact of this flooding.*

Floodplain Regulations Link: https://www.codepublishing.com/WA/Fife/#!/Fife15/Fife1540.html#15.40

Sub Planning Area: Hylebos and Mid Puyallup Basin

Flood Projects

Project Description	Location	Type of Flooding	Potential Solution	Estimated Cost	1. Existing land use of affected area	2. Severity of potential flood or channel migration	3. Area of impact	4. Frequency of flood or channel migration occurrence impact	5. Project Effectiveness	6. Phasing and Sequencing of Projects	7. Multiple Projects benefits	8. Partnerships and Opportunity	9. Best Management Practices	Total
Residential yard flooding along Wapato Creek	Circle Drive E. David Ct. E.	Riverine	Analysis, design and construction of Additional inlets pipes, and other drainage features to increase drainage, as called out in 2021-2026 - CIP project 2.	$400,000	6	4	6	9	7	3	4	1	4	44
City Center Flooding	Fife Ditch @ 15th St	Urban	Upsizing Culverts	$250,000	5	5	3	8	10	5	2	3	4	45
City Center Flooding	Fife Ditch @ 12th St	Urban	Upsizing Culverts	$300,000	5	4	3	8	10	5	2	3	4	44

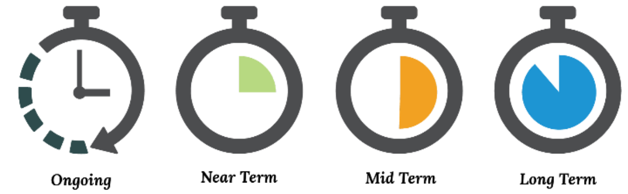
Flood Problems

Problem Description	Location	Type of Flooding
A lack of clarity in floodplain elevations and mapping. The 2017 regulated flood plain placed most of Fife in a "seclusion area" noting the uncertainty in flood elevations based on the certification status of the Puyallup River levees.	Lower Puyallup River	Riverine
Flood levels nearly resulted in levee overtopping downstream of Freeman Road in 1996 (within 2-3 inches) and 2009 (within 2 feet); there has been sloughing of soil and vegetation below the road.	Puyallup River, Downstream from Freeman Rd E	Riverine
Flood levels nearly resulted in levee overtopping near 54th Ave E. in 2006 and 2009 (within 2 feet of overtopping)	Puyallup River, At intersection with 54th Ave E.	Riverine

High river levels, and/or beaver activity do not allow for the oxbow to drain to the river, this is threatening a sewer lift station.	5500 blk of Levee Red E. Puyallup River	Riverine
Flooding of commercial properties along Fife Ditch. Starting at Sportco going downstream, under interstate 5, to fallout into Hylebos.	20th St E/Alexander, North to the outfall to Hylebos Creek.	Riverine
Humbs and bumps in N Levee Road.	Entire length of Levee Rd in Fife.	Riverine
Entire system of Fife Ditch is controlled at Hylebos. (3 pumps 2 tide gates) In need of maintenance and retrofitting/upgrades.		Urban
Culvert undersized and causes back up	Crossing at 4th St E	Urban
Ditch back up due to routine build up in storm pipes.	55th Ave / 2nd St & 57th Ave E	Urban
Flooding out of ditch an on to ROW.	8th St E, west of 54th.	Urban
Yard and ROW flooding. No constructed storm system in Willow neighborhood.	Willows Neighborhood.	Urban
Localized flooding due to development that blocked storm systems from entering the Erdahl Ditch system.	1301 26th Ave E	Urban
Homeless activity in the Erdahl ditch area may impact flows.	From Pacific Highway out to Puget Sound.	Urban
Oxbow Flooding /Sewer Lift Station Protection (RB RM 5.0 and backwater area)	5620 Radiance Blvd	Urban
Flooding along northside of UPRR railroad, in Dacca dog park, homes off 27th St E and business park off frank albert.	Erdahl Ditch parallel to Railroad tracks.	Urban
Flooding across Frank Albert Parkway ROW. First time in 2022.	Frank Albert, south of railroad tracks.	Urban
Major Parking lot flooding	4700 - 4800 block 20th St E	Urban
St Martins of Tours Church yard and parking lot flooding.	2301 Valley	Urban
Flooding across Freeman Rd E.	4600 Freeman Rd E	Urban

City Programmatic Recommendations

Timeline	Action	Lead Department	Partners	Progress
	Coordinate with Drainage District 23 to address deficiencies and develop a pathways approach moving forward.	City Fife PW	Pierce County Surface Water Management	
	Address "seclusion area" in the lower Puyallup watershed.	Pierce County Surface Water Management	City of Puyallup ~~and~~ City of Fife, and Pierce County.	
	Create working group to discuss North Levee Rd setback	Pierce County Surface Water Management	City of Puyallup and City of Fife.	
	Coordinate with Tacoma regrading Fife Ditch @ 4th st E.	City of Fife PW	City of Tacoma	


Ongoing
Near Term
Mid Term
Long Term

Jurisdiction Name: City of Fircrest

Problem Statement: *Urban flooding affects the City of Fircrest city wide causing widespread roadway flooding.*

Floodplain Regulations Link: https://www.codepublishing.com/WA/Fircrest/#!/Fircrest22/Fircrest2299.html#22.99

Sub Planning Area: Chambers/ Clover Basin

Flood Problems		
Problem Description	**Location**	**Type of Flooding**
Increased sediment and organic debris in MS4	City Wide	Urban
Heavy rainfall in relation to amount of impervious surface impacting the headwaters of Leach Creek	City Wide	Urban
Urban flooding	1200,1300, and 1400 blocks Drake St/Head waters of Leach Creek	Urban

Jurisdiction Name: City of Gig Harbor

Problem Statement: *Gig Harbor is fortunate to have a lot of topographic relief and miles of marine waterfront that generally allow for great drainage. However, the city currently experiences minor urban flooding due to stormwater runoff and coastal flooding during periods of king tides.*

Floodplain Regulations Link: https://www.codepublishing.com/WA/GigHarbor/#!/GigHarbor18/GigHarbor1810.html#18.10

Sub Planning Area: Gig Harbor Basin

Flood Projects

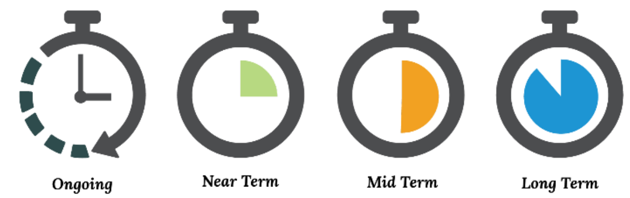
Project Description	Location	Type of Flooding	Potential Solution	Estimated Cost	1. Existing land use of affected area	2. Severity of potential flood or channel migration	3. Area of impact	4. Frequency of flood or channel migration occurrence impact	5. Project Effectiveness	6. Phasing and Sequencing of Projects	7. Multiple Projects benefits	8. Partnerships and Opportunity	9. Best Management Practices	Total
Burnham Dr at 96th Ave	Burnham Dr & 96th Ave	Urban		$2,290,000	7	5	4	10	12	5	10	9	2	64
Sewer Lift Station #5	2823 Harborview Drive	Coastal		$2,900,000	8	7	8	5	11	3	8	5	2	57

Flood Problems

Problem Description	Location	Type of Flooding
38th Ave flooding	4300 block of 38th Ave	Urban
Lighthouse coastal flooding	Mouth of Gig Harbor Bay	Coastal
Skanskie park flooding	3207 Harborview Drive	Coastal
Austin Park	4009 Harborview Drive	Coastal

City Programmatic Recommendations

Timeline	Action	Lead Department	Partners	Progress
	Work with Pierce County to address the 38th Ave flooding issue.	Gig Harbor	Pierce County	



Jurisdiction Name: City of Lakewood

Problem Statement: Clover Creek overflows during large events

Floodplain Regulations Link: https://lakewood.municipal.codes/LMC/14

Sub Planning Area: Chambers/Clover Basin

Flood Projects

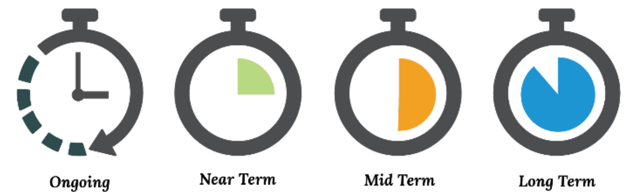
Project Description	Location	Type of Flooding	Potential Solution	Estimated Cost	1. Existing land use of affected area	2. Severity of potential flood or channel migration	3. Area of impact	4. Frequency of flood or channel migration occurrence impact	5. Project Effectiveness	6. Phasing and Sequencing of Projects	7. Multiple Projects benefits	8. Partnerships and Opportunity	9. Best Management Practices	Total
Clover Creek overflows during large events (Construction)	Clover Creek between JBLM and just west of Sound Transit RR.	Riverine	Construct setback levee along Clover Creek between City limits and Bridgeport Way SW and spot improvements downstream to Steilacoom Lake to prevent localized flooding outside of the main floodplain.	Final recommended solution will be in the millions	9	9	10	7	7	3	18	0	3	66

Flood Problems

Problem Description	Location	Type of Flooding
Clover Creek overflows during large events (Analysis)	Clover Creek between JBLM and just west of Sound Transit RR.	Riverine

City Programmatic Recommendations

Timeline	Action	Lead Department	Partners	Progress
	Clover Creek Flooding Engineering Alternatives Analysis workgroup	City of Lakewood	WSDOT, Dept of Ecology, Dept of Fish and Wildlife, Sound Transit, Pierce Transit, Nisqually Tribe of Indians, Puyallup Tribe of Indians, JBLM, Pierce County SWM, Pierce County FCZD	
	Construct setback levee along Clover Creek between City limits and Bridgeport Way SW and spot improvements downstream to Steilacoom Lake to prevent localized flooding outside of the main floodplain.	City of Lakewood	WSDOT, Dept of Ecology, Dept of Fish and Wildlife, Sound Transit, Pierce Transit, Nisqually Tribe of Indians, Puyallup Tribe of Indians, JBLM, Pierce County SWM, Pierce County FCZD	



Jurisdiction Name: City of Milton

Problem Statement: The City of Milton is experiencing severe climate change impacts on its aging infrastructure that is causing major urban flooding issues.

Floodplain Regulations Link: https://www.codepublishing.com/WA/Milton/#!/Milton15/Milton1520.html#15.20.220

Sub Planning Area: Hylebos Basin

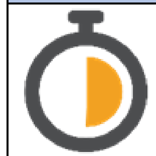
Flood Projects

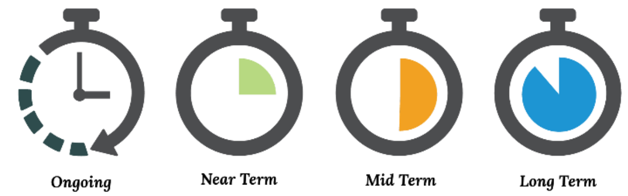
Project Description	Location	Type of Flooding	Potential Solution	Estimated Cost	1. Existing land use of affected area	2. Severity of potential flood or channel migration	3. Area of impact	4. Frequency of flood or channel migration occurrence impact	5. Project Effectiveness	6. Phasing and Sequencing of Projects	7. Multiple Projects benefits	8. Partnerships and Opportunity	9. Best Management Practices	Total
Culvert gets plugged creating water over the road which floods into people's driveways.	910 70th Ave	Urban	Put in a Type 2 Catch basin	$27,000	8	8	2	10	6	5	5	5	1	50
5th Ave Hylebos culvert	5th Ave	Urban	Install a large box culvert and one foot diameter pipe		10	8	7	10	9	5	10	9	1	69

Flood Problems

Problem Description	Location	Type of Flooding
Flooding in the backyards of property owners	10th Ave Taylor St/Porter Way	Urban
Pipes/ditches are not big enough; they can't keep up with heavy rain.	11th Ave/Milton Way	Urban
Debris issues at the Pond which is causing the pipes to get plugged which is causing the pond to overflow.	82 26th Ave Ct	Urban
Catch basin flooding issue	Pacific Highway (Federal Way and Fife)	Urban

City Programmatic Recommendations

Timeline	Action	Lead Department	Partners	Progress
	Address the catch basin flooding issue on Pacific Highway	City of Milton	WSDOT, Federal Way, Fife, Pierce Transit, Sound Transit	



Jurisdiction Name: City of Orting

Problem Statement: Many of the City of Orting Problems with Riverine Flooding are under the control of other jurisdictions. Partnering is the City's goal in reaching solutions and a pathway to completing in the future.

Floodplain Regulations Link: https://codelibrary.amlegal.com/codes/ortingwa/latest/orting_wa/0-0-0-8730

Sub Planning Area: Mid Puyallup Basin

Flood Projects

Project Description	Location	Type of Flooding	Potential Solution	Estimated Cost	1. Existing land use of affected area	2. Severity of potential flood or channel migration	3. Area of impact	4. Frequency of flood or channel migration occurrence impact	5. Project Effectiveness	6. Phasing and Sequencing of Projects	7. Multiple Projects benefits	8. Partnerships and Opportunity	9. Best Management Practices	Total
Backwater from the Carbon River during high flows causes Voight Creek and Coplar Creek to flow laterally along the riparian zone outside of the Carbon River left bank levee resulting in flooding down Corrin Ave. NW and SR162. This results in water over roads and flooding of some homes, including crawl spaces and some finished floors.	Carbon River DS 3.9 RMP UP 4.0 RMP Left Bank.	Riverine	Possible solutions include upsizing of a 36" concrete culvert carrying creek flows to the Carbon River at approx. RM 3.9 and construction of a cut-off berm to divert flows back into the Carbon River and prevent excess flows from flowing down Corrin Ave. NW	To be determined in 2023	8	8	5	7	12	3	21	0	0	64
City of Orting has identified 61 different gravel bars along the city boundary	Upper Puyallup River DS 19.4 RMP UP 22 RMP	Riverine	Gravel bar scalping would temporarily increase the flood carrying capacity of the river channel through this reach. Suggestions are letter the river re-take more room to naturally flow back to historic locations. RMP 21.3	To be determined in 2023	10	6	5	7	5	1	18	0	0	52
Calistoga Storm Water Project	Carbon River (well 1)	Urban	Upsizing the stormwater piping	$1.6 million	6	5	5	7	11	5	2	8	0	49
Water infiltration into sewer lines creating flooding issues inside the treatment plant	Old town Orting	Groundwater	Rehabilitation of Existing sewer lines	$5-10 million	8	9	7	8	9	1	4	7	0	53

Flood Problems

Problem Description	Location	Type of Flooding
Flooding in the City of Orting occurs when water from the State and the County fields flows into open ditches on 178th, Noble L~~l~~ane, and Orville Road. The flooding occurs because there is a choke~~ck~~ point by well house #1 (178th and Hwy 162). Water flows from the County and State ditches into the city's pond behind the well house #1. Water exits from the pond and flows through a 12" diameter pipe for approximately 350 feet. After 350 feet the pipe increases in size to 24". This chock point backs up the water causing it to flow along state highway 162 into the senior mobile home park of Mountain View Estates. This water flows into the Mountain view estates pond which only has a 12" outfall pipe causing the water to backup into other areas of the City. Water on highway 162 becomes a safety problem as drivers can't identify the fog line nor when you can see the ditches.	Crossing at ~~hwy~~ Hwy 162 and 178th ~~ave~~ Ave east Orting WA 98360 is the first cho~~c~~ke point.	Urban
Address the sediment issues along the Carbon and Puyallup Rivers	Carbon and Puyallup Rivers	Riverine

City Programmatic Recommendations

Timeline	Action	Lead Department	Partners	Progress
~~Mid Term~~	Continue to work with Pierce County to develop and construct the Jones Levee	Pierce County	City Orting, USACE	
~~Mid Term~~	Form a workgroup to solve localized urban flooding in the community	City of Orting	Pierce County, WSDOT	
~~Mid Term~~	Develop a plan to upsize the river outfalls in Orting	City of Orting	Pierce County, USACE	
~~Mid Term~~	Form a sediment workgroup to address the sediment issues along the Carbon and Puyallup Rivers	City of Orting	Pierce County, City of Sumner, FEMA, USACE, Tribes	

Ongoing Near Term Mid Term Long Term

Jurisdiction Name: City of Pacific

Problem Statement: ***The City of Pacific has major flooding issues due to the sediment issues in the White River***

Floodplain Regulations Link: ***https://www.codepublishing.com/WA/Pacific/#!/Pacific01/Pacific01.html***

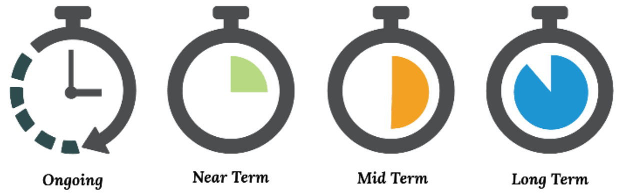
Sub Planning Area: White River Basin

Flood Problems

Problem Description	Location	Type of Flooding
White River sediment buildup	Between BNSF tracks and Stewart Road bridge	Riverine
Milwaukee (Soatin) Creek flooding	North of Stewart Road (adjacent to SR 167)	Riverine
Government Canal	Next to Union Pacific railroad tracks/ south of County line	Riverine

City Programmatic Recommendations

Timeline	Action	Lead Department	Partners	Progress
	Develop a working group to discuss how to address the sediment buildup on the White River	King County	Pierce County and City of Pacific	
	Flood Analysis on Milwaukee Creek is needed to address the flooding and drainage issues in the area	City of Pacific	King County	



Jurisdiction Name: City of Puyallup

Problem Statement: *The City of Puyallup experiences urban flooding on roadways located on the valley floor that are in low areas which drain to Puyallup River, Deer Creek, and Clarks Creek. The primary cause is backwater from river or creek flooding or urban drainage not being able to exit freely because of high water is the receiving river or creeks.*

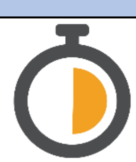
Floodplain Regulations Link: https://www.codepublishing.com/WA/Puyallup/#!/Puyallup21/Puyallup2107.html#21.07

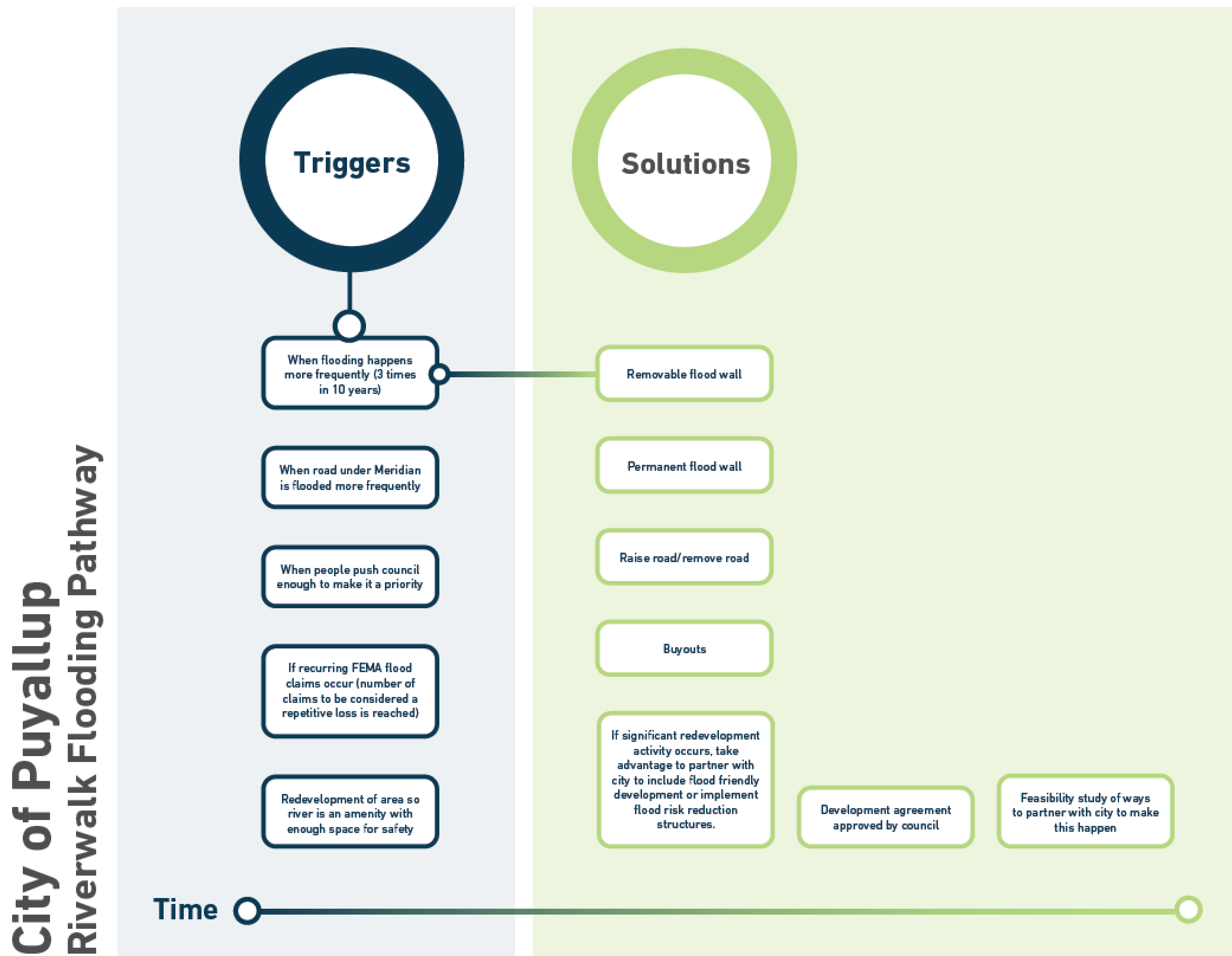
Sub Planning Area: Clear/Clarks, Middle Puyallup/ and Hylebos Basins

Flood Projects

Project Description	Location	Type of Flooding	Potential Solution	Estimated Cost	1. Existing land use of affected area	2. Severity of potential flood or channel migration	3. Area of impact	4. Frequency of flood or channel migration occurrence impact	5. Project Effectiveness	6. Phasing and Sequencing of Projects	7. Multiple Projects benefits	8. Partnerships and Opportunity	9. Best Management Practices	Total
Flooding of commercial/industrial properties on Deer Creek (project) East Main Deer Creek Culvert Crossing	Upstream of confluence with Puyallup River to point of Deer Cr. Crossing under BNSF	Riverine	Severity of flooding needs to be better understood and detail the cost of flood damage. Work with property owners to come up with individual solutions which could include flood proofing or evacuation plans.	$3,053,341.03	7	4	5	8	7	3	12	4	2	52
Linden Golf Course Oxbow Setback Levee	Lower Puyallup River (LB RM 9.6 -RM 10.5)	Riverine	Preliminary design for Levee setback, trail realignment, habitat restoration, erosion protection, landfill removal and floodplain modifications.	$58,263,994.14	8	7	8	7	10	1	18	4	2	65
Deer Creek Emergency Culvert Replacement	27th Street SE and the intersection of 12th Ave SE and 25th Street SE	Riverine	By replacing 4 fish barriers and undersized culverts, realigning Deer Creek along 27th, reconnecting floodplain to stream channels and providing wetland mitigation	$8,610,573.00	6	9	3	10	8	3	14	6	2	61
4th Ave SW Storm Replacement (Phase N-1)	This phase begins at 5th St NW form 3rd Ave NW and continues north for approximately 3,134 LF and ends just north of River Rd.	Urban	A new mainline will be installed rerouting flows form the existing 4th Ave SW storm line north the Puyallup River.	$11,252,000	6	6	6	8	9	5	10	9	2	61

Flood Problems		
Problem Description	**Location**	**Type of Flooding**
Potential Overtopping or Breaching of N. Levee Road	West of SR 161/167 river crossing	Riverine
Flooding of commercial properties and parking lot	north of East Main Ave and east of SR 512 crossing	Riverine
Flooding of area of old landfill, left bank Puyallup	Just downstream of confluence with the White River	Riverine
Potential erosion of left bank of Puyallup river	Just upstream of BNSF/Traffic Ave crossing.	Riverine
Tiffany's Skate Inn/Riverwalk Floodwall	Lower Puyallup river (RB RM 8.1 - RM 8.6)	Riverine
Puyallup Executive Park “Flash Cube building”	Lower Puyallup River (LB RM 9.1 - RM 9.25)	Riverine
4th Ave SW Storm Replacement (Phase N-2)	This phase begins at the intersection of 4th Ave SW and 5th St SW and continues north for 1,403 LF along 5th St SW until 3rd Ave NW.	Urban
5th Ave SW Storm Replacement (Phase N-3)	This phase begins at the intersection of 4th Ave SW and 5th St SW and continues north 1,724 LF along 4th Ave SW until 2nd St SE.	Urban
6th Ave SW Storm Replacement (Phase N-4)	This phase begins at the intersection of 4th Ave SW and 2nd St SE and continues for 905 LF along 4th Ave SW until 5th St SE. A reach of pipe replacement included in this phase extends from 4th Ave SE to the north along 3rd St SE for 412 LF	Urban
7th Ave SW Storm Replacement (Phase N-5)	This phase begins at 6th St SW and continues along W Stewart Street for 1,484 LF until 2nd St NW.	Urban
Wapato Creek Diversion Repair	Diversion Extends from just north of Valley Ave S to the Puyallup River crossing under N Meridian	Riverine
Flooding on E Pioneer	25th St SE to Shaw Rd E and E Pioneer S Curves on eastern city limits	Urban
Sam Peach Park Flooding	16th St NW and 10th Ave NW: 18th St NW and 10th Ave NW	Urban
12th Ave SW Stormwater Improvements	W Main to 4th Ave SW	Urban
Riverwalk Levee (left bank), Linden Golf Course Side	Lower Puyallup River (LB RM 9.6 – RM 10.5)	Riverine

City Programmatic Recommendations				
Timeline	**Action**	**Lead Department**	**Partners**	**Progress**
	Develop a regional work group to address the overtopping or breaching of N. Levee Road	TBD	Pierce County, City Fife, Port of Tacoma, City of Puyallup, WSDOT	


City of Puyallup
Riverwalk Flooding Pathway
Triggers
Solutions
When flooding happens more frequently (3 times in 10 years)
When road under Meridian is flooded more frequently
When people push council enough to make it a priority
If recurring FEMA flood claims occur (number of claims to be considered a repetitive loss is reached)
Redevelopment of area so river is an amenity with enough space for safety
Removable flood wall
Permanent flood wall
Raise road/remove road
Buyouts
If significant redevelopment activity occurs, take advantage to partner with city to include flood friendly development or implement flood risk reduction structures.
Development agreement approved by council
Feasibility study of ways to partner with city to make this happen
Time

Jurisdiction Name: City of Sumner

Problem Statement: *Sumner is bordered by both the Puyallup and White River. Each river floods affecting land uses ranging from light industrial to residential.*

Floodplain Regulations Link: **https://www.codepublishing.com/WA/Sumner/#!/html/Sumner15/Sumner1552.html**

Sub Planning Area: White River and Mid Puyallup Basins

Flood Projects

Project Description	Location	Type of Flooding	Potential Solution	Estimated Cost	1. Existing land use of affected area	2. Severity of potential flood or channel migration	3. Area of impact	4. Frequency of flood or channel migration occurrence impact	5. Project Effectiveness	6. Phasing and Sequencing of Projects	7. Multiple Projects benefits	8. Partnerships and Opportunity	9. Best Management Practices	Total
Lower White River Flood Protection -Left Bank 24th Setback	White River (RM 1.8-4.2)	Riverine	170+ Acre floodplain restoration creating in-stream salmon habitat and floodwater storage. Relocation of water, sewer, gas, and power utilities from within flood area.	$76,000,000	9	7	9	9	10	5	18	13	5	85
Lower White River Flood Protection-Sumner Pointbar	White River (RM 3.9-4.5)	Riverine	Floodplain property acquisition, 25+ Acres of Floodplain reconnection, installation of flood wall eliminating flow path from river to MIC	$59,000,000	9	8	9	9	10	3	18	13	5	84
Lower White River Flood Protection -Stewart Setback	White River (RM 4.4-4.9)	Riverine	Floodplain property acquisition, 10+ Acres of Floodplain reconnection, installation of flood wall eliminating flow path from river to MIC	.	9	8	9	9	10	3	18	13	5	84
Lower White River Flood Protection -Stewart Road Bridge	White River (RM 5.0)	Riverine	Widening of Stewart Road Bridge, reducing risk of large woody debris backup causing upstream flooding by reducing number of piers within river.	$29,000,000	10	9	7	9	10	5	16	13	5	84
Salmon Creek Undersized culverts	Salmon Creek	Urban	Salmon Creek Culvert Replacements	$3,259,000	5	4	5	9	8	3	14	7	5	60

Flood Problems

Problem Description	Location	Type of Flooding
Sumner Commercial Setback Levee (right bank side)	Lower White River (right bank)	Riverine
Sumner Wastewater Treatment Plant access road flooding	State St. Flood wall or Emergency Access (LB RM 0.2 - RM 0.3)	Riverine

City Programmatic Recommendations

Timeline	Action	Lead Department	Partners	Progress
	Collaborate with Pierce County to address the flooding in Rainier Manor	Pierce County	City of Sumner	

Jurisdiction Name: City of Tacoma

Problem Statement: *The City of Tacoma aims to minimize flooding to protect life and properties.*

Floodplain Regulations Link: https://www.cityoftacoma.org/UserFiles/Servers/Server_6/File/cms/cityclerk/Files/MunicipalCode/Title13-LandUseRegulatoryCode.pdf

Sub Planning area: Clear/Clarks, Hylebos, -and Chambers/Clover Basins

Flood Projects

Project Description	Location	Type of Flooding	Potential Solution	Estimated Cost	1. Existing land use of affected area	2. Severity of potential flood or channel migration	3. Area of impact	4. Frequency of flood or channel migration occurrence impact	5. Project Effectiveness	6. Phasing and Sequencing of Projects	7. Multiple Projects benefits	8. Partnerships and Opportunity	9. Best Management Practices	Total
Leach Creek Flooding	Leach Creek	Riverine	Channel reconfiguration within the Holding Basin to expand pump operation and to function better at removing peak flows that can cause Leach Creek Flooding	$4,500,000	8	7	4	8	6	5	5	6	1	50
South Tacoma Way flooding part 1	Pacific Ave and South Tacoma Way	Urban	Add new pipe and realignment of some stormwater flows to oldest pipes.	$31,000,000	10	10	7	10	11	5	2	6	1	62
South Tacoma Way flooding part 2	Pacific Ave and 21st to 15th street	Urban	Add new pipe and outfall. realignment of stormwater flows to new outfall.	$26,000,000	10	10	7	10	11	5	2	7	1	63
Commencement Bay Resilience & Restoration Master Plan (phase 1)	Commencement Bay	Coastal	Master Plan will address Commencement Bay Coastal flooding issues	$750,000	10	6	5	10	7	5	12	7	1	63
Stability slope issue on 5-mile Drive	5 miles Drive Tacoma	Coastal	Redesign of roadway & repaving	$2,000,000	7	6	3	7	6	3	7	9	1	49
Ruston Way shoreline condition assessment & preliminary design	North Tacoma slopes	Coastal	Conduct a condition assessment for shoreline protection against sea level rise	$1,000,000	10	8	7	9	8	1	15	10	1	69

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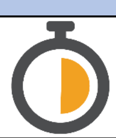
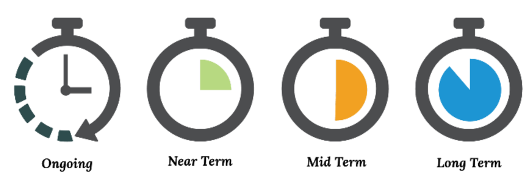
Flood Problems		
Problem Description	**Location**	**Type of Flooding**
Leach Creek Flooding	Leach Creek	Riverine
Flett Creek flooding (Stormwater Feasibility study)	Flett Creek	Riverine
Flett Creek flooding Construction	Flett Creek	Coastal
Treatment Plant flooding related to surrounding outfall	Tacoma Wastewater Treatment plant	Riverine
Bullfrog Junction flooding	Bay Street, North side of I-5 at Puyallup River, Rail interchange yard, RR and Tribal owned Properties, Tacoma ROW along Puyallup River down to Central Wastewater Treatment Plant	Riverine
Stormwater drainage issues throughout the city	Throughout the city of Tacoma	Urban
Stability Slope issue on 5-mile drive	5-mile drive	Coastal

City Programmatic Recommendations				
Timeline	**Action**	**Lead Department**	**Partners**	**Progress**
	Hire a consultant to address the Stormwater drainage issues throughout the city	City of Tacoma		



Jurisdiction Name: City of University Place

Problem Statement: *Since incorporation in 1995 the city has made vast improvements to the storm drainage system. Despite improvements and ongoing maintenance, a few areas remain where urban and coastal flooding occurs during infrequent events.*

Floodplain Regulations Link: https://www.codepublishing.com/WA/UniversityPlace/#!/UniversityPlace14/UniversityPlace1415.html

Sub Planning area: Chambers/Clover Basin

Flood Projects

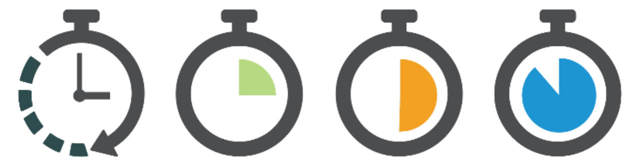
Project Description	Location	Type of Flooding	Potential Solution	Estimated Cost	1. Existing land use of affected area	2. Severity of potential flood or channel migration	3. Area of impact	4. Frequency of flood or channel migration occurrence impact	5. Project Effectiveness	6. Phasing and Sequencing of Projects	7. Multiple Projects benefits	8. Partnerships and Opportunity	9. Best Management Practices	Total
Olympic/Brookside urban flooding	Olympic and Brookside Road	Urban	Upsize conveyance pipping, provide additional detention, improve debris barriers to prevent blocking in the system.	$2,000,000	6	6	2	10	8	5	6	2	1	46

Flood Problems

Problem Description	Location	Type of Flooding
High Tide issue	Sunset Beach	Coastal
UP Shoreline Sewer Pump Station	Beach Rd	Urban
Shoreline Coastal flooding	South side of Day Island on Day Island Blvd W.	Coastal
Danbridge Development flooding	Olympic and Brookside Road	Urban
Minor street flooding	Lakewood Drive and 64th street	Urban

City Programmatic Recommendations

Timeline	Action	Lead Department	Partners	Progress
	Work with Pierce County to address the UP Shoreline Sewer Pump Station issue	Pierce County	City of University Place; FEMA	



Jurisdiction Name: Town of South Prairie

Problem Statement: *The South Prairie Creek floods several times a year cutting off South Prairie by closing SR 162 (WSDOT) and South Prairie Road (Pierce County) and flooding several neighborhoods plus the Fire station, the community rallying location. The Town's only sewer outfall is directly threatened by erosion caused by regular flooding with loss of bank happening at an escalating rate. If the Town loses the outfall, it will lose all sewage treatment capacity until the outfall can be rebuilt.*

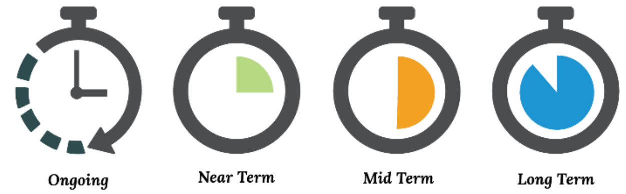
Floodplain Regulations Link: https://southprairie.municipal.codes/SPMC/15.16

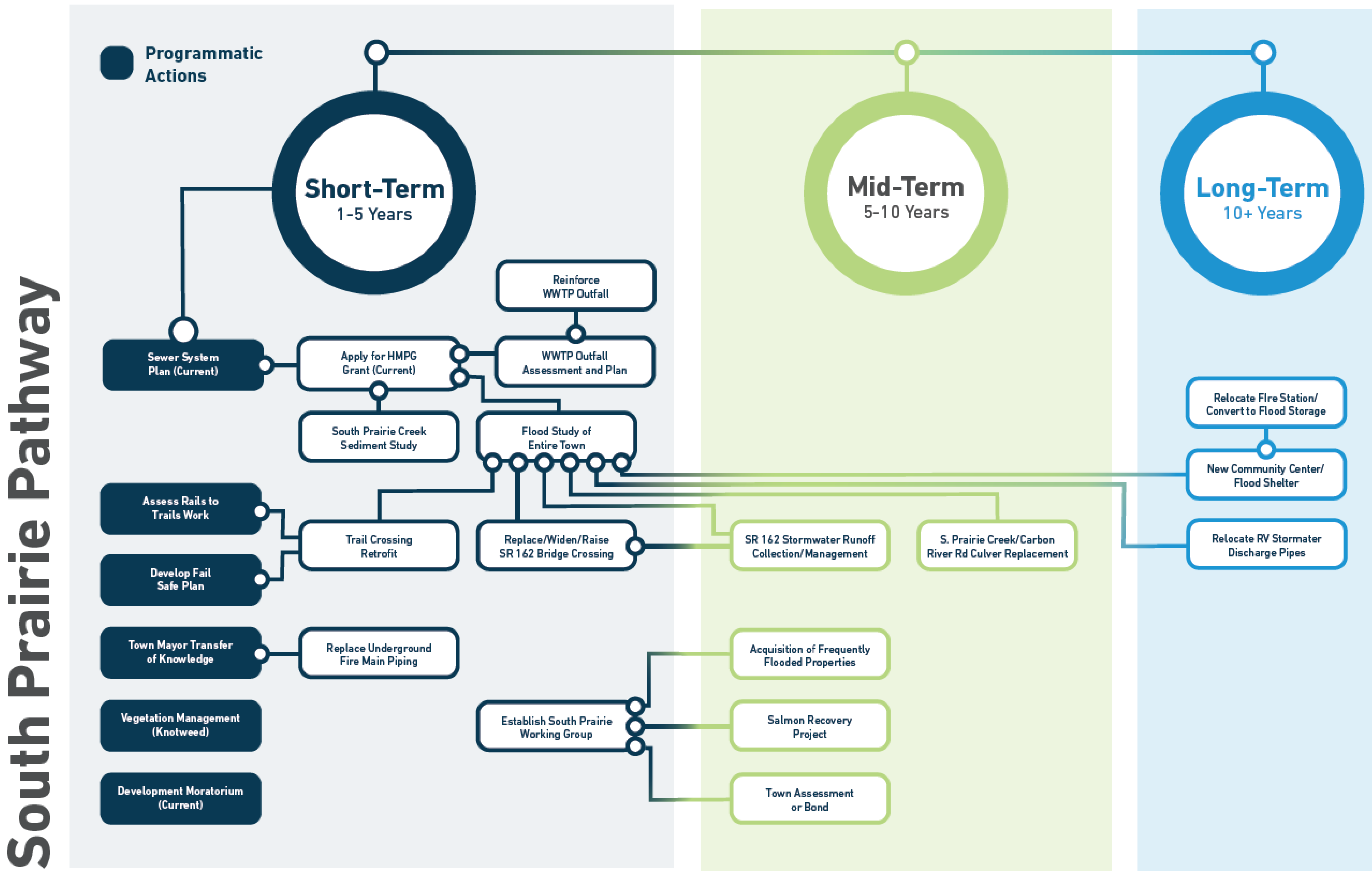
Sub Planning Area: Upper Puyallup Basin

Flood Problems		
Problem Description	**Location**	**Type of Flooding**
Flooding of South Prairie Creek	At Foothills Trail	Riverine
Flooding of South Prairie Creek	At Wastewater Treatment Outfall	Riverine
Flooding of South Prairie Creek	At Fire Station and SR 162	Riverine
Flooding of South Prairie Creek	At South Prairie Road	Riverine
Flooding of South Prairie Creek	Pioneer Neighborhood	Riverine
South Prairie Floodplain Acquisitions	South Prairie Creek RB RM1.6 - RM 3.5	Riverine
South Prairie Fire Station Flood Protection		Riverine

City Programmatic Recommendations				
Timeline	**Action**	**Lead Department**	**Partners**	**Progress**
	Develop an invasive species management plan	Town of South Prairie	Pierce Conservation District	
	Conduct a Flood Study for the Town of South Prairie	Pierce County	Town of South Prairie; WSDOT	
	Conduct a Wastewater Treatment Outfall Assessment	Pierce County	Pierce County, Department of Ecology, and the Tribes	

	Establish a South Prairie Working Group to address flooding in the town	Town of South Prairie	Pierce County, Tribes, Washington State Department of Ecology, USACE	
	Conduct a sediment study for South Prairie Creek	Pierce County	Town of South Prairie	




South Prairie Pathway
Programmatic Actions
Short-Term
1-5 Years
Mid-Term
5-10 Years
Long-Term
10+ Years
Sewer System Plan (Current)
Apply for HMPG Grant (Current)
Reinforce WWTP Outfall
WWTP Outfall Assessment and Plan
South Prairie Creek Sediment Study
Flood Study of Entire Town
Assess Rails to Trails Work
Develop Fail Safe Plan
Trail Crossing Retrofit
Replace/Widen/Raise SR 162 Bridge Crossing
SR 162 Stormwater Runoff Collection/Management
S. Prairie Creek/Carbon River Rd Culver Replacement
Relocate FIre Station/ Convert to Flood Storage
New Community Center/ Flood Shelter
Relocate RV Stormater Discharge Pipes
Town Mayor Transfer of Knowledge
Replace Underground Fire Main Piping
Vegetation Management (Knotweed)
Development Moratorium (Current)
Establish South Prairie Working Group
Acquisition of Frequently Flooded Properties
Salmon Recovery Project
Town Assessment or Bond

Jurisdiction Name: Town of Steilacoom

Problem Statement: *The Town of Steilacoom is a coastal community impacted by rising ocean levels and urban flooding issues.*

Floodplain Regulations Link: https://townofsteilacoom.org/274/Municipal-Code

Sub Planning Area: Chambers/Clover Basin

Flood Projects

Project Description	Location	Type of Flooding	Potential Solution	Estimated Cost	1. Existing land use of affected area	2. Severity of potential flood or channel migration	3. Area of impact	4. Frequency of flood or channel migration occurrence impact	5. Project Effectiveness	6. Phasing and Sequencing of Projects	7. Multiple Projects benefits	8. Partnerships and Opportunity	9. Best Management Practices	Total
Damage to seawall caused by high tides and rising waters. Other park improvements threatened and hazardous condition created.	Sunnyside Beach	Coastal	Portions of the Sunnyside Beach seawall were severely damaged in 2021. This project will repair/replace the seawall in order to prevent further damage to the park and other improvements.	$300,000	2	2	2	9	10	5	6	3	3	42

Flood Problems

Problem Description	Location	Type of Flooding
Urban flooding along Union Avenue due to large amounts of discharge from Farrell's Marsh during storm events or unplanned release of water held behind a beaver dam in Farrell's Marsh.	5th Street Waterway Union Avenue Culverts	Urban
Deteriorating culverts could potentially collapse leading to flooding.	Puyallup and Balch Streets.	Urban
Flooding during storm events at Roe and Lexington Streets caused by capacity deficiency.	Roe Street, Marietta Street, Lafayette Street, Cedar Street, Steilacoom Boulevard, unopened rights-of-way, Sunnyside Beach outfall.	Urban
Capacity deficiency on private property leading to flooding during storm events.	Stevens Street.	Urban

Capacity deficiency leading to flooding during storm events.	Farrell Drive	Urban
Capacity deficiency leading to flooding during storm events.	Marietta Place and Steilacoom Boulevard	Urban
Capacity deficiency leading to flooding during storm events.	Maple Lane	Urban
Capacity deficiency leading to flooding during storm events.	Saltars Point Elementary	Urban
Capacity deficiency leading to flooding during storm events.	Beech Avenue	Urban
Capacity deficiency leading to flooding during storm events.	Lafayette Street	Urban
Capacity deficiency leading to flooding during storm events.	Jackson Street ROW	Urban
Capacity deficiency leading to flooding during storm events.	2nd Street Culverts at Montgomery and Gove	Urban
Capacity deficiency leading to flooding during storm events.	Nisqually Street	Urban
Capacity deficiency leading to flooding during storm events.	3rd Street	Urban
Capacity deficiency leading to flooding during storm events.	Martin Street	Urban
Capacity deficiency leading to flooding during storm events.	Galloway, Lexington, and Worthington Street	Urban
Capacity deficiency leading to flooding during storm events.	5th Street Waterway between 5th Street and Union Avenue.	Urban

Jurisdiction Name: Town of Wilkeson

Problem Statement: The Town of Wilkeson has several areas deeply impacted by high waters. The last several years have been highlighted issues with the creek and our utility lines being exposed due to bank erosion and shifts in the waters path.

Floodplain Regulations Link: https://www.codepublishing.com/WA/Wilkeson/#!/Wilkeson19/Wilkeson1909.html

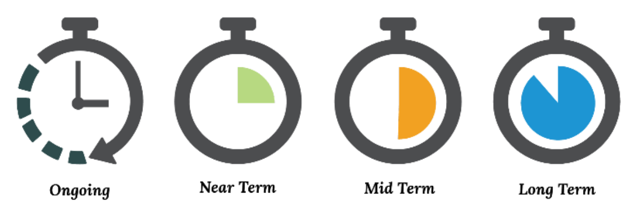
Sub Planning area: Upper Puyallup Basin

Flood Projects

Project Description	Location	Type of Flooding	Potential Solution	Estimated Cost	1. Existing land use of affected area	2. Severity of potential flood or channel migration	3. Area of impact	4. Frequency of flood or channel migration occurrence impact	5. Project Effectiveness	6. Phasing and Sequencing of Projects	7. Multiple Projects benefits	8. Partnerships and Opportunity	9. Best Management Practices	Total
Wilkeson Creek and Bridge Stabilization	Watershed/ End of town on Wilkeson creek (47.101083, -122.046454)	Riverine	The creek rerouted in the January 2022 Storm exposing the water mainline. This line travels from the storage tanks, under the creek at the exit to the watershed, into the town for distribution.	$75,000	10	8	8	9	11	5	10	11	0	72
Business District Storm Water Collection Extension	East of the Historic Business District	Urban	Add additional storm water connections to convey the water away from the residences and into a collection system.	$50,000	7	4	4	8	10	5	6	9	0	53

Flood Problems		
Problem Description	**Location**	**Type of Flooding**
Gall Property Retaining Wall Failure	Corner of Davis and Church St	Riverine
House on Fir	Southern Most Part of town	Riverine
School Yard Damage	Wilkeson Elementary	Riverine
Houses on Cothary- Continued Property loss	Cothary Street	Riverine
Railroad Ave House	Railroad Avenue	Riverine

City Programmatic Recommendations				
Timeline	**Action**	**Lead Department**	**Partners**	**Progress**
	Complete an updated Channel Migration Zone Study for Wilkeson Creek	Pierce County	Town of Wilkeson	



Jurisdiction Name: Unincorporated Pierce County

Problem Statement: Pierce County operates and maintains a continuous flood risk reduction infrastructure. Flooding is when areas are inundated beyond their typical or seasonal levels. Pierce County believes that it is best to avoid or accommodate for flooding wherever possible.

Floodplain Regulations Link: https://pierce.county.codes/PCC/18E.70

Sub Planning Area: Middle Puyallup Basin, White River Basin, Clear/Clarks Creek Basin

Flood Projects

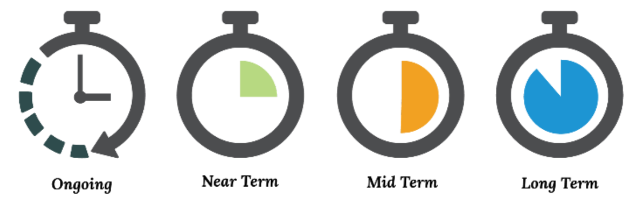
Project Description	Location	Type of Flooding	Potential Solution	Estimated Cost	1. Existing land use of affected area	2. Severity of potential flood or channel migration	3. Area of impact	4. Frequency of flood or channel migration occurrence impact	5. Project Effectiveness	6. Phasing and Sequencing of Projects	7. Multiple Projects benefits	8. Partnerships and Opportunity	9. Best Management Practices	Total
Jones Setback Levee	Upper Puyallup River RM 21.2-22.5 right bank upstream of Calistoga Bridge in Orting	Riverine	See Chapter 6 "recommended Capital projects"	$26.1 million	6	7	6	5	9	3	10	9	4	59
Rainier Manor/Riverwalk/Rivergrove and SR-410 Flood Wall and Levee	Middle Puyallup River RM 10.7 -12.0 right bank	Riverine	See Chapter 6 "recommended Capital projects"	$14.5 million	8	8	8	6	9	1	5	5	4	54
Alward Road Floodplain Acquisition and Setback Levee	Carbon River RM 6.4-8.4 left bank	Riverine	See Chapter 6 "recommended Capital projects"	$26.9 million	6	7	5	9	9	1	10	5	4	56
128th Street Corridor River Improvements	Middle Puyallup River RM 15.8 right bank and left bank and 17.4 right bank and left bank	Riverine	See Chapter 6 "recommended Capital projects"	$17.5 million	6	6	6	8	9	1	10	5	4	55
Orville Road Revetment at Kapowsin Creek	Upper Puyallup River RM 26.3-26.8 left bank	Riverine	See Chapter 6 "recommended Capital projects"	$8.4 million	7	6	5	7	7	4	7	8	3	54
Neadham Road Floodplain Reconnection	Upper Puyallup RM 25.3-27.0 right bank	Riverine	See Chapter 6 "recommended Capital projects"	$10.5 million	4	4	4	8	10	4	8	8	4	54
Carbon River Setback Levee LB Bridge Street to Upstream of Voights Creek	Carbon River RM 3.0-4.5 left bank	Riverine	See Chapter 6 "recommended Capital projects"	$19.6 million	7	6	6	5	7	1	9	5	3	49
Upper Carbon/Fairfax Rd Bank Stabilization	Carbon River RM 21.5-22.9 left bank	Riverine	See Chapter 6 "recommended Capital projects"	$5 million	6	5	1	7	7	2	8	5	3	44
Carbon River Floodplain Connection Right Bank	Carbon River RM 3.2-4.2 right bank	Riverine	See Chapter 6 "recommended Capital projects"	$4.1 million	4	2	2	3	4	3	6	7	3	34

White River Butte Pit Setback	Lower White River RM 4.8-5.5 right bank	Riverine	See Chapter 6 "recommended Capital projects"	$30.6 million	8	8	5	8	8	2	8	8	4	59
Puyallup River Ford Setback - Capital Maintenance	Upper Puyallup River RM 23.5-24.9 right bank	Riverine	See Chapter 6 "recommended Capital projects"	$2.3 million	7	6	6	8	8	4	4	7	3	53
Carbon River Setback Levee LB Upstream of Voights Creek to SR 162 Bridge	Carbon River RM 4.5-5.9 left bank	Riverine	See Chapter 6 "recommended Capital projects"	$25 million	6	5	4	4	5	2	6	3	3	38
White and Puyallup Rivers Confluence Property Acquisition	Lower Puyallup River RM 9.4 and 10.3 right bank, downstream of its confluence with White River	Riverine	See Chapter 6 "recommended Capital projects"	$3.0 million	5	2	1	1	7	4	7	4	4	35
Clear Creek Floodplain Reconnection project (RM 2.9, right bank, confluence of Clear Creek and Puyallup River)	Lower Puyallup River RM 2.9 right bank, confluence of Clear Creek and Puyallup river	Riverine	See Chapter 6 "recommended Capital projects"	$58.1 million	9	9	8	10	7	3	10	9	5	70

Flood Problems

Problem Description	Location	Type of Flooding
North Levee Road	Puyallup River right bank (RM 8.1-2.7)	Riverine
River Road Levee Floodwall	Puyallup River left bank (RM 3.0-7.2)	Riverine
Alward Rd Floodplain Acquisition from SR 162 bridge to fish ladder	Carbon River left bank (RM 5.9-6.4)	Riverine
Carbon Confluence Setback Levee	Carbon River left bank (RM 0 - RM 0.4)	Riverine
Bowman Hilton Mobile Home	Puyallup River left bank (RM 13.0-13.3)	Riverine
Riverside Dr. Setback Levee	Puyallup River right bank (RM 12.8-13.2)	Riverine
SR-507 Bridge Approach Protection/Bank Stabilization	Nisqually River left bank (RM 21.9)	Riverine
Kernahan Bridge Abutment Protection	Upper Nisqually river right bank (RM 61.7)	Riverine
Ashford/ Elbe Channel migration issue	Nisqually River	Riverine
Mid Nisqually flooding	Middle Nisqually river right bank (RM 25.6-30.3)	Riverine
McKenna Area Floodplain Acquisition	Nisqually river right bank (RM 21.6 - RM 22.0)	Riverine
Ski Park	Carbon river right bank (RM 5.9-7.0)	Riverine

Additional County Programmatic Recommendations				
Timeline	**Action**	**Lead Department**	**Partners**	**Progress**
	Develop a regional River Road working group (RM 3.0-8.1) to address long term improvements to the system	Pierce County Surface Water Management	City Fife, Port of Tacoma, City of Puyallup, Pierce County, WSDOT, Railroad, Puyallup Tribe of Indians, U. S Army Corps of Engineers	
	Develop a regional work group to address the overtopping or breaching of N. Levee Road	Pierce County Surface Water Management	City Fife, Port of Tacoma, City of Puyallup, Pierce County, WSDOT, Railroad, Puyallup Tribe of Indians, U. S Army Corps of Engineers	



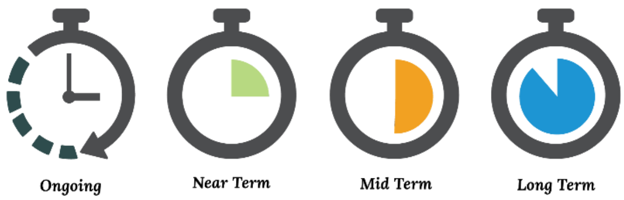
Appendix E

In June 2022, the cities and towns of Pierce County and staff representing unincorporated Pierce County, participated in two Disappearing Task Group meetings to develop Programmatic Recommendations that the cities/towns along with the County would work on together throughout the life of this flood plan. Programmatic recommendations are plans or procedures for dealing with some matter, e.g., regulations, policy guidelines, site design standards, operational policies and procedures, technical assistance, enforcement, and public outreach and educational programs. The below table lists the programmatic recommendations the cities and towns would like to accomplish over the next 10 years.

Programmatic Recommendations				
Timeline (Near Term completed within 2 years >; Mid Term Completed within a 2–6-year time frame. >>; Long Term within a 10-year time frame)	Action	Lead Department	Partners	Progress
	Work with other municipalities in Pierce County to gather additional information on grant opportunities and data collection (lidar etc.)	Pierce County Department of Emergency Management	All cities and towns in Pierce County	
	Develop a regulatory working group to develop consistent floodplain regulations. This workgroup would also work towards promoting a regional	Pierce County Planning and Land Services, Pierce County Surface Water Management, Pierce County Department of Emergency Management	All cities and towns in Pierce County, Transportation Coordination Committee, and the Growth Management	

	discussion about residual flood risks, developing consistent messaging, and would work towards all jurisdictions adopting best available data including existing CMZ maps and existing studies.		Coordinating Committee	
	Partner with the County annually on flood related emergency preparedness events and exercises.	Pierce County Department of Emergency Management	All cities and towns in Pierce County	
	Cities and towns should provide technical assistance and education to residents and businesses within frequently flooded areas on issues related to septic systems, source control, proper storage, isolation of hazardous materials, chemicals, wastes and other pollutants to prevent contamination of flood waters and to isolate them from exposure	Tacoma Pierce County Health Department	All cities and towns in Pierce County and their residents	

	Conduct Stormwater Modeling studies across City and County boundaries where mutually identified.	City of Lakewood	All cities and towns in Pierce County	
	Develop a workgroup to set baseline climate change projections for all jurisdictions in Pierce County to use.	Pierce County Surface Water Management, University of Washington Climate Impacts Group, City of Tacoma, Pierce County Department of Emergency Management	All cities and towns in Pierce County	
	Develop a workgroup to gather information from the cities and towns to identify flood prone areas (i.e. coastal, groundwater, urban, riverine flooding) that may be suitable for a home or road elevations, acquisition, or relocation.	Pierce County Department of Emergency Management	All cities and towns in Pierce County	
	Floodplain communities should explore the option of participating in the NFIP's Community Rating System (CRS) program to weigh the benefits of the program verses the cost and commitment.	Pierce County Surface Water Management	All cities and towns in Pierce County	

	Cities and the County should coordinate in the development of consistent coastal, urban, and groundwater outreach materials.	Pierce County Department of Emergency Management and Pierce County Surface Water Management	All cities and towns in Pierce County	
				

Throughout the summer of 2022, the cities and towns also created their own appendix for the flood plan. Each appendix includes the city or town name, a problem statement, a link to their floodplain regulations along with the sub planning area where the city or town is located. During the planning process, cities and towns identified flooding issues in their communities and ranked and scored each identified flood project using the *"problem and project ranking criteria's (see appendix C)."*

Some cities and towns also listed programmatic recommendations that they would like to pursue over the next 10 years and also developed a PATHWAYS diagram to possibly solve a specific flood issue in their community. In this appendix, you will see appendices created for the following cities:

- City of Bonney Lake
- City of Dupont
- City of Edgewood
- City of Fife
- City of Fircrest
- City of Gig Harbor
- City of Lakewood
- City of Milton
- City of Orting
- City of Pacific
- City of Puyallup
- City of Sumner
- City of Tacoma
- Town of Steilacoom
- Town of South Prairie
- Town of Wilkeson

- Unincorporated Pierce County
  - City of University Place

River Gauge Flood Warning Threshold Matrix (Flood Matrix)

Surface Water Management completed a project to create a comprehensive set of static flood inundation maps for selected reaches of Pierce County's River system. These maps were created to supplement, but not replace, FEMA's Flood Insurance Rate Maps. The new maps will serve as a helpful planning and communication tool to estimate impacts along our rivers for a variety of river flows. The mapping for each reach presents three key pieces of data: Surface Water Elevations, Water Depth and Water Velocity. The rivers and general reaches modeled and mapped include the following:

- Puyallup River:
  - Lower Puyallup – Commencement Bay to Puyallup
  - Middle Puyallup – Puyallup to McMillan
  - Upper Puyallup – McMillan to Electron
- Carbon River
  - Below South Prairie Creek
  - Above South Prairie Creek along 177th St E
  - Upper Carbon River – downstream of Mt. Rainier National Park
- South Prairie Creek
- White River
  - Lower – Sumner to Pacific
  - Upper – Greenwater to Crystal Village
- Nisqually River
  - Middle Nisqually River McKenna to Wilcox Farms
  - Upper Nisqually River – Elbe to Mt. Rainier National Park

These maps are a non-regulatory planning level tool that is still in draft form and will be available in near the future. Since the completion of this project SWM was able to create Flood Warning Matrices for the river reaches mentioned above. The Flood Warning Matrices were developed as an interpretive guidance tool to be used along with the Rivers Flood Inundation Mapping layers available in CountyView Pro by County staff responding to high water events. The Flood Matrix attempts to provide insight into anticipated impacts along mapped river segments using three anticipated impact categories: Channel Characteristics, Potential Water Over Roadways and Community Notifications. Channel Characteristics is meant to serve as a guide to provide insights of how the river channel may respond given a specific flow prediction. Similarly, Potential Water Over Roadways serves as a guide to anticipate which roadways may be impacted by flood waters. And lastly, Notify Community of Potential Flood Waters serves as a guide to provide insights into which communities may be impacted by flood waters. The Flood Matrix is divided into four Flood Phases. Flood and erosion risks increase as the flood phase level increases. Phase levels shown have been coordinated to correlate with the National Weather Services' Flood Phase Thresholds.

Flood Phase	PHASE I: Action Flow	PHASE II: Minor Flooding	PHASE III: Moderate Flooding	PHASE IV: Major Flooding
LOWER PUYALLUP RIVER River Mile Range: 0.0 – 10.3 (From the mouth of the Puyallup River to the mouth of the White River)				
USGS Gauge Station #: 12101500		**Gauge Name: Puyallup River at Puyallup, WA**		
Gauge Location: Near River Road & 77th Ave. E		**River Mile: 6.55**		
Flow/Stage Range	**< 35,500 CFS < 26.2 FT**	**35,500 - 45,000 CFS 26.2 – 28.8 FT**	**45,000 – 50,000 CFS 28.8 FT – 30.1 FT**	**> 50,000 CFS > 30.1 FT**
ANTICIPATED IMPACTS				
	Channel Characteristics • Flow is likely over the silt bench. • Flow primarily remains within the channel. • Floodplain's filling. • Elevated flow stages. **Potential Water over Roadways** • Flow likely over the trail and dead end along 11th St. NW • SR161 underpass may be flooding. **Notify community of potential flood waters.** • Shuler and River Road Landscaping beginning to flood. • Flooding along trail by Riverwalk Apts. • Parking lot and Riverview MHP by RM 9.2 is beginning to flood. • Water is over parts of trail upstream of SR512. • Golf Course beginning to flood. • Keep an eye on the Clear Creek Area. The tide gate will close around a stage of 12.4Ft. Closure is tidally influenced, and closure will vary with river flow.	**Channel Characteristics** • Flow is getting near the top of bank along most of the reach. • Flow primarily remains within the channel downstream of Meridian Bridge. • Flows upstream of the Meridian Bridge are overtopping the channel banks in multiple locations. • Velocities are high. • Beware of floating debris • Flow stage continues to rise. • Expect flooding of low-lying areas. **Potential Water over Roadways** • Trail is under water. • Dead end along 11th St. NW • SR161 underpass is likely flooded. • 4th St. NE & 10th Ave. Ct NE beginning to flood. • East Main close to flooding. **Notify community of potential flood waters.** • Clear Creek area is near flooding. • Shuler and other adjacent houses along Clarks Creek and River Road Landscaping area likely flooding. • Businesses along River Road between 15th St. NW and 7th St. NW likely flooding. • Riverwalk Apts. and surrounding businesses likely flooding. Resident should evacuate. • Upstream of SR 512 bridge - businesses, MHP, and apartments along the left bank are near or likely flooding. Evacuation is encouraged.	**Channel Characteristics** • Flow is near or at top of bank along most of the reach. • Flow primarily remains within the channel downstream of Meridian Bridge. • Flows upstream of the Meridian Bridge are leaving the channel is multiple locations. • Velocities are very high. • Erosion potential is high. • Beware of fast-moving floating debris. • Expect widespread flooding upstream up Meridian Bridge. • Bridges should be monitored for debris accumulations. **Potential Water over Roadways** • Trail is under water. • Dead end along 11th St. NW • SR161 underpass is flooded. • 4th St. NE & 10th Ave. Ct NE are likely flooding. • East Main is likely flooding. **Notify community of potential flood waters.** • Clear Creek area likely flooding. • Shuler and other adjacent houses along Clarks Creek, River Road Landscaping and adjacent neighbors are flooding. • Majestic MHP is likely flooding • Several businesses downstream of the Meridian bridge are likely flooding, others need to be aware. • Upstream of the Meridian Bridge - Riverwalk Apts. and surrounding	**Channel Characteristics** • Flow is at or above the top of bank along most of the reach. • Flows upstream of the Meridian Bridge are overtopping the channel banks in multiple locations. • Velocities are extremely high. • Erosion potential is extremely high. • Beware of very fast-moving floating debris. • Bridges should be closed. • Expect widespread flooding. **Potential Water over Roadways** • Widespread flooding is occurring. Many roads will be underwater and escape routes will be limited. **Notify community of potential flood waters.** • Wide-spread flooding expected. • Low lying areas along the river channel should evacuate.

		• Properties along the right bank should be warned of rising water. Some may be flooding. • Golf Course is flooding. • Other tributary streams (i.e Deer Creek) will likely backwater and flood adjacent property.	businesses are flooding. Resident should evacuate. • Upstream of SR 512 bridge - businesses, MHP, and apartments along the left bank are flooding. Evacuation should occur. • Properties along the right bank should be warned of rising water others are likely flooding. • Golf Course flooding is spreading.	

Flood Phase	PHASE I: Action Flow	PHASE II: Minor Flooding	PHASE III: Moderate Flooding	PHASE IV: Major Flooding
MIDDLE PUYALLUP RIVER **River Mile Range: 10.3 – 17.4** **(From the mouth of the White River to the mouth of the Carbon River)**				
USGS Gauge Station #: 12096500		**Gauge Name: Puyallup River at Alderton, WA**		
Gauge Location: SR 162 Bridge near 80th St. E.				**River Mile 12.04**
Flow/Stage Range	**<20,000CFS** **54.6 FT**	**20,000 - 30,000 CFS** **54.6 FT – 57.0 FT**	**30,000 - 45,000 CFS** **57.0 FT – 60.0 FT**	**> 45,000 CFS** **60.0 FT**
ANTICIPATED IMPACTS				
	Channel Characteristics • Flow is near top of bank. • Flow primarily remains within the channel. • Elevated flow stages. • Floodplains beginning to fill. • Tributary creeks are backwatering. **Potential Water over Roadways** • No road flooding anticipated. **Notify community of potential flood waters.** • Floodplain upstream of Traffic Ave., left bank becoming engaged. • Residents behind the Mosby private levee should be notified of potential flooding.	**Channel Characteristics** • Flow is beginning to overtop its banks along the reach in several locations. • Expect flooding of low-lying areas. • Waters continue to rise. • Floodplains continue to fill. • Tributary creeks may be flooding. **Potential Water over Roadways** • Access road to Sumner WWTP may be under water. • 76th St. E near Riverside Dr. may be underwater and have logs sweeping the top of bank • 116th St. may be underwater • McCutcheon Road may be underwater. **Notify community of potential flood waters.** • Sumner Wastewater Treatment Plant should be notified of potential flooding. • Residents in Rainier Manor MHP, River Grove apartments and the Riverwalk condominiums should be notified of potential flooding. • Notify resident to implement evacuation plan for low lying RV's at River Park MHP and Bowman-Hilton MHO where flooding is likely. • Residents at 76th St E are likely flooding and have debris impacts. • Riverside Park is likely flooding. • All residents south of 116th St. E. are experiencing flooding or will be soon.	**Channel Characteristics** • Flow overtopping most of the levees. • Expect widespread flooding throughout the reach. • Velocities are high. • Beware of floating debris • High erosion potential. **Potential Water over Roadways** • Most roads along the river are likely under water. • SR 410 is likely flooded. • Consider closing bridges at 96th St. E and 128th St. E. **Notify community of potential flood waters.** • All communities along the reach should be notified and encouraged to evacuate. • Residents on the right bank, 8400 block of Riverside Dr could have flooded homes.	**Channel Characteristics** • Flow overtopping most of the levees. • Widespread flooding throughout the reach. • Velocities are extremely high. • Beware of fast-moving floating debris loads. • Extremely high erosion potential. **Potential Water over Roadways** • Most roads along the river are likely under water. • SR 410 is likely flooded. • All bridges over the river should be closed. **Notify community of potential flood waters.** • Most communities along the reach should be evacuated.

Flood Phase	PHASE I: Action Flow	PHASE II: Minor Flooding	PHASE III: Moderate Flooding	PHASE IV: Major Flooding
UPPER PUYALLUP RIVER River Mile Range: 17.4 – 28.6 (From the mouth of the Carbon River to the bridge crossing)				
USGS Gauge Station #: 12093500		**Gauge Name: Puyallup River near Orting, WA**		
Gauge Location: Near Orville Road E & Brooks Road E		**River Mile 25.21**		
Flow/Stage Range	**<10,000 CFS 10.0 FT**	**10,000 – 13,500 CFS 10.0 FT – 10.8 FT**	**13,500 – 16,000 CFS 10.8 FT – 11.3 FT**	**> 16,000 CFS > 11.3 FT**
ANTICIPATED IMPACTS				
	Channel Characteristics • Floodplains becoming engaged. • Elevated flow stages. • Flow primarily remains within the channel. • Bank erosion and channel migration risk is moderate. **Potential Water over Roadways** • No road flooding anticipated. **Notify community of potential flood waters.** • Residents across from the Ford Setback Levee (Plat of The Country and Tombola subdivision), between RM 24.0 – 24.5, should be alerted to elevating erosion and channel migration risk.	**Channel Characteristics** • Flow is near top of bank. • Flow primarily remains within the channel. • Flow stage continues to elevate. • Expect flooding of low-lying fields. • Overtopping expected along High Cedars Golf Course. • Floodplains continue to fill spreading across the channel connecting side channels and wetlands. • Bank erosion and channel migration risk is moderate to high. **Potential Water over Roadways** • No road flooding anticipated. **Notify community of potential flood waters.** • Residents just upstream of the SR 162 bridge along the right bank should be alerted of potential flooding. • Backyards along the river in Cedar Bend and River Bend Estates are likely beginning to flood. • Residents across from the Ford Setback Levee (Plat of The Country and Tomolla subdivision), between RM 24.0 – 24.5, should be alerted to high erosion and channel migration risk.	**Channel Characteristics** • Flow is at the top of bank. • Flow likely leaving channel in a few locations. • Expect localized flooding downstream of the Calistoga Bridge • Velocities are high. • Beware of floating debris • Bank erosion and channel migration risk is high. **Potential Water over Roadways** • Many roads in and around Orting are likely flooding. • Brooks Road maybe flooded. **Notify community of potential flood waters.** • Residents and businesses in and around Orting should be prepared to evacuate. • Residents across from the Ford Setback Levee (Plat of The Country and Tomolla subdivision), between RM 24.0 – 24.8, should be alerted to extremely high erosion and channel migration risk.	**Channel Characteristics** • Flow is at the top of bank and overtopping in multiple locations. • Expect moderate to severe flooding around and downstream of the Calistoga Bridge • Velocities are very high. • Beware of fast-moving floating debris loads. • Extremely high erosion potential **Potential Water over Roadways** • Multiple roads and driveways around and downstream of the Calistoga Bridge are likely under water. • Brooks Road is likely under water. • Brooks Road embankment just upstream of the high bridge is extremely vulnerable to erosion. • Orville Road at Kapowsin Creek crossing is likely under water. **Notify community of potential flood waters.** • Flooding becoming widespread in the Orting area. • Residents just upstream of the SR 162 bridge along the right bank should be encouraged to evacuate. • Residents around and downstream of the Calistoga Bridge should be encouraged to evacuate. • Residents across from the Ford Setback Levee (Plat of The Country and Tombola subdivision), between RM 24.0 – 24.8, should be alerted to extremely high erosion and channel migration risk. Residents closest to the river should evacuate.

Flood Phase	PHASE I: Action Flow	PHASE II: Minor Flooding	PHASE III: Moderate Flooding	PHASE IV: Major Flooding
CARBON RIVER River Mile Range: 0.0 – 8.3 (From the confluence with the Puyallup River to the end of Alward Road (177th St. E.) Note: No known infrastructure or populations within the floodplain between RM 8.3 – 15.99.				
USGS Gauge Station #: 12094000		**Gauge Name: Carbon River near Fairfax, WA**		
Gauge Location: Approx. 1.1 SE of SR 165 Bridge		**River Mile 15.99**		
Flow/Stage Range	**5,000 – 7,500 CFS 12.0 FT – 13.5 FT**	**7,500 – 9,500 CFS 13.5 FT – 14.5 FT**	**9,500 – 12,500 CFS 14.5 FT – 15.9 FT**	**> 12,500 CFS > 15.9 FT**
ANTICIPATED IMPACTS				
	Channel Characteristics • Floodplains becoming engaged. • Elevated flow stages. • Flow primarily remains within the channel. **Potential Water over Roadways** • South Prairie Creek Road East – getting close to roadway the near confluence with South Prairie Creek. **Notify community of potential flood waters.** • Community around the confluence need to be aware of rising flood waters.	**Channel Characteristics** • Floodplains continue to fill. • Rising waters are spreading across floodplains. • Flow stage continues to elevate. • Flow primarily remains within the channel. **Potential Water over Roadways** • South Prairie Creek Road East – water likely over roadway near confluence with South Prairie Creek. **Notify community of potential flood waters.** • Community around the confluence of South Prairie Creek needs to be aware of encroaching flood waters.	**Channel Characteristics** • Water is near the top of banks. • Velocities are high. • Beware of floating debris • Erosion potential is very high which could lead to levee failure. • Flow primarily remains within the channel. **Potential Water over Roadways** • South Prairie Creek Road East – water over roadway near confluence with South Prairie Creek. Beware of swift water. • SR 162 may have water over roadway. **Notify community of potential flood waters.** • Community around the confluence of South Prairie Creek need to be aware of encroaching flood waters. • Flood water likely leaving left bank upstream of SR162 bridge by 177th St E. Downstream and upstream communities need to be warned. • The City of Orting needs to be warned. They may experience flooding upstream of Bridge Street.	**Channel Characteristics** • Water is at or above the top of banks. • Velocities are high. • Beware of floating debris • Erosion potential is extremely high which may lead to levee failure. • Residents may experience severe flooding • Flood potential becoming extremely hazardous. **Potential Water over Roadways** • South Prairie Creek Road East – water over roadway near confluence with South Prairie Creek. Beware of swift water. • SR 162 may have water over roadway. **Notify community of potential flood waters.** • Community around the confluence of South Prairie Creek need to be aware of encroaching flood waters. • Levee is at high risk of failure and possible split flow directed to Crocker. Flood water likely leaving left bank upstream of SR162 bridge by 177th St E. Downstream and upstream communities need to be warned of likely flooding. • The City of Orting needs to be warned. They may experience flooding upstream of Bridge Street. • Floodplain near the confluence with the Puyallup River is likely inundated along the left bank.
Note: To quantify flows downstream of the SR 162 Bridge near South Prairie Creek, add together the flow values for South Prairie Creek gauge and the Fairfax gauge.				

<table>
<tr><th>Flood Phase</th><th>PHASE I: Action Flow</th><th>PHASE II: Minor Flooding</th><th>PHASE III: Moderate Flooding</th><th>PHASE IV: Major Flooding</th></tr>
<tr><td colspan="5">UPPER CARBON RIVER
River Mile Range: 16.1 – 22.9
(Fairfax Gauge to MRNP)
Note: No known infrastructure or populations within the floodplain between RM 8.3 – 15.99.</td></tr>
<tr><td colspan="2">USGS Gauge Station #: 12094000</td><td colspan="3">Gauge Name: Carbon River near Fairfax, WA</td></tr>
<tr><td colspan="2">Gauge Location: Approx. 1.1 SE of SR 165 Bridge</td><td colspan="3">River Mile 15.99</td></tr>
<tr><td>Flow/Stage Range</td><td>5,000 – 7,500 CFS
12.0 FT – 13.5 FT</td><td>7,500 – 9,500 CFS
13.5 FT – 14.5 FT</td><td>9,500 – 12,500 CFS
14.5 FT – 15.9 FT</td><td>> 12,500 CFS
> 15.9 FT</td></tr>
<tr><td colspan="5">ANTICIPATED IMPACTS</td></tr>
<tr><td></td>
<td>Channel Characteristics
• Floodplains becoming engaged.
• Elevated flow stages.
• Flow primarily remains within the channel.
• In-channel debris beginning to mobilize.

Potential Water over Roadways
• Beware of erosion potential along Fairfax Forest Reserve Road East.

Notify community of potential flood waters.
• Residents along Kolisch Road East need to be alert to rising waters and potential impact to bridge.
• Residents along Manley Moore Road East need to be alert of increasing erosion hazard.</td>
<td>Channel Characteristics
• Floodplains continue to fill.
• Rising waters are spreading across floodplains.
• Flow stage continues to elevate.
• Flow primarily remains within the channel.

Potential Water over Roadways
• Increasing erosion potential along Fairfax Forest Reserve Road East.
• Increasing hazard to USFS Road 7810 and Kolisch Road East bridge crossings

Notify community of potential flood waters.
• Residents along Kolisch Road East should be notified of rising waters and potential impact to bridge.
• Residents along Manley Moore Road East should be alerted of increasing erosion hazard.</td>
<td>Channel Characteristics
• Water is near the top of banks.
• Velocities are high.
• Beware of floating debris
• Erosion potential is very high
• Flow primarily remains within the channel but activating high-flow side channels.

Potential Water over Roadways
• Erosion potential along Fairfax Forest Reserve Road East is very high.
• High potential of impacts to USFS Road 7810 and Kolisch Road East bridge crossings from floating debris

Notify community of potential flood waters.
• Residents along Kolisch Road East should be notified to evacuate to avoid the potential of being cut-off due to impacts to bridge.
• Residents along Manley Moore Road East should be alerted of extremely high erosion hazard and consider evacuation.</td>
<td>Channel Characteristics
• Water is overtopping banks.
• Velocities are extremely high.
• Beware of fast-moving floating debris
• Erosion potential is extremely high

Potential Water over Roadways
• Erosion potential is extremely high along Fairfax Forest Reserve Road East.
• Extremely high potential of impacts to USFS Road 7810 and Kolisch Road East bridge crossings from floating debris and high water.

Notify community of potential flood waters.
• Residents along Kolisch Road East should be notified to evacuate to avoid the potential of being cut-off due to impacts to bridge.
• Residents along Manley Moore Road East should be alerted of extremely high erosion hazard and should evacuate.</td></tr>
</table>

Flood Phase	PHASE I: Action Flow	PHASE II: Minor Flooding	PHASE III: Moderate Flooding	PHASE IV: Major Flooding
LOWER WHITE RIVER River Mile Range: 0.0 – 6.2 (From the confluence with the Puyallup River to "A" Street Bridge)				
USGS Gauge Station #: 12100490		**Gauge Name: White River at "R" Street near Auburn, WA**		
Gauge Location: "R" Street Bridge		**River Mile 7.50**		
Flow/Stage Range	**5,000 CFS 114.1 FT**	**5,000 – 7,500 CFS 114.1 FT – 115.2 FT**	**7,500 – 12,000 CFS 115.2 FT – 116.8 FT**	**> 12,000 CFS 116.8 FT**
ANTICIPATED IMPACTS				
	Channel Characteristics • Floodplains becoming engaged. • Elevated flow stages. • Flow primarily remains within the channel. • In-channel debris beginning to mobilize. **Potential Water over Roadways** • No water over roadways anticipated. **Notify community of potential flood waters.** • Government Ditch is starting to backwater.	**Channel Characteristics** • Water is near the top of banks and likely overtopping in localized areas. • Velocities are high. • Beware of floating debris. • Erosion potential is high which could lead to levee failure. • Flow primarily remains within the channel along lower reach south RM 2.5. **Potential Water over Roadways** • 16th St. E & 20th St. E likely flooding • Roads near Pacific Park may experience localized flooding. • Segments of trail may be under water. **Notify community of potential flood waters.** • Parking lot north of Tacoma Ave. beginning to flood. • Warehouses on right bank likely beginning to flood. • Homes at north end of 146th Ave. E. and north side of 16th St. E. should be warned they will likely begin to experience flooding and consider evacuation. • Vacant fields on left bank likely flooding. • Overbank flooding is likely to occur in the City of Pacific near Government Ditch and Butte Ave. • Pacific Park and homes adjacent to the park are likely beginning to flood.	**Channel Characteristics** • Water is likely overtopping the banks along most of the reach. • Velocities are very high. • Beware of fast-moving floating debris. • Erosion potential is very high which could lead to levee failure. • Vacant fields on left bank are flooding **Potential Water over Roadways** • Houston Road and access road to Sumner WWTP are likely under water. • Most roads between Ellingson Road and Puyallup Road are flooded. • Segments of trail are under water. **Notify community of potential flood waters.** • All residents and businesses between Ellingson Road and Puyallup St should be warned of likely flooding and encouraged to evacuate.	**Channel Characteristics** • Widespread flooding is likely throughout the reach. • Velocities are extremely high and deep. • Beware of fast-moving floating debris. • Erosion potential is extremely high which could lead to levee failure. **Potential Water over Roadways** • Houston Road and access road to Sumner WWTP are under water. • Most roads between Ellingson Road and Puyallup Road are flooded. • Beware of impacts to bridges due to floating debris. • Most of the trail is under water. **Notify community of potential flood waters.** • All residents and businesses between Ellingson Road and Puyallup St should be encouraged to evacuate.

Flood Phase	PHASE I: Action Flow	PHASE II: Minor Flooding	PHASE III: Moderate Flooding	PHASE IV: Major Flooding
UPPER WHITE RIVER River Mile 44.4 – 50.5 (Greenwater to Crystal Village)				
USGS Gauge Station #: 12097850		**Gauge Name: White River below Clearwater River* at Buckley, WA** ***USGS Map shows gauge near confluence with Canyon Creek**		
Gauge Location: South of SR 410, approx., Mile Post 32		**River Mile 32.77**		
Flow/Stage Range	**<10,000 CFS 52.9 FT**	**10,000 - 15,000 CFS 52.9 FT - 54.2 FT**	**15,000 - 20,000 CFS 54.2 FT - 55.3 FT**	**> 20,000 CFS 55.3 FT**
ANTICIPATED IMPACTS				
	Channel Characteristics • Floodplains becoming engaged. • Elevated flow stages. • Flow remains within most of the channel. • In-channel debris beginning to mobilize. • Channel migration hazard is increasing. **Potential Water over Roadways** • Greenwater Village may be experiencing some localized flooding of roads. **Notify community of potential flood waters.** • Residents along the right bank between the confluence with the Greenwater River upstream to Greenwater Village may experience flooding. • Residents in Crystal Village should be aware of rising waters and increased channel migration risk. • Greenwater River Communities Residents along the river should be aware of increasing erosion and channel migration hazard potential.	**Channel Characteristics** • Floodplains engaged along the majority of the channel. • Flow is at or near top banks. • In-channel debris is likely mobilized. • Velocities are high • Low lying areas may flood. • Increasing channel migration risk. **Potential Water over Roadways** • Water is likely over the roadways in Greenwater Village. • Water may be flooding roads in Crystal Village along the right bank. **Notify community of potential flood waters.** • Residents along the right bank between the confluence with the Greenwater River upstream to Greenwater Village are likely flooding. Residents should consider evacuation. • Residents in Crystal Village should be aware of rising waters, chance of flooding and increased channel migration risk. • Greenwater River Communities Residents along the river should be aware of moderate erosion and channel migration hazard potential.	**Channel Characteristics** • Water is likely overtopping most banks. • Velocities are very high. • Beware of floating debris • Erosion and channel migration potential is very high **Potential Water over Roadways** • All roads are likely flooded in Greenwater Village. • Crystal Drive East is likely flooded in Crystal Village along the right bank. • Beware of rising waters and potential flooding of roads within Crystal Village **Notify community of potential flood waters.** • Residents along the right bank between the confluence with the Greenwater River upstream to Greenwater Village should be evacuated. • Residents along the river in Crystal Village are likely experiencing flooding in low lying areas and should consider evacuation. • Greenwater River Communities Residents along the river should be aware of high erosion and channel migration hazard potential.	**Channel Characteristics** • Water is overtopping banks. • Velocities are extremely high. • Beware of fast-moving floating debris • Erosion potential is extremely high **Potential Water over Roadways** • All roads are likely flooded in Greenwater Village. • Crystal Drive East and Willow Tree Way are likely flooded in Crystal Village. • Beware of rising waters and potential flooding of other roads within Crystal Village **Notify community of potential flood waters.** • Residents along the right bank between the confluence with the Greenwater River upstream to Greenwater Village should be evacuated. • Residents along the river in Crystal Village are likely experiencing flooding. • Residents in low lying areas near the river should be evacuated. • Greenwater River Communities Residents along the river should be aware of extremely high erosion and channel migration hazard potential.

Flood Phase	PHASE I: Action Flow	PHASE II: Minor Flooding	PHASE III: Moderate Flooding	PHASE IV: Major Flooding
MIDDLE NISQUALLY RIVER **River Mile Range: 19.1 – 30.5** **(Rail line NW of the Town of McKenna to Tanwax Creek)**				
USGS Gauge Station #: 12089500		**Gauge Name: Nisqually River at McKenna, WA**		
Gauge Location: SR 507 Bridge		**River Mile 21.90**		
Flow/Stage Range	**10,000 - 14,700 CFS** **8.0 FT - 10.0 FT**	**14,700 - 23,200 CFS** **10.0 FT – 12.99 FT**	**23,200 - 26,500 CFS** **12.99 FT – 14.0 FT**	**> 26,500 CFS** **> 14.0 FT**
ANTICIPATED IMPACTS				
	Channel Characteristics • Flow is near top of bank. • Floodplains are engaged and flow remains primarily within the channel. • Low field will likely begin to be flooded. • Elevated flow stages. • In-channel debris beginning to mobilize. • Overbank flow is unlikely. **Potential Water over Roadways** • Local access roads on Wilcox Farm may be flooding. **Notify community of potential flood waters.** • Wilcox Farm fields next to the river will likely be flooding.	**Channel Characteristics** • Floodplains continue to fill. • Flow is likely at the top of banks and overtopping in localized areas. • In-channel debris is likely mobilized. • Velocities are high • Low lying areas may flood. • Increasing channel migration risk. **Potential Water over Roadways** • Local access roads are likely flooding. **Notify community of potential flood waters.** • Homes in McKenna are likely flooding. Resident should be prepared for high water or possible evacuation. • Flooding on Wilcox Farm fields next to the river is spreading.	**Channel Characteristics** • Water is near the top of banks. • Velocities are high. • Beware of floating debris • Erosion potential is very high which could lead to bank failure. • Flow primarily remains within the channel. **Potential Water over Roadways** • Water over SR 507 • Local access roads are likely flooding. **Notify community of potential flood waters.** • Flooding around and upstream of McKenna is widespread. • Multiple homes and businesses are flooding. • Flooding on Wilcox Farm fields next to the river is spreading.	**Channel Characteristics** • Flow overtopping most banks. • Widespread flooding throughout the reach. • Velocities are extremely high. • Beware of fast moving floating debris loads. • Significantly high potential for bank erosion. **Potential Water over Roadways** • Water over SR 507 • Bridge approaches are likely under water. • Local access roads are likely flooding. **Notify community of potential flood waters.** • Flooding around and upstream of McKenna is widespread. • Multiple homes and businesses are flooding. • Flooding on Wilcox Farm fields and homes that access along 420th St. S.

Flood Phase	PHASE I: Action Flow	PHASE II: Minor Flooding	PHASE III: Moderate Flooding	PHASE IV: Major Flooding
UPPER NISQUALLY RIVER **River Mile Range: 50.4 – 65.9** **(From the Town of Elbe to Tahoma Creek - Mt. Rainier National Park)**				
USGS Gauge Station #: 12082500		**Gauge Name: Nisqually River near National, WA**		
Gauge Location: South of SR 706 & 265^{th} Ave E		**River Mile 55.95**		
Flow/Stage Range	**< 10,000 CFS** **<10.2 FT**	**10,000 - 15,000 CFS** **10.2 FT – 11.7 FT**	**15,000 - 20,000 CFS** **11.7 FT – 13.1 FT**	**> 20,000 CFS** **> 13.1 FT**
ANTICIPATED IMPACTS				
	Channel Characteristics • Floodplains and side channels becoming engaged. • Elevated flow stages. • Flow primarily remains within the channel. • In-channel debris beginning to mobilize. **Potential Water over Roadways** • None anticipated. **Notify community of potential flood waters.** • Residents close to the river need to be on alert to rising waters and increasing erosion hazard	**Channel Characteristics** • Flow is near or at the top of banks. • Rising waters are spreading across floodplains. • Flow stage continues to elevate. • Flow primarily remains within the channel. • Some low-lying fields may begin to flood. **Potential Water over Roadways** • No water over roadway anticipated. • Low bridge may be impacted by floating debris. **Notify community of potential flood waters.** • Residents about ¼ mile upstream of SR 7 Bridge • Home at 22780 SR 706 should be warned of developing flood risk. • Residents in Alpine Meadows should be on alert to rising waters and increasing erosion hazard. • Community along Rainier Vista Dr. should be alerted of potential flood threat. • Mt. Rainier National Park should be warned of potential high water and impacts.	**Channel Characteristics** • Water is likely beginning to overtop the banks. • Side channels are mostly engaged. • Velocities are very high. • Beware of floating debris. • Erosion potential is very high. **Potential Water over Roadways** • SR 7 south of river likely has water over the roadway. • Bridge crossing likely impacted by floating debris. **Notify community of potential flood waters.** • Residents about ¼ mile upstream of SR 7 Bridge • Home at 22780 SR 706 should be notified to consider evacuation. • Residents of Alpine Meadows, Echo Valley and Nisqually Park should be alerted of high water and channel migration potential. • Community along Rainier Vista Dr. should be alerted of potential flood threat. • Mt. Rainier National Park should be advised to prepared to respond to likely flooding near the Nisqually entrance.	**Channel Characteristics** • Flow is likely above the top of bank. • Flow likely leaving channel in multiple locations. • Velocities and erosion potential are extremely high. • Beware of fast-moving floating debris loads. **Potential Water over Roadways** • SR 7 south of river likely has water over the roadway. • Bridge approaches likely under water. • Kernahan Bridge crossing likely impacted by floating debris or eroded embankments. Bridge closure should be considered. **Notify community of potential flood waters.** • Residents about ¼ mile upstream of SR 7 Bridge should be evacuated. • Home at 22780 SR 706 should evacuate. • Residents of Alpine Meadows, Echo Valley and Nisqually Park should evacuate. • Community along Rainier Vista Dr. should be alerted of potential flood threat. • Mt. Rainier National Park should be prepared to close the Nisqually entrance and evacuate the area.

<table>
<tr><th>Flood Phase</th><th>PHASE I: Action Flow</th><th>PHASE II: Minor Flooding</th><th>PHASE III: Moderate Flooding</th><th>PHASE IV: Major Flooding</th></tr>
<tr><td colspan="5">SOUTH PRAIRIE CREEK
River Mile Range: 0.0 – 7.6
(From the confluence with the Carbon River to Spiketon Ditch)</td></tr>
<tr><td colspan="2">USGS Gauge Station #: 12095000</td><td colspan="3">Gauge Name: South Prairie Creek at South Prairie, WA</td></tr>
<tr><td colspan="2">Gauge Location: Foothills Trail Bridge</td><td colspan="3">River Mile 6.01</td></tr>
<tr><td>Flow/Stage Range</td><td><4,000 CFS
29.4 FT</td><td>4,000 - 5,500 CFS
29.4 FT - 30.3 FT</td><td>5,500 - 8,000 CFS
30.3 FT- 31.6 FT</td><td>> 8,000 CFS
31.6 FT</td></tr>
<tr><td colspan="5">ANTICIPATED IMPACTS</td></tr>
<tr><td></td>
<td>Channel Characteristics
• Floodplains becoming engaged.
• Elevated flow stages.
• Flow primarily remains within the channel.

Potential Water over Roadways
• South Prairie Carbon River Road East may be flooding.
• Spring Site Road East – water likely over roadway.

Notify community of potential flood waters.
• South Prairie Creek Road East – notify community of potential flood waters.
• Homes on Spring Site Rd to evacuate or face being trapped.</td>
<td>Channel Characteristics
• Floodplains continue to fill.
• Rising waters are spreading across floodplains.
• Flow stage continues to elevate.
• Flow is leaving the channel.

Potential Water over Roadways
• Many roads between the Carbon River and South Prairie are near flooding or are underwater.
• Lower Burnett Road near the 26700 block is likely flooding.

Notify community of potential flood waters.
• South Prairie Creek Rd E
• Home between RM 2.6 – 2.7
• VFW park
• Homes near the confluence with the Carbon River.</td>
<td>Channel Characteristics
• Floodplains mostly full.
• Flooding continues to spread across the floodplain.
• Flow stage continues to elevate.
• Flow is leaving the channel.
• Erosion potential is likely moderate to high with high velocity.

Potential Water over Roadways
• Most roads between the Carbon River and South Prairie are near flooding or are underwater.
• Lower Burnett Road is flooded.
• South end of Spiketon Rd at risk of more erosion

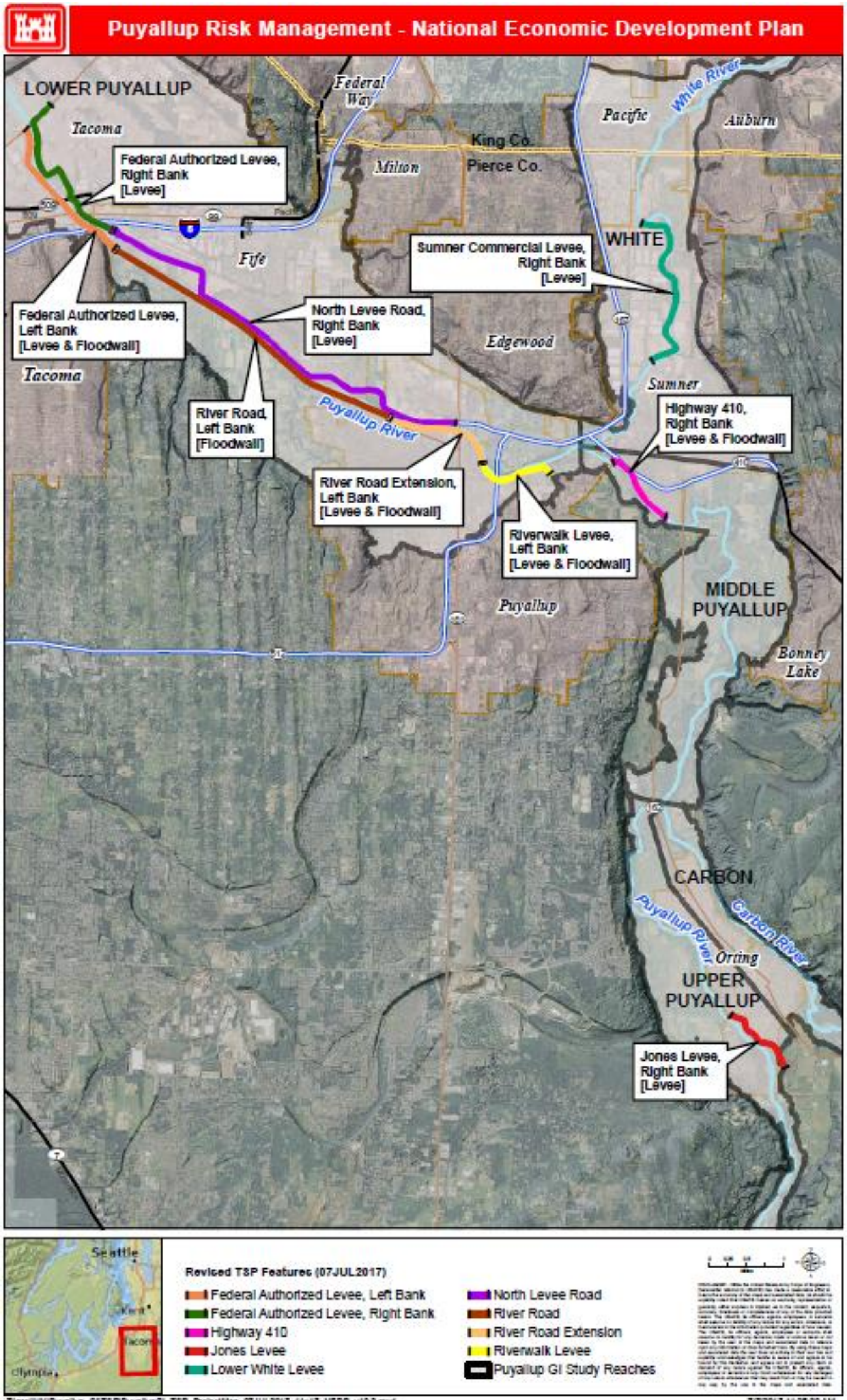
Notify community of potential flood waters.
• Most properties and communities along the creek are experiencing flooding.</td>
<td>Channel Characteristics
• Widespread flooding along the creek throughout the valley.
• Erosion potential is likely high with high velocity.

Potential Water over Roadways
• Multiple roads and structures impacted by flood waters.

Notify community of potential flood waters.
• South Prairie is likely cut-off due to flooded roads.
• Likely flood impacts to the fire station</td></tr>
</table>

United States Army Corps of Engineers (USACE) General Investigations for the Puyallup River Next steps

Pierce County and the FCZD collaborated with the USACE on the Lower Puyallup River Basin Flood Risk Management General Investigation (GI) Study to be eligible for federal funding for flood facility investments needed to protect the Lower Puyallup basin, including the economic assets of the Port of Tacoma. The study area included 28 levee segments that are currently in the USACE National Levee Database (NLD). This study also included 26 non-federal levees and two federally owned and operated levees. The estimated cost for the proposed improvements exceeded $398 million. Below is a map of the Pierce County projects that were listed in the GI study.


Puyallup Risk Management - National Economic Development Plan
LOWER PUYALLUP
Tacoma
Federal Way
King Co.
Pierce Co.
Pacific
White River
Auburn
Milton
Federal Authorized Levee, Right Bank [Levee]
Fife
WHITE
Sumner Commercial Levee, Right Bank [Levee]
Federal Authorized Levee, Left Bank [Levee & Floodwall]
North Levee Road, Right Bank [Levee]
Edgewood
Tacoma
Sumner
River Road, Left Bank [Floodwall]
Puyallup River
Highway 410, Right Bank [Levee & Floodwall]
River Road Extension, Left Bank [Levee & Floodwall]
Riverwalk Levee, Left Bank [Levee & Floodwall]
MIDDLE PUYALLUP
Puyallup
Bonney Lake
CARBON
Puyallup River
Carbon River
Orting
UPPER PUYALLUP
Jones Levee, Right Bank [Levee]
Seattle
Olympia
Revised TSP Features (07JUL2017)
Federal Authorized Levee, Left Bank
Federal Authorized Levee, Right Bank
Highway 410
Jones Levee
Lower White Levee
North Levee Road
River Road
River Road Extension
Riverwalk Levee
Puyallup GI Study Reaches
7/7/2017 11:25:39 AM

Several local stakeholders executed an Inter-Local Agreement with Pierce County to financially support the County's non-federal sponsor cost share including: City of Tacoma, City of Sumner, City of Puyallup, City of Orting, City of Pacific, City of Fife, Puyallup Tribe of Indians, Washington State Department of Transportation (WSDOT), Port of Tacoma, and the City of Auburn. In April 2018, USACE informed Pierce County that the Corps moved the GI study to inactive status. With this being said, the County began to work with the cities to put together a plan to determine alternate options to prioritize, fund, and move forward with projects that were in the study. Below is a summary table of the projects listed in the USACE study draft Tentatively Selected Plan along with the location in the CFHMP.

Project Name	Project Sponsor	Page Number in the CFHMP	Notes
Lower Puyallup			
Federal Authorized Levee Right Bank	US Army Corps	N/A	
Federal Authorized Levee Left Bank	US Army Corps	N/A	
North Levee Road Setback	Pierce County	See Unincorporated Pierce County Appendix	
River Road Levee Floodwall (left bank side)	Pierce County	See Unincorporated Pierce County Appendix	
River Road Extension (left bank side)	City of Puyallup	See City of Puyallup Appendix	
Riverwalk Levee (left bank side, Linden Golf Course)	City of Puyallup	See City of Puyallup Appendix	
Middle Puyallup			
Highway 410 Setback Levee and Floodwall (right bank side)	Pierce County and City of Sumner (WSDOT)	See Unincorporated Pierce County Appendix	
Upper Puyallup			

Jones Setback Levee (right bank side)	Pierce County	Unincorporated Pierce County Appendix	Carried forward under the Continuing Authorities Program (CAP) Program.
White River			
Sumner Commercial Setback Levee (right bank side)	Sumner	See City of Sumner Appendix	

LOCAL, STATE, AND FEDERAL REGULATIONS AND PROGRAMS

Summary of Washington State Laws and Administrative Codes Governing Flood Management (Chapters 86.12 and 86.16 RCWs and WAC 173-145-040)

Applicability of RCWs 86.12 and 86.16, and WAC 173-145 to the Comprehensive Flood Hazard Management Plan

Chapter 86.12 RCW grants counties the authority to develop and adopt comprehensive flood control management plans (CFCMP). It provides the guidance for flood plan elements and establishes the process for participation by local stakeholders in the development of the plan. It also gives counties the authority to raise funds to implement the plan. Chapter 86.16 includes requirements for the development of floodplain management regulations and compliance with the National Flood Insurance Program. It also establishes the Department of Ecology's authority to review and approve ordinances and amendments to floodplain regulations for participation in the NFIP. WAC 173-145 addresses specific elements that must be included in a CFCMP to be eligible for state Flood Control Assistance Account Program (FCAAP) funding. Pierce County will follow the elements and guidance of RCWs 86.12 and 86.16, and WAC 173-145 in development of the Comprehensive Flood Hazard Management Plan to ensure that the Plan is eligible for FCAAP funding and meets the requirements of the NFIP.

Overview

The Washington State flood control laws and regulations that govern county flood control activities are contained within the Revised Code of Washington (RCW) Chapters 86.12 and 86.16 and the Washington Administrative Code (WAC) 173-145. RCW 86.12 governs flood control by counties, RCW 86.16 governs floodplain management regulations, and WAC 173-145 addresses the administration of the flood control assistance account program, including the development of comprehensive flood control management plans (CFCMP).

RCW 86.12 – Flood Control by Counties

RCW 86.12 governs flood control by counties and gives counties the authority to annually levy a tax for purposes of generating a "river improvement fund" and to expend funds for controlling flood waters by construction and operation of flood facilities such as dams, dikes, levees, revetments and other protection. It also grants counties the use of eminent domain to obtain property for public use in providing flood control.

Section 86.12.200 authorizes counties to adopt a comprehensive flood control management plan for any drainage basin in the county. It notes that a comprehensive flood control management plan shall include the following elements:

1. Designation of areas susceptible to periodic flooding, including the river's meander belt or floodway;
2. Establishment of a comprehensive approach to flood control protection and improvements for areas subject to periodic flooding, including: (a) determining the need for, and location of, flood control improvements to protect or preclude flood damage to structures and improvements; (b) establishing the level of flood protection; (c) identifying alternatives to in-stream flood control work; (d) identifying areas where flood waters could be directed during a flood to avoid damage to buildings and other structures; and (e) identifying sources of revenue that will be sufficient to finance the flood control protection and improvements;
3. Establishing land use regulations that preclude the location of structures, works, or improvements in critical portions of areas subject to periodic flooding, including a river's meander belt or floodway, and permitting only flood-compatible land uses in such areas;
4. Establishing restrictions on construction activities in areas subject to periodic floods that require flood proofing of those structures that are permitted to be constructed or remodeled; and
5. Establishing restrictions on land clearing activities and development practices that exacerbate flood problems by increasing the flow or accumulation of flood waters, or the intensity of drainage, on low-lying areas.

Section 86.12.210 addresses the participation of local officials in the development of the comprehensive flood control management plan. It notes that the Plan shall be developed by the county with the full participation of officials from the city or town, special districts including conservation districts, and appropriate state and federal agencies. Following adoption by the county, city or town, a comprehensive flood control management plan shall be binding on each jurisdiction and special district that is located within an area included in the plan.

RCW 86.16 – Floodplain Management and Regulations

The Department of Ecology is the state agency in Washington responsible for coordinating the floodplain management regulation elements of the National Flood Insurance Program (NFIP). This includes the federal National Flood Insurance Act of 1968 and the Flood Disaster Protection Act of 1973. RCW 86.16.020 requires that statewide floodplain management regulations shall be exercised through: (1) local governments' administration of the NFIP regulation requirements, (2) the establishment of minimum state requirements for floodplain management, and (3) the issuance of regulatory orders.

Washington State has adopted higher standards than the minimum requirements for participation under the NFIP. All local floodplain management regulations must be reviewed and approved by the Department of Ecology before a community is eligible to participate in the NFIP. Section 86.16.025 grants Ecology the authority to examine, approve or reject designs and plans for any structure or works, public or private, to be constructed upon the banks, in or over the channel, or over and across the floodway of any stream or body of water in the state. Section 86.16.041 authorizes Ecology to review and approve or disapprove all floodplain management ordinances and amendments. This shall apply to areas designated as special flood hazard areas on the most recent maps provided by the federal emergency management agency for the NFIP.

WAC 173-145 – Administration of the Flood Control Assistance Account Program (FCAAP) and Comprehensive Flood Control Management Plans (CFCMP)

WAC 173-145 specifies that the Department of Ecology shall determine priorities and allocate available funds from the FCAAP among those counties applying for assistance, and establishes the criteria by which those allocations are made. To be eligible for FCAAP funds, the requirements of WAC 173-145-040 (Comprehensive Flood Control Management Plan) must be complied with by the appropriate local authority with flood control jurisdiction over the area where the proposed project is located.

CFCMPs must be approved by the Department of Ecology in consultation with the Department of Fish and Wildlife. The Plan must include:

1. Determination of the need for flood control work, including (a) description of the watershed; (b) identification of types of watershed flood problems; (c) location and identification of specific problem areas; (d) description of flood damage history; (e) description of potential flood damages; (f) short-term and long-term goals and objectives for the planning area; (g) description of rules that apply within the watershed including, but not limited to, local shoreline management master programs, and zoning, subdivision, and flood hazard ordinances; and (h) determination that the instream flood control work is consistent with applicable policies and rules.
2. Alternative flood control works, including: (a) description of potential measures of instream flood control work; and (b) description of alternatives to instream flood control work.
3. Identification and consideration of potential impacts of instream flood control work on the following instream uses and resources: (a) fish resources; (b) wildlife

resources; (c) scenic, aesthetic, and historic resources; (d) navigation; (e) water quality; (f) hydrology; (g) existing recreation; and (h) other impacts.

4. Area of coverage for the comprehensive plan shall include, as a minimum, the area of the one-hundred-year frequency floodplain within a reach of the watershed of sufficient length to ensure that a comprehensive evaluation can be made of the flood problems for a specific reach of the watershed.
5. Conclusion and proposed solutions. The CFCMP must be finalized by the following action from the appropriate local authority: (a) evaluation of problems and needs; (b) evaluation of alternative solutions; (c) recommended corrective action with proposed impact resolution measures for resource losses; and (d) corrective action priority.
6. A certification from the State Department of Community, Trade, and Economic Development that the local emergency management organization is administering an acceptable comprehensive emergency operations plan.

Washington State Growth Management Act

In 1990, the State Legislature enacted the Growth Management Act (GMA) which initiated and required the development of rational policies to manage growth in Washington State. All urban counties and their cities and towns were required to develop comprehensive plans and regulations to implement those plans. Plans must address land use, transportation, housing, capital facilities, utilities, and rural lands, and must guide development and accommodate the population growth forecast for the next 20 years.

The Revised Code of Washington 35.70A requires "A capital facilities plan element consisting of: (a) An inventory of existing capital facilities owned by public entities, showing the locations and capacities of the capital facilities; (b) a forecast of the future needs for such capital facilities; (c) the proposed locations and capacities of expanded or new capital facilities; (d) at least a six-year plan that will finance such capital facilities within projected funding capacities and clearly identifies sources of public money for such purposes; and (e) a requirement to reassess the land use element if probable funding falls short of meeting existing needs and to ensure that the land use element, capital facilities plan element, and financing plan within the capital facilities plan element are coordinated and consistent"

Other elements of comprehensive plans, such as the environment, utilities, transportation, economic elements, must also be internally consistent. GMA requires functional plans, such as the Rivers Plan, to be consistent with the comprehensive plan, including the community plans and basin plans. Moreover, GMA requires that functional plans such as the Rivers Plan be consistent with the plans of adjacent counties, cities, and towns. "Consistency" means that no feature of a plan or regulation is incompatible with any other feature of a plan or regulation. Consistency is indicative of a capacity for orderly integration or operation with other elements in a system.

Pierce County County-wide Planning Policies

GMA mandates counties and cities to create collaboratively countywide planning policies to govern the development of comprehensive plans. The primary purpose of countywide planning policies is to ensure consistency between the comprehensive plans of counties and cities sharing a common border or related regional issues. Pierce County and the cities and towns in the County adopted Countywide Planning Policies first in 1992. Amendments passed in 1996 and 2005.

Vision 2040 Multi-County Planning Policies

Multi-county planning policies are adopted by two or more counties and establish a common region-wide framework that ensures consistency among county and city comprehensive plans adopted pursuant to RCW 36.70A.070, and countywide planning policies adopted pursuant to RCW 36.70A.210. The following multi-county planning policies bear on flood hazard management within King, Pierce, Snohomish, and Kitsap Counties:

Environmental Stewardship

MPP-En-5 *Locate development in a manner that minimizes impacts to natural features. Promote the use of innovative environmentally sensitive development practices, including design, materials, construction, and on-going maintenance.*

MPP-En-6 *Use the best information available at all levels of planning, especially scientific information, when establishing and implementing environmental standards established by any level of government.*

Earth and Habitat

MPP-En-10 *Preserve and enhance habitat to prevent species from inclusion on the Endangered Species List and to accelerate their removal from the list.*

MPP-En-11 *Identify and protect wildlife corridors both inside and outside the urban growth area.*

MPP-En-12 *Preserve and restore native vegetation to protect habitat, especially where it contributes to the overall ecological function and where invasive species are a significant threat to native ecosystems.*

Water Quality

MPP-En-13 *Maintain natural hydrological functions within the region's ecosystems and watersheds and, where feasible, restore them to a more natural state.*

MPP-En-14 *Restore – where appropriate and possible – the region's freshwater and marine shorelines, watersheds, and estuaries to a natural condition for ecological function and value.*

MPP-En-16 *Identify and address the impacts of climate change on the region's hydrological systems.*

Flood Control and Coastal Emergency Act (PL 84-99)

Implications of the Flood Control and Coastal Emergency Act on the Comprehensive Flood Hazard Management Plan

Pierce County Planning and Public Works and Surface Water Management Division has 33.9 miles of levee and revetment facilities eligible for emergency response activities and rehabilitation under the Flood Control and Coastal Emergency Act (Public Law 84-99). Maintaining this eligibility is critically important in meeting emergency response and rehabilitation needs of Pierce County's levee system facilities.

Pierce County is also committed to improving habitat conditions for salmonids along its major rivers where feasible. The County has a vegetation management agreement with the Puyallup Tribe that contain specific requirements for vegetation maintenance in performing maintenance activities along the levees.

Proposed changes to maintenance activities on river management facilities should consider implications for ongoing federal support under the PL84-99 program and broader flood hazard management and habitat-related objectives.

Overview

PL 84-99 authorizes the Army Corps of Engineers to perform emergency management activities before, during, and after disasters. Emergency management activities include: (1) disaster preparedness and "advance measures", (2) emergency operations/response activities (flood responses and post-flood response), and (3) rehabilitation of flood control works threatened or destroyed by flood. Funding for the USACE emergency response under this authority is provided by Congress through the annual Energy and Water Development Appropriation Act.

Disaster Preparedness and Emergency Response Activities

Disaster preparedness activities include coordination, planning, training, and conduct of response exercises with local, state, and federal agencies. PL 84-99 allows for "advance measures" assistance to prevent or reduce flood damage conditions of imminent threat of unusual flooding. PL 84-99 allows the Corps of Engineers to supplement State and local entities in flood fighting urban and other non-agricultural areas under certain conditions

(Engineering Regulation 500-1-1 provides specific details). All flood fight efforts require a Project Cooperation Agreement (PCA) signed by the Public Sponsor and requirement for the Sponsor to remove all flood fight material after the flood has receded.

Rehabilitation

Under authority of PL 84-99, an eligible flood protection system can be rehabilitated if damaged by a flood event. The flood system would be restored to its pre-disaster status at no cost to the Federal system owner (Corps constructed, locally operated and maintained), and at 20% cost to the eligible non-Federal system owner (constructed by non-federal interest or Works Project Administration). All systems considered eligible for PL84-99 rehabilitation assistance have to be in the Rehabilitation and Inspection Program (RIP) prior to the flood event. Acceptable operation and maintenance of the public levee sponsor are verified by levee inspections conducted by the Corps on a regular basis. The Corps has the responsibility to coordinate levee repair issues with interested Federal, State, and local agencies following natural disasters events where flood control works are damaged. For a non-federal flood control project to be eligible for Rehabilitation Assistance, it must have been inspected, evaluated and accepted into the Corps RIP and still be active (based on the latest continuing eligibility inspection) at the time of the flood.

Eligibility

To be eligible to enter the RIP, urban levees (those protecting land with residences, public or commercial buildings, industrial facilities, etc.) must provide at least a 10-year level of protection, with a minimum of 2 feet of freeboard below the top of the levee. The minimum

Vegetation Management on Levees

Because of concerns about the structural integrity of levees, the Corps of Engineers has stringent requirements for PL 84-99 eligible levees relative to vegetation management. The specific concern is that trees greater than 4 inches in diameter pose a risk due to potential for erosion around the tree and toppling of the tree during flood events, thus weakening the levee. In recent years, there has been extensive discussion about vegetation management on levees where there are conflicting federal mandates relative to salmonid listings under the Endangered Species Act.

Rivers and Harbors Act (Section 10) and Clean Water Act (Sections 401 and 404)

Applicability of Federal Jurisdiction to the Comprehensive Flood Hazard Management Plan Rivers depends upon location and activity.

Permits or approvals are required from the U.S. Army Corps of Engineers (COE) for many activities within and adjacent to Pierce County Rivers. The specific permits required depend upon the location of the activity and the nature of the activity.

Section 10 of the Rivers and Harbors Act

Section 10 of the Rivers and Harbors Act of 1899 gave to the COE (that branch of the government that had been involved in coastal defense construction since 1775), the authority to preserve the public's ability and right for unobstructed commerce within navigable waters of the United States. Section 10 prohibits the unauthorized obstruction or alternation of any navigable water of the United States. Activities proposed within navigable waters that have the potential to interfere with navigation (this includes most activities) are subject to review and permitting by the COE and permits may be issued that authorize such obstruction or alteration when appropriate mitigation and compensation are provided.

Navigable waters--those waters subject to Section 10 jurisdiction—are those waters that are subject to the ebb and flow of the tide or that have ever been or that ever may be used to transport interstate or foreign commerce. Within Pierce County navigable waters have been determined to be limited to Puget Sound and the lower three miles of the Puyallup River. Examples of activities subject to Section 10 permitting include dredging, excavation, marina development, piers, wharves, floats, intake and outake pipes, pilings, bulkheads and other shoreline protection, ramps, fills, and overhead transmission lines. The construction of bridges is permitted under Section 9 of the River and Harbors Act, which is administered by the U.S. Coast Guard.

Federal Clean Water Act: Sections 401 and 404

The Clean Water Act (CWA) regulates discharges of pollutants into the waters of the United States. The basis of the CWA was enacted in 1972 and was called the Federal Water Pollution Control Act, but the Act was significantly reorganized and expanded in 1977; "Clean Water Act" became the Act's common name. This act supplemented the COE's traditional Section 10 permitting program, by giving them the additional authority of regulating the discharge of dredge or fill material into U.S. waters, including wetlands.

Section 404 of the CWA authorizes the Secretary of the Army; acting through the Chief of Engineers, to issue permits, after public notice and opportunity for public hearing, for the discharge of dredged or fill material in waters of the United States. Whereas Section 10 of the Rivers and Harbors Act applies only to Navigable Waters of the United States, Section 404 applies to *all* waters of the U.S. However, the question of what constitutes waters "of the United States" must still be addressed.

“Waters of the United States” include all navigable waters of the U.S., but also include all interstate waters including interstate wetlands (i.e. crossing state lines); all other waters and wetlands, the use, degradation, or destruction of which could affect the integrity of interstate or foreign commerce; tributaries of these waters; and wetlands adjacent to these waters or having a significant nexus with these waters.

Section 404 permits (also known commonly as “Corps Permits” or “Corps of Engineers Permits”) are required for most capital construction activities (such as the construction of new levees or revetments or gravel removal) in navigable waters of the United States, including adjacent wetlands and tributaries to navigable waters. Maintenance of existing facilities (such as replacing rock along a levee following a damaging flood) may be exempt from Section 404 permitting so long as there is no modification that changes the character, scope, or size of the original fill design.

Depending upon the nature of a proposed activity, one of several nationwide permits may be approved for a project, or an Individual Section 404 permit may be required. The COE has already issued 49 permits that apply nationwide, for specific activities determined to have minimal impacts to water of the United States. If a project proponent can show that a project will be done so as to meet all of the nationwide and regional general conditions then authorization letters to use a nationwide permit may be granted from the COE. It is unwise to undertake an action prior to receiving this authorization even if it is believed that all of the permit conditions will be met, because the COE has the sole right to judge whether or not the conditions are going to be met. Falsely concluding the applicability of a nationwide permit can place a project proponent into a Federal enforcement situation. Nationwide permits are desirable because they take significantly less time to process.

Nationwide permits expire (and are reissued—often with significant revisions) every five years. If a project receives a nationwide permit authorization letter and the permit expires, the applicant typically has 1 year from the date of permit expiration to complete the work. If the work will not be completed within that timeframe, a permit re-authorization must be requested. The current nationwide permits will expire March 12, 2012.

Section 401 of the CWA directs states to certify that federally permitted activities are consistent with State Water Quality laws. The Washington State Department of Ecology (DOE) is responsible for administering the state certification program. DOE has certified each nationwide permit and individually certifies individual Section 10 and 404 permits. The DOE Water Quality Certification occasionally adds additional mitigation/monitoring requirements or requires alterations to design features. The certification is required by federal law as a prerequisite to obtaining a federal permit. Structural flood control measures such as stream bank protection and gravel removal have the potential to create temporary instream turbidity in excess of state water quality standards during construction. Construction must be timed and undertaken in such a way as to avoid and minimize short term exceedances of state water quality standards.

Federal Disaster Mitigation Act of 2000

Hazard Mitigation Requirements for Funding of Disaster Recovery

The Disaster Mitigation Act of 2000 amended the Robert T. Stafford Disaster Relief and Emergency Assistance Act (Stafford Act) and represents United States Federal Law. The intent of the Congress in passing this Act was to provide an orderly and continuing means of assistance to State and local governments in carrying out their responsibilities to alleviate the suffering and damage which result from disasters by:

- Encouraging the development of comprehensive disaster preparedness and assistance plans, programs, capabilities, and organizations by States, Indian Tribal and local governments;
- Achieving greater coordination and responsiveness of disaster preparedness and relief programs

All state, local, and tribal government jurisdictions must have an approved local mitigation plan prior to receipt of HMGP funding.

Mitigation Planning is…A process for State, local, and Indian Tribal governments to identify policies, activities, and tools to implement mitigation actions. Mitigation is any sustained action taken to reduce or eliminate long-term risk to life and property from a hazard event. This process has four steps:

- organizing resources;
- assessing risks;
- developing a mitigation plan; and
- implementing the plan and monitoring progress.

A local mitigation plan represents the jurisdiction's commitment to reduce risks from natural hazards; it is a guide for policy makers as they commit resources to reduce the effects of such hazards.

The *Process and Content* of the plans is prescribed as follows:

PROCESS:

An open, public process is essential, and shall include:

- An opportunity for public comment during the process
- An opportunity for neighboring communities, regional agencies, businesses, academia, and non-profit interests to participate
- Review and include other plans, studies, reports, technical information, etc

CONTENT:

The Plan shall include:

- Documentation of the planning process
  - o Who prepared the Plan
  - o How it was prepared
  - o How the public was involved
- A Risk Assessment (RA) which provides a factual basis for activities proposed to reduce losses. The RA must be sufficient to enable the jurisdiction to identify and prioritize mitigation strategies. The Risk Assessment shall include:
  - o Type, location, extent, & probability of all natural hazards (+ previous)
  - o Description of vulnerability (impact to the community)
  - o Types & numbers of all structures (inc. future)
  - o Potential $$ losses
  - o General description of land uses and trends
- A Mitigation Strategy that provides a blueprint for reducing the losses identified to include:
  - o Mitigation goals to reduce or avoid long term vulnerabilities
  - o A section that ID's mitigation efforts particularly for new and existing structures
  - o An action plan to those strategies can be prioritized, emphasizing cost/benefit
  - o A Plan Maintenance Section which includes:
  - o A schedule and method for monitoring, evaluating, and updating the plan (5 year)
  - o A process by which jurisdictions incorporate the plan into other planning documents and capital improvement plans
  - o A process to involve the public in the maintenance process
  - o Documentation that the plan has been formally adopted by the jurisdiction
- A Plan Review that:
  - o Must be submitted to the State EMD, then to FEMA for approval.
  - o Must be reviewed and re-submitted within 5 years for continued eligibility

National Flood Insurance Program – Endangered Species Act Model Ordinance

Applicability of the Model Ordinance to the Pierce County Flood Plan

Pierce County has been identified as a community that is doing a lot of things right. It has adopted standards much stricter than the FEMA minimums and participates in FEMA's Community Rating System as a Class 2 community. (Class 10 is a community with minimum standards and Class 1 is as high as you can go.) Pierce County has already adopted Channel Migration Zone Mapping and standards, a zero rise criteria for building within the floodplain, and requirements for compensatory storage to offset any fill placed in the floodplain. These are a few of the new requirements within the model ordinance that will need to be considered for adoption by the cities.

There are a few areas of the biological opinion that will require Pierce County code changes. The biggest change will be requirements to adopt riparian habitat zones up to 250 feet, measured from the ordinary high water mark. These and other code changes will have to be examined and proposed to the County Council in order for the County to comply with the new requirements.

Overview

The National Flood Insurance Program (NFIP) was created in 1968 as a way to offer an alternative to disaster assistance for properties subject to flood damage. In return for federally supported flood insurance, local governments had to agree to regulate development in their floodplains in accordance with the Program's criteria. Since 1979, the program has been administered by FEMA. The NFIP has proven very effective as a way to shift the cost of flood damage from taxpayers to insur-ance policy holders.

While the intention of the NFIP was to shift the financial burden of flood damage to those living in the flooded areas it wasn't intended to address other floodplain management concerns such as the natural habitat of floodplains. This is especially true of those communities that only adopt the minimum regulations that FEMA mandates. A lawsuit was won by the National Wildlife Federation against FEMA claiming that the NFIP by offering flood insurance to structures in the floodplain actually encourages development in the floodplain and could adversely affect wildlife that uses the floodplain as habitat. The lawsuit was intended to force FEMA to abide by the Endangered Species Act and to enter into consultation with the National Marine Fisheries Service to determine if the NFIP has enough adverse effects on habitat to jeopardize a threatened species.

In 2008, the National Marine Fisheries Service issued a Biological Opinion pursuant to consultation resulting from a lawsuit brought against FEMA (Nat'l Wildlife Fed'n v. FEMA, 345 F. Supp. 2d 1151 (W.D. Wash. 2004). That opinion noted that continued implementation of the NFIP in the Puget Sound adversely affects the habitat of certain threatened and endangered species.

An earlier Biological Opinion that followed consultation ordered by litigation in the Florida Keys reached a similar conclusion (see, e.g., Fla. Key Deer v. Paulison, 522 F.3d 1133 (11th Cir. Fla. 2008) and Florida Key Deer v. Stickney, 864 F. Supp. 1222 (S.D. Fla. 1994)).

Endangered Species Conservation Biological Opinion

A copy of the Biological Opinion can be located by clicking [Biological Opinions | NOAA Fisheries]. The biological opinion goes into lengthy (some 250+ pages) descriptions of reasons why the current NFIP program adversely affects the species. Then it goes on to list out seven Reasonable and Prudent Alternatives (RPAs) that FEMA should adopt. They are:

1. Notification of Communities currently participating in the NFIP
2. Changes to Mapping Standards
3. Changes to Minimum Floodplain Management Criteria
4. Changes to the Community Rating System
5. Levees and Development
6. Mitigation
7. Monitoring and Adaptive Management

Potential Funding Sources for Flood Damage Reduction and Mitigation Projects

Applicability of this section to the Pierce County Rivers Flood Hazard Management Plan

There are numerous potential sources of federal and state funding to implement flood damage and mitigation projects as described below. However, funding for flood damage reduction and mitigation projects is invariably limited and not adequate to address all the needs. Pierce County has in the past and will continue to pursue these funding sources to address riverine flood reduction and mitigation projects in order to implement several of the recommendations from the Pierce County Rivers FHMP.

Overview

The primary sources of funding to implement flood damage and mitigation projects are administered by the Federal Emergency Management Agency (FEMA) and State of Washington Department of Ecology (WDOE). Specific programs offered by FEMA include Hazard Mitigation Grant Program (HMGP), Pre-Disaster Mitigation (PDM), Flood Mitigation Assistance (FMA), Repetitive Flood Claims (RFC) and Severe Repetitive Loss (SRL). Programs offered by WDOE include the Flood Control Assistance Account Program (FCAAP). Community Development Block Grants are typically made available following a Presidential Declared Disaster and are administered by local jurisdictions.

The above listed FEMA funding programs fall under the parent category of FEMA Hazard Mitigation Assistance (HMA). FEMA's HMA grants are provided to eligible Applicants (States/Tribes/Territories) that, in turn, provide subgrants to local governments and communities. The Applicant selects and prioritizes subapplications developed and submitted to them by subapplicants. These subapplications are submitted to FEMA for consideration of funding. The HMA grant programs provide funding opportunities for pre-and post-disaster mitigation. While the statutory origins of the programs differ, all share the common goal of reducing the risk of loss of life and property due to Natural Hazards.

The following is a description for each of the funding programs listed above:

Hazard Mitigation Grant Program (HMGP)

The HMGP awards grants to states and local governments to implement long-term hazard mitigation measures after a major disaster declaration. The purpose of the program is to reduce the loss of life and property due to natural disasters and to enable mitigation measures to be implemented during the immediate recovery from a disaster. Cost share for this grant is 75 percent federal, 12.5 percent state and 12.5 percent local.

Building Resilient Infrastructure and Communities (BRIC) - The BRIC program provides funds to states, territories, Indian tribal governments, communities, and universities for hazard mitigation planning and the implementation of mitigation projects prior to a disaster. Funding these plans and projects reduces overall risks to the population and structures, while also reducing reliance on funding from actual disaster declarations. Cost share for this grant is 75 percent federal and 25 percent local. The State does not cost share in BRIC program.

Flood Mitigation Assistance (FMA)

The FMA program was created as part of the National Flood Insurance Reform Act of 1994 (42 U.S.C. 4101) with the goal of reducing or eliminating claims under the National Flood Insurance Program (NFIP). FEMA provides FMA funds to assist states and communities in implementing measures that reduce or eliminate the long-term risk of flood damage to buildings, manufactured homes, and other structures insurable under the NFIP. Cost share for this grant is 75 percent federal and 25 percent local. The State does not cost share in FMA grants.

Natural Resource Damage Assessment (NRDA) Restoration Program

The NRDA Restoration Program was created to restore natural resources injured due to oil spills or hazardous substance releases into the environment. In partnership with affected state, tribal and federal trustee agencies, the program conducts damage assessments which is the first step toward resource restoration and use to provide the basis for determining restoration needs that address the public's loss and use of natural resources.

Flood Control Account Assistance Program (FCAAP)

RCW 86.26.050 provides that counties and other municipal corporations responsible for flood control maintenance may apply to Ecology for financial assistance for the preparation of comprehensive flood control management plans and for flood control capital and maintenance projects. The purpose of the plans is described in RCW 86.26.105. Ecology determines priorities and allocates available funds from the FCAAP among those counties applying for assistance, and adopts rules establishing the criteria by which those allocations are made. State cost sharing varies between 50 and 80 percent, depending upon the type of project applied for. The remainder is the local share.

Coastal Protection Fund – Terry Husseman Account (THA)

RCW 90.48.390 provides support for locally sponsored projects that restore or enhance the natural environment. These projects address water quality issues or fish and wildlife protection enhancement in or adjacent to waters of the state, such as streams, lakes, wetlands, or the ocean.

Floodplains by Design (FbD) Grant Program

To help communities live better in the floodplain, the competitive FbD grant program is a modern public-private partnership between Department of Ecology and The Nature Conservancy, focused on re-establishing floodplain functions in Washington's major river corridors. These multi-benefit projects reduce flood hazard risks to communities while restoring the natural functions of state rivers and their floodplains. The goal of this funding source includes benefitting an entire community and floodplain system, improving floodplain protection for towns and farms, restoring habitat for salmon and other important aquatic species, improving water quality, and enhancing outdoor recreation. State cost sharing is 80 percent, with local share covering the remaining 20 percent.

Stormwater Capacity Grant

A non-competitive funding source, awarded to Phase I and Phase II National Pollutant Discharge Elimination System (NPDES) municipal permittees for activities and equipment necessary for permit implementation.

Stormwater Grants of Regional or Statewide Significance (GROSS)

The Municipal Grant of Regional or Statewide Significance program will provide financial assistance to Phase I and Phase II cities and counties for projects that support implementation of the National Pollutant Discharge Elimination System (NPDES) Municipal Stormwater General Permits statewide or across a region. These projects can include assistance for permittees in a region or statewide to implement permit requirements, development of a product that can be used regionally or statewide, or regional or statewide access to advances in stormwater management technology or resources.

Streamflow Restoration Program

RCW 90.94.060 provides funding to help organizations implement local watershed plans and projects to improve streamflow and aquatic resources. There is no requirement for matching costs.

Water Quality Combined Funding (WQC)

This funding program provides grants for projects that improve and protect water quality throughout the state. This program combines grants and loans from state and federal funding sources to fund wastewater, stormwater, nonpoint and onsite sewage system projects. Depending on where the initial funding source came from, normally, the state/federal portion will fund 75 percent while the local share matched at 25 percent.

Wetlands Conservation Grant

This opportunity is a competitive grant matching program administered by the United States Fish and Wildlife Service (USFWS) to acquire, restore, and enhance wetlands of United States coastal states and trust territories. While only open to state agencies, counties, cities, and tribes are encourages to partner with the state for projects.

Brian Abbott Fish Barrier Removal Board (FBRB)

This grant opportunity funds projects such as removing a culvert or bridge or planning for a project to remove a barrier to provide or improve fish migration upstream and downstream of road crossings, dams, and other in-stream barriers. These may include replacing barrier culverts with fish passable culverts or bridges, removing barriers, or constructing fishways. The entity covers 85 percent of the project cost, while the applicant is responsible for 15 percent.

Salmon Recovery Funding Board (SRFB)

This board provides grants to protect or restore salmon habitat and assist related activities. In addition, the board funds elements necessary to achieve overall salmon recovery, including habitat projects and other activities that result in sustainable and measurable benefits for salmon and other fish species. The entity covers 75 percent and requires the applicant to be responsible for 15 percent.

Salmon Recovery and Puget Sound Acquisition and Restoration (PSAR)

This program is to help implement the most important habitat protection and restoration priorities. The projects address goals and actions defined in the regional recovery plans or lead entity strategies. RCO covers 75 percent of the project costs and requires the applicant be responsible for 15 percent.

National Flood Insurance Program (NFIP) and Community Rating System (CRS)

The National Flood Insurance Program (NFIP) was created in 1968 to address the rising cost of taxpayer funded disaster relief. The goal of the program is to decrease the amount of money the federal government pays in post-flood disaster relief by encouraging jurisdictions to reduce the risk to property owners through floodplain mapping, regulations, education and other programs. The NFIP is administered by the Federal Insurance Administration, which is part of the Federal Emergency Management Agency (FEMA).

The NFIP provides the financial backing for flood insurance policies within participating communities, making them more affordable to private property owners. There is an incentive for jurisdictions to adopt standards that exceed the minimum standards of the NFIP by reducing the cost of flood insurance premiums within jurisdictions with higher standards. The NFIP makes available affordable flood insurance to communities that adopt approved floodplain management regulations that meet or exceed FEMA standards.

While participation in the NFIP is technically not required under federal law, it is highly impractical for Pierce County to not participate in the program. Since most federally-backed mortgage loans require the purchase of flood insurance, non-participating communities are not eligible for flood insurance. Also, local jurisdictions are generally not eligible for federal assistance pursuant to Presidential Declared Disasters without being a NFIP participating community and having a good standing in the program. To continue flood insurance coverage, the County must remain in the NFIP and maintain and enforce minimum floodplain management regulations.

As a reward for communities that do more than meet minimum NFIP requirements by taking actions to minimize flood losses and promote public awareness of flood hazards, FEMA created the Community Rating System (CRS). Community participation in the CRS is voluntary. The CRS offers reduced insurance rates based upon the class rating of a community. The CRS contains ten classes. “Class 1” gives the greatest insurance premium reduction. A “Class 10” community receives no premium reduction. Pierce County was the first county in the nation to earn a “Class 5” rating and has continued to strive for even better ratings. Pierce County currently holds a “Class 2” rating, which results in a premium reduction of 40 percent.

FEMA's Flood Insurance Rate Maps (FIRMs) form the basis for critical area floodplain mapping for flood hazards. The FIRMs are used as the flood hazard regulatory mapping document.

Flood hazard management regulations are codified in Title 18E.70 of the Pierce County Code and criteria, and procedures are laid out in Chapter Nine of the *Pierce County Stormwater Management and Site Development Manual.*

Basin and floodplain management plans serve as part of the flood hazard mitigation plan for Pierce County. Improvement projects associated with the basin plan should, if possible, reduce flood hazards and improve the County's rating. Future flood hazard reductions could help to raise the County's rating from "Class 3" to a better class.

Community Rating System (CRS) – Section 510 (Floodplain Management Planning)

Applicability of CRS Section 510 (Floodplain Management Planning) to the Comprehensive Flood Hazard Management Plan

The Comprehensive Flood Hazard Management Plan will be used by Pierce County as the comprehensive floodplain management plan, specified in Section 510 of the CRS guidance, for credit points towards the community's National Flood Insurance Program (NFIP). The planning process will follow the guidance as much as is feasible in order to maximize the number of credit points available towards the County's CRS rating. This will also help any other jurisdiction seeking CRS credit points through adoption of the Plan.

Overview

Section 510 of the Community Rating System (CRS) program contains the guidance on planning for receiving credit points towards a community's National Flood Insurance Program (NFIP) rating (e.g., Class 3). Credit is provided for preparing, adopting, implementing, evaluating, and updating a comprehensive floodplain management plan or repetitive loss area analyses. The CRS does not specify what must be in a plan, but it only credits plans that have been prepared according to the standard planning process explained in Section 511. The planning process requires implementation of the following 10 planning steps: (1) organize to prepare the plan; (2) involve the public; (3) coordinate with other agencies; (4) assess the hazard; (5) assess the problem; (6) set goals; (7) review possible activities; (8) draft an action plan; (9) adopt the plan; and (10) implement, evaluate, and revise.

1. <u>Organize to prepare the plan</u> – the planning process must be conducted through a committee composed of staff from those community departments that will be implementing the majority of the plan's recommendations. When a multi-jurisdictional plan is prepared, at least one representative from each community

seeking CRS credit must be involved on the planning committee that is credited under this item.

2. <u>Involve the public</u> – the planning process must include an opportunity for the public to comment on the plan during the drafting stage and before approval (Required). The term "public" includes residents, businesses, property owners in the floodplain, and other stakeholders in the community. If the planning process is conducted through a planning committee, the committee must hold a sufficient number of meetings that involve planning steps 4 through 9. A public meeting must be held at the beginning of the planning process to obtain public input on hazards, problems, and possible solutions. Another public meeting must be held near the end of the process to obtain input of the draft plan.
3. <u>Coordinate with other agencies</u> – this includes neighboring communities, local, regional, state and federal agencies, businesses, academia, and other private and non-profit organizations.
4. <u>Assess the hazards</u> – this includes an assessment of flood hazards in the planning area, repetitive loss areas, and surface flooding identified in existing studies. It also includes a description of known flood hazards, including source of water, depth of flooding, velocities, and warning time, and a discussion of past floods.
5. <u>Assess the problem</u> – this includes a description of the impact that the hazards identified in step 4 have on: (a) life, safety, and health and the procedures for warning and evacuating residents; (b) critical facilities and infrastructure; and (c) the community's economy and tax base. The assessment should also include: (a) the number and types of buildings subject to the flood hazards, (b) properties that have received flood insurance claims, (c) areas that provide natural and beneficial functions, such as wetlands, riparian areas, and habitat for rare or endangered species, and (d) a description of development, redevelopment, and population trends.
6. <u>Set goals</u> – the Plan should include a statement of goals of the community's floodplain management program. Some plans set more specific objectives under each goal.
7. <u>Review possible activities</u> – the Plan must describe those activities or actions that were considered and note why they were or were not recommended. The discussion of each activity needs to be detailed enough to be useful to the lay reader. Activities to be considered include: (a) preventive activities such as zoning, floodplain regulations, and preservation of open space; (b) property protection activities such as acquisition, retrofitting or flood insurance; (c) plan review activities such as wetlands protection; (d) emergency services activities such as flood warning and sandbagging; (e) structural actions such as levee modifications, setback levees, or flood storage; and (f) public information activities, such as outreach projects and environmental education programs.

8. Draft an action plan – The action plan specifies those activities appropriate to the community's resources, hazards, and vulnerable properties. For each recommendation, the action plan must identify who does what, when it will be done, and how it will be financed. The actions must be prioritized and include a review of the benefits of the proposed projects and their associated costs.
9. Adopt the Plan – The Plan must be officially adopted by the community's governing body (Pierce County Council). If a multi-jurisdictional plan is prepared, it must be adopted by the governing board of each community seeking CRS plan credit.
10. Implement, evaluate and revise – provisions should be included to monitor plan implementation, review progress, and recommend revisions to the Plan in an annual evaluation report. To maintain CRS credit, the community must submit a copy of its annual evaluation report with its recertification each year and update the Plan at least every five years.

Pierce County - WA Region 5 Hazard Mitigation Plan and Addendum
Mitigation Planning in Pierce County

In 2019 the Pierce County Department of Emergency Management implemented the planning process for the County's Hazard Mitigation Plan. The eighteen-month process called together County departments to identify their roles in providing and maintaining a disaster resilient county government. A Hazard Mitigation Committee (HMC) was formed including representatives of all Pierce County departments.

Each department identified its role in providing services and its capabilities to protect and preserve Pierce County. The departments listed their "critical infrastructure" and their locations, hazard maps were developed for each natural hazard risk. Departments then identified where their infrastructure was at risk. Mitigation Strategies were then developed to identify the steps necessary to protect and preserve the assets and/or services of each department in line with the goals of the Plan.
The Pierce County Hazard Mitigation Plan was adopted by the County Council in August 2004, and the County then became eligible for funding for disaster relief as well as "pre-disaster funds" for implementing the mitigation strategies of the Plan. The HMC was to meet annually to review the progress towards mitigation and determine if changes to the Plan were necessary. Each Mitigation Plan was subject to a requirement to update the Plan within a five-year window.

In 2008, PC DEM undertook the update of the 2004 Plan. The initial effort was for each department to assess the progress made for each of their 2004 Mitigation Strategies and determine if other changes to their infrastructure listings were appropriate. One change obvious to the process was a change in the nomenclature from "critical infrastructure" to "infrastructure;" further, a determination was made to include only owned infrastructure for which the County would be responsible.
The new HMC determined the goals of the 2009 Plan update to be:

- Protect Life and Property
- Ensure Continuity of Operations
- Establish and Strengthen Partnerships for Implementation
- Protect the Environment
- Increase Public Preparedness for Disasters
- Promote a Sustainable Economy

The partner departments identified their natural hazard risks to be the same as the 2004 Plan:

- Earthquake
- Volcano (lahar)
- Flood

- Severe Storms
- Landslide
- Tsunami
- WUI Fire

In addition to the mitigation strategies carried over from the 2004 Plan, new mitigation strategies were added to the update. These mitigation strategies provide a “game plan” for further action by each department.

Additionally, FEMA revised Plan elements to address the National Flood Insurance Plan and “repetitive loss” properties. When losses to properties occurred on an on-going basis and costs of assistance were in excess of 125% of the value, additional losses would not be compensated.

In 2006 PC DEM received planning funds to undertake a two-and-a-half-year mitigation planning effort on behalf of other local jurisdictions. In 2009 the WA Region 5 Hazard Mitigation Plan was adopted as a “base plan” with 48 addenda representing jurisdictions across Pierce County. That Plan, highly acclaimed by Washington State Emergency Management and FEMA, would be the “base plan” to which subsequent plans, including the Pierce County Unincorporated Hazard Mitigation Plan, would be attached.

The Unincorporated Pierce County Addendum was adopted by the Pierce County Council on December 4, 2009. Also completed in 2009, was a Phase II and a Phase III mitigation plan were an additional 21 Addenda were added to the existing Region 5 Hazard Mitigation Plan bringing the total Addenda to 68 (several mergers in Fire Districts changed the original numbers). The final approval from FEMA for these additional addenda came on January 13, 2010. In addition, there are eight health and medical hazard mitigation plans that were completed under a contract from Multi-Care Organization, and these have also been incorporated into the larger Region 5 Hazard Mitigation Plan. A review and update from the original plan that expired on November 24, 2013, was completed and FEMA granted an extension allowing for further hazard analysis incorporating HAZUS-MH. That update encompassed the work of the 75 original jurisdictions under the direction and guidance of staff from the Pierce County Department of Emergency Management. In addition to the original jurisdictions, one new jurisdiction; Tanner Electric Company was added bringing the total Addenda to 76. A complete review of the July 23, 2015, edition occurred during 2019 and 2020. This current update originally began with the 76 existing Addenda with 5 deciding not to update their plans bringing the number down to 71. Two jurisdictions having standalone mitigation plans decided to join the Region 5 Mitigation Program and an additional 3 jurisdictions developed their first-time plans bringing the total Addenda back up to 76. The Pierce County Council formally adopted the Region 5 All Hazard Mitigation Plan “base plan” and the Unincorporated Pierce County Addendum in July 2020. These two plans must go through a formal review update process every five years.

Pierce County Comprehensive Plan (Title 19A)

The Pierce County Comprehensive Plan (Comprehensive Plan) is divided into multiple elements. Elements addressing land use, environment, utilities, and capital facilities include policies regarding flood control for major rivers in Pierce County. The Comprehensive Plan also divides the County into several subareas based upon geographic and community boundaries known as community plan areas. The Alderton-McMillin, Graham, Mid-County, and Upper Nisqually Community Plan areas lie within the Rivers Plan study area.

Land use policies provide a strategy for managing future growth and guide the adoption of countywide land use regulations. This includes specific policies restricting the development of industrial areas and public and community facilities within floodplains to only the facilities whose location is dependent on that specific location. The objective is to prevent loss of life, environmental damage, and capital expenditures associated with damages that could be caused by the location of such facilities within floodplains. Policies encourage zoning decisions that take into consideration the location of floodways and surface water to ensure low intensity uses that minimize hazards to public safety or loss of public and private property in a flood event.

Environment and critical area policies builds further upon the themes of loss-prevention. They encourage designations of flood-prone areas to rural areas to prevent high-intensity uses generally associated with urban designations from locating in floodplains. Policies also encourage the mitigation of potential impacts within flood hazard areas, especially to ensure no loss of floodwater storage. This includes the continued maintenance of County flood-control facilities and the acquisition and protection of floodplains to prevent future development within these areas.

Utility policies direct the protection and maintenance of existing flood control facilities. Structural policies also include provisions for the protection of critical habitat and species. Practices such as continued participation in the National Flood Insurance Program (NFIP), preservation of important undeveloped land such as streams, wetlands, coastal zones, channel migration zones, and floodways, and promotion of low impact development techniques are encouraged. Long range planning goals emphasize a systematic and comprehensive approach to surface water and flooding around the County. These goals include a balance of economic, environmental, engineering, and social factors in planning for flood control, a preference for nonstructural measures over structural measures, public education of measures taken and needed for cooperation, and a regional approach to surface water and flood water issues.

Capital facility policies include standards for the maintenance of existing facilities and establish levels of service for such facilities as the County grows. It also specifically identifies those levee systems maintained by the County. The adopted level-of-service for surface water management facilities is the 100-year, 24-hour storm.

Pierce County Park, Recreation and Open Space Plan (2020-2030)

The *Pierce County Parks, Recreation, and Open Space Plan, 2020-2030* (PROS Plan) is the guide for parks, trails, open space, and recreation planning for Pierce County Parks. The plan includes 10-year capital facilities improvement priorities based on an in-depth demand and needs assessment, adopted project priorities, and system preservation and improvement needs. The Plan uses an Adaptive Park System approach which provides regional elements serving a countywide audience, while balancing needs for local park service in urbanized residential unincorporated areas. The Adaptive Park System will provide significant recreation opportunities for many underserved residents by providing recreation opportunities in areas where they are needed most connected by a system of regional trails. A Regional Trail Plan is incorporated into the PROS Plan.

Some of the implementation goals addressed in the plan include:

- Coordination with other County departments to evaluate properties owned by Pierce County and consider how these sites fit into the community's vision for public use.
- Develop and manage parks and trails maintaining system quality and growing the park system to serve the growing County population, especially in urban unincorporated areas, while protecting unique environmental features.
- Establish a park system improvement plan that can be accomplished in the planning period based on fiscally conservative principles for capital improvements.

Additional information can be found at the following location: [Parks, Recreation & Open Space Plan | Pierce County, WA - Official Website (piercecountywa.gov)]

Flood Risk Assessment and Economic Analysis

Pierce County, Washington

April 2022

Prepared for:

Pierce County Planning and Public Works,
Surface Water Management Division

Prepared by:

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- Puget Sound Regional Council
- Washington State Department of Transportation
- Washington State Department of Revenue

That assistance notwithstanding, ECONorthwest is responsible for the content of this report. The staff at ECONorthwest prepared this report based on their general knowledge of economic benefits of floodplain restoration, and on information derived from the reports or data of others and sources believed to be reliable. ECONorthwest has not independently verified the accuracy of all such information, and makes no representation regarding its accuracy or completeness. Any statements nonfactual in nature constitute the authors' current opinions, which may change as more information becomes available. ECONorthwest staff that contributed to this study include Laura Marshall, Virginia Wiltshire-Gordon, Justin Sherrill, Shivangi Jain, Annalise Helm, Mark Buckley, and others.

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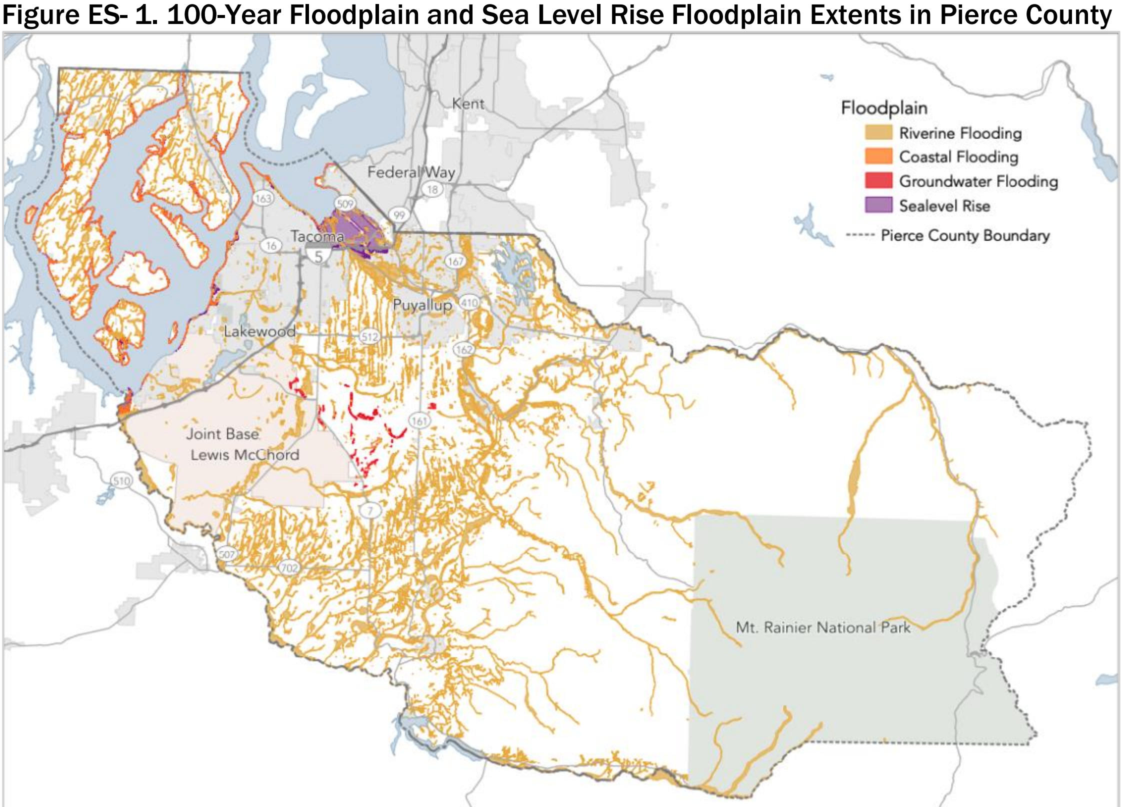
Executive Summary

Pierce County, Washington, spans from the heights of Mount Rainer in the east to the coastal waters and peninsulas of the Puget Sound in the west. The 1,806 square miles of the County contain a diversity of people, industries, and economic resources that together contribute to the $47.8 billion in Gross Regional Product for the County. Past flooding has imposed costs on society resulting from disruptions, damages, costs, and repairs. Major flooding has occurred as recently as 2021, with other large flood events in prior years.

This report was prepared for Pierce County Planning and Public Works, Surface Water Management Division to provide an analysis of the county-wide conditions associated with current and future flooding in Pierce County. The purpose of this analysis is to provide information to support implementing the *2023 Pierce County Comprehensive Flood Hazard Management Plan*.

There are two types of flood extents evaluated in this report: the 100-year floodplain and flooding from future sea level rise. Floods do not always behave predictably, and the floodplain maps depicted in this report may vary from actual flood events in the past and future. Figure ES- 1 depicts the 100-year floodplain extent – which includes riverine, groundwater, and coastal flooding – and sea level rise floodplain extent used for the analyses in this report.

Figure ES- 1. 100-Year Floodplain and Sea Level Rise Floodplain Extents in Pierce County



Source: Created by ECONorthwest

Summary of Impacts

There are 76,046 of acres of land within Pierce County within the **100-year floodplain**, representing approximately 7.0 percent of the County's total area. Approximately 27 percent of lands within the 100-year floodplain are residential, commercial, or industrial lands, the remainder are agricultural, public lands, recreation and open space, or other land types. A total of $2.8 billion of assessed value in on properties that are within the 100-year floodplain extent. The impacts of flooding in Pierce County within the 100-year floodplain include:

- Impacts to businesses and employees due to flooding depends upon the type of disruption. Physical damage from flooding can result in closures, as well as repair costs. Road closures can affect shipping and receiving, and cause delays or inaccessibility for employees. Flooding elsewhere can result in business owners or employees being unable to work due to emergencies elsewhere in the County. There are approximately 1,958 business establishments and 15,416 employees located in the 100-year floodplain. **A total of $4.3 million in labor income and $13.4 in output could be lost if all businesses and employees are disrupted for a one-day period due to flooding.**
- Properties and infrastructure within the floodplain can be damaged by water inundation and debris. Damage can require repairs and replacement, and some damaged items like mementos are irreplaceable. Flood damage to property varies by the depth of the inundation. Based on estimates of buildings within the floodplain, **approximately $947.3 million in property damage to buildings** could occur from a one-foot flood inundation for the entire 100-year floodplain extent. These estimates do not include costs associated with damage to landscaping or vehicles.
- Infrastructure can also be damaged by flooding, including roads, bridges, tunnels, telecommunication cables, electrical infrastructure, culverts, and others. Total damages from a 100-year flood are estimated as **$838.9 million for roads and bridges alone**. For households, businesses, and public entities, spending time and money on flood response means there are fewer resources that can be spent on other activities.
- Impacts to the transportation network due to flooding can ripple through the local economy because people rely on roads, bridges, rail, and other transportation for personal and business travel. If flooding results in transportation network closures then goods, services, and people take longer to reach their destination or forgo their trip entirely. Road closures can also restrict people's access to emergency services, such as hospitals, police, and fire stations. The impacts to the transportation network vary by the severity of the flood. **In a large flood event, road closures could cause up to $3.0 million in costs due to transportation disruptions. If a catastrophic levee breech occurs, the costs from transportation delays alone would be $59.3 million**.
- Agricultural producers will be most affected by flooding depending on the time of year when flooding occurs. Flooding when crops are most vulnerable is during the planting and harvesting season, generally spring, summer, and fall. **Approximately $49,232 in daily farmland gross revenue is located within the 100-year floodplain**. Agricultural processors are unlikely to be severely impacted because many source their inputs from outside the County. Other large processors like Wilcox Farms have limited land in the

floodplain and would be most likely to be disrupted from transportation impacts and supply chain delays due to flooding.

- **Flooding disproportionally affects people living in mobile homes** which are more likely to be located in a floodplain (10.2% of all mobile homes) compared to single family homes (7.9%) and multi-family homes (4.4%). On average, people located within the 100-year floodplain have a higher median household income and per capita income, are less likely to be renters, are less likely to be people of color, and are more likely to be over the age of 65.
- Outdoor recreation is a source of economic value for people who live in and visit Pierce County. The County is endowed with an array of recreation resources, including mountains, rivers, and the Puget Sound, as well as many developed recreation areas. Flooding impacts recreation amenities by inundating the resource or resulting in accessibility due to road closures. In the peak season, a one-week closure at Mount Rainier National Park, such as those that have occurred in the past due to landslides that restrict vehicle access, would result in a **loss of $1.6 million in visitor spending**. Other large recreation areas that would result in large reductions in visitor spending due to closures include Crystal Mountain Ski Resort, Chambers Creek Regional Park, and Point Defiance Park. In addition, flooding on fields during the fall and spring sports seasons will impact field sports and the people who play them, particularly youth sports.
- There are four wastewater treatment plants (WWTPs) in Pierce County that are located within either the 100-year or sea level rise floodplain. Flooding of WWTPs could result in discharge of untreated wastewater into the natural system, as well as damage infrastructure within the WWTP, particularly electrical components. All four wastewater treatment plants have implemented measures to reduce flood risks and are not expected to be impacted by a 100-year flood. **Tacoma Central Wastewater Treatment Plant, Puyallup Water Pollution Control Plant, and Sumner WWTP are protected by 100-year flood standards but could experience impacts in a 500-year flood or other flood high enough to breach the floodwalls. Orting WWTP is protected from a 500-year flood by levee standards, but it could impact from levee breach or overtopping.**

The sea level rise floodplain comprises approximately 9,307 acres or 0.9 percent of land area in Pierce County. Pierce County has approximately 225 miles of coastline. If sea level rise flooding were to occur today, there would be a total of $2.7 billion in assessed values of properties located within the floodplain extent. Additional impacts from future sea level rise include:

- **Sea level rise is expected to inundate large portions of the Port of Tacoma**. The Port is a central hub for imports and exports for Pierce County and is a source of **42,100 jobs and almost $3 billion dollars of economic activity**.[1] In 2020, 3.3 million containers were processed through the Port, valued at over $65.8 billion.
- Sea level rise flooding could impair access to the transportation network, including roads, railroads, and ferry landings. During a flood emergency, this may mean that people are unable to access or have longer routes to critical services, such as hospitals

[1] Port of Tacoma, *About*, available at: https://www.portoftacoma.com/about.

and fire stations. **Areas that are accessed via bridge as well as dead end roads, both of which are most common in the Key Peninsula area and on the islands, will face the longest detour times and be most at risk of being unable to access services.**

Table ES- 1. Key Findings: Flooding in Pierce County

	100-Year Floodplain	Sea Level Rise Floodplain	Total for Pierce County SPA Area
Number of Acres	76,046	9,307	1,080,272
Population	69,794	9,028	871,555
Acres of Farmland	6,289	484	24,287
Number of Business Establishments	1,958	1,578	70,872
Number of Employees	15,416	29,598	456,452
Avg. Daily Total Labor Income	$4.3 million	$8.9 million	$81.3 million
Avg. Daily Total Output	$13.4 million	$29.7 million	$212.7 million
Total Assessed Value of Properties	$2.8 billion	$2.74 billion	137.7 billion
Property Damage Estimate	$947.2 million	$1.13 billion	N/A

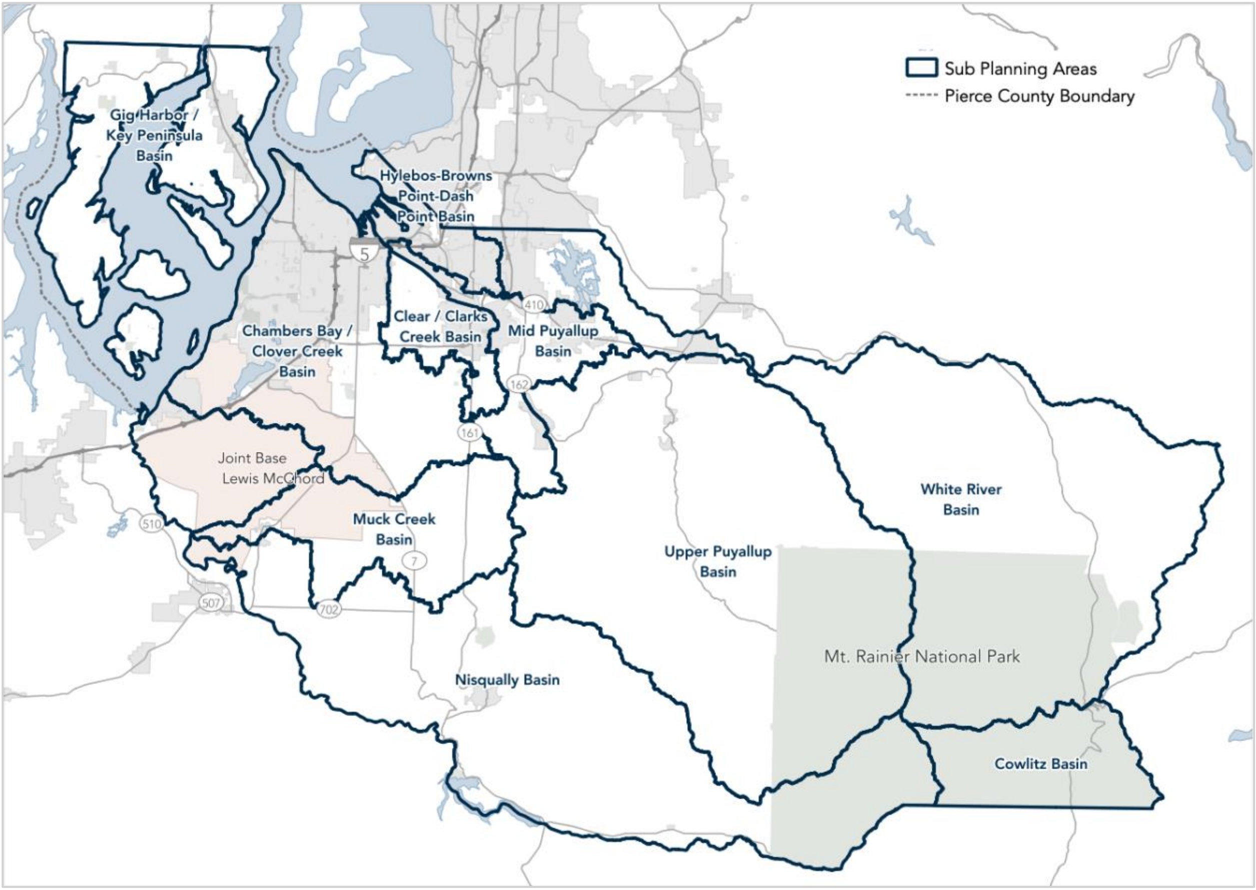
Source: Created by ECONorthwest

Sub-Planning Area Detailed Impacts

Sub-planning areas (SPAs) correspond to the watersheds in Pierce County and are used throughout this analysis to provide regional descriptions of flood risk. There are nine SPAs used for this analysis.[2] Figure ES- 2 provides a map of Pierce County with the location of each SPA. The subsections below detail flood impacts specific to each SPA.

[2] Cowlitz Basin, located in the southeast portion of Mt. Rainier National Park, does not have flooding and has a terminus outside of Pierce County, so it is not considered as a SPA.

Figure ES- 2. Sub-Planning Areas (SPAs) in Pierce County



Source: Created by ECONorthwest

Chambers Bay/Clover Creek Basin SPA Impacts

Chambers Bay/Clover Creek Basin SPA extends from Point Defiance to Elk Plain, extends South to the City of DuPont, and contains the Southwest portion of the City of Tacoma and a portion of the Port of Tacoma. It also contains 35 percent of Joint Base Lewis–McChord. This SPA contains a portion of the Puyallup Tribe of Indians Reservation area. The Chambers Bay/Clover Creek Basin SPA has the highest population of all the SPAs – approximately half of the County's total population live here. It also has the highest number of businesses and employees, but it has the smallest percentages of those that are affected by flooding of the SPAs. Chambers Bay/Clover Creek Basin SPA has the most groundwater flooding of any SPA, concentrated in the area between Elk Plain, Fredrickson, and Graham.

Chambers Bay/Clover Creek Basin SPA contains 1,463 acres that are within the sea level rise floodplain extent (1.4 percent of the SPA land area total). In addition to areas along the coastline, sea level rise is expected to impact the areas of this SPA within the Port of Tacoma.

This SPA is home to Point Defiance Zoo and Aquarium and the Fort Nisqually Living History Museum which have a total annual visitation of over 700,000 people. Chambers Creek Regional Park, which sees over 500,000 people per year who use the two large trail systems and includes the Chambers Bay Golf Resort, is also within this SPA. Tacoma Central Wastewater Treatment Plant is also located within this SPA.

Table ES- 2. Key Findings: Flooding in Chambers Bay/Clover Creek Basin SPA

	100-Year Floodplain	Sea Level Rise Floodplain	Total for SPA
Number of Acres	7,314	1,463	106,798
Population	22,709	2,660	477,574
Acres of Farmland	37	37	1,450
Number of Business Establishments	330	318	37,915
Number of Employees	1,490	4,724	248,582
Avg. Daily Labor Income	$409,019	$1,530,879	N/A
Avg. Daily Output	$1.2 million	$5.4 million	N/A
Total Assessed Value of Properties	$303.6 million	$731.2 million	N/A
Property Damage Estimate	$127.5 million	$283.4 million	N/A

Source: Created by ECONorthwest

Clear/Clarks Creek Basin SPA Impacts

Clear/Clarks Creek Basin SPA is the second smallest SPA by geographic area (after Hylebos-Browns Point-Dash Point Basin SPA). This SPA extends east of the City of Tacoma and contains tributaries to the Puyallup River. This SPA contains a portion of the Puyallup Tribe of Indians Reservation area. The Clear/Clarks Creek Basin SPA does not contain any portion of the Port of Tacoma, but is subject to sea level rise flooding at the confluence with the Puyallup River. This SPA is suburban and rural, containing parts of the City of Puyallup and the communities of Waller, Summit, and South Hill. For its size, Clear/Clarks Creek Basin SPA has a larger portion of agricultural revenues located in the 100-year floodplain extent at $2.1 million per year, which supports an estimated 48 jobs. Over half of the total agricultural revenue in this county is for berry and vegetable crops.

Table ES- 3. Key Findings: Flooding in Clear/Clarks Creek Basin SPA

	100-Year Floodplain	Sea Level Rise Floodplain	Total for SPA
Number of Acres	2,680	353	21,044
Population	6,225	316	74,516
Acres of Farmland	406	44	882
Number of Business Establishments	269	18	6,241
Number of Employees	2,618	146	36,205
Avg. Daily Labor Income	$779,533	$44,442	N/A
Avg. Daily Output	$1.9 million	$131,116	N/A
Total Assessed Value of Properties	$272.6 million	$7.8 million	N/A
Property Damage Estimate	$186.8 million	$14.6 million	N/A

Source: Created by ECONorthwest

Gig Harbor/Key Peninsula Basin SPA Impacts

Gig Harbor/Key Peninsula Basin SPA differs significantly from the other SPAs because it contains the islands and peninsulas of Pierce County. This area is mostly rural, comprised of smaller communities, with the exception of the City of Gig Harbor. There is some riverine flooding, particularly on Key Peninsula, but most flood risks are due to coastal flooding and sea level rise given the large amount of coastline. Transportation impacts are particularly severe for this SPA due to the number of bridges and dead-end roads that can cause long delays and even inaccessibly, which have economic costs and pose threats to safety for emergency service access. Gig Harbor/Key Peninsula Basin SPA has by far the largest amount of agriculture located within the sea level rise floodplain extent with $7.7 million in annual market value – however, almost all of that value is for shellfish – which is likely not actually impacted by sea level rise flooding (1,613 acres impacted by sea level rise are pastureland).

Table ES- 4. Key Findings: Flooding in Gig Harbor/Key Peninsula Basin SPA

	100-Year Floodplain	Sea Level Rise Floodplain	Total for SPA
Number of Acres	6,794	2,394	79,292
Population	5,409	1,514	65,335
Acres of Farmland	265	322	882
Number of Business Establishments	210	284	7,320
Number of Employees	400	701	22,705
Avg. Daily Labor Income	$109,613	$160,496	N/A
Avg. Daily Output	$333,102	$412,882	N/A
Total Assessed Value of Properties	$322.1 million	$671.1 million	N/A
Property Damage Estimate	$77.3 million	$124.8 million	N/A

Source: Created by ECONorthwest

Hylebos-Browns Point-Dash Point Basin SPA Impacts

The Hylebos-Browns Point-Dash Point Basin SPA has the highest value of economic activity located in the floodplain of any of the SPAs, despite it being the smallest of the SPAs. This SPA is urban and industrial. It contains a large portion of the Port of Tacoma that extends to I-5, goes North along the county line to Dash Point in the west and ends just before the City of Sumner in the east. This SPA contains the City of Fife, the City of Milton, and Puyallup Tribal Reservation land. Unlike the other urban SPA, Chambers Bay/Clover Creek Basin SPA, Hylebos-Browns Point-Dash Point Basin SPA is subject to large areas of sea level rise flooding in the Port of Tacoma as well as flooding from Wapato Creek. Although it is urban, there are agriculture lands in this SPA that are within the 100-year floodplain extent, including berries and vegetable crops. A large portion, approximately 63 percent, of land within the 100-year floodplain in this SPA is commercial, industrial, or residential. Accordingly, this SPA has the highest land values and estimates of property damage due to flooding of any of the SPAs.

Table ES- 5. Key Findings: Flooding in Hylebos-Browns Point-Dash Point Basin SPA

	100-Year Floodplain	Sea Level Rise Floodplain	Total for SPA
Number of Acres	1,159	4,127	15,959
Population	5,374	3,446	46,402
Acres of Farmland	105	20	923
Number of Business Establishments	144	833	4,202
Number of Employees	4,179	20,804	38,737
Avg. Daily Labor Income	$975,529	$6.2 million	N/A
Avg. Daily Output	$3.2 million	$19.9 million	N/A
Total Assessed Value of Properties	$187.7 million	$1.18 billion	N/A
Property Damage Estimate	$61.1 million	$668.8 million	N/A

Source: Created by ECONorthwest

Mid Puyallup Basin SPA Impacts

The Mid Puyallup SPA is the third-smallest SPA of the nine, but has the highest percentages of its population (17 percent of total in SPA) and business establishments (9.3 percent of total in SPA) located within the 100-year floodplain extent. Approximately 57.3 percent of the land impacted by flooding is commercial, industrial, or residential land. This SPA does not have any coastline, so there is no coastal or sea level rise flooding, only riverine flooding. This SPA contains the Puyallup River from Interstate 5 to Orting and extends east to include Bonney Lake. The western portion contains primarily industrial lands and then as the SPA extends east it is primarily through rural areas. This SPA contains a portion of the Puyallup Tribe of Indians Reservation area. This SPA is home to the Puyallup Water Pollution Control Plant and a portion of the Sumner WWTP (this WWTP is at the confluence of the Puyallup River and White River). The Mid Puyallup SPA has the third most farmland of any SPA. This SPA has a large portion of nursey crops $3.9 million of annual revenues are in the floodplain for this crop type out of $6.5 million total for the SPA. This SPA has the highest amount of roadway that could be damaged by flooding with 106,017 feet.

Table ES- 6. Key Findings: Flooding in Mid Puyallup Basin SPA

	100-Year Floodplain	Sea Level Rise Floodplain	Total for SPA
Number of Acres	5,798	585	33,357
Population	13,268	516	78,181
Acres of Farmland	942	61	3,330
Number of Business Establishments	568	125	6,100
Number of Employees	3,723	3224	33,806
Avg. Daily Labor Income	$1.1 million	$1.1 million	N/A
Avg. Daily Output	$3.5 million	$3.8 million	N/A
Total Assessed Value of Properties	$604.7 million	$153.1 million	N/A
Property Damage Estimate	$317.2 million	$43.0 million	N/A

Source: Created by ECONorthwest

Muck Creek Basin SPA Impacts

The Muck Creek Basin SPA is the only other SPA, other than Chambers Bay/Clover Creek Basin SPA, that has groundwater flooding. This SPA is located in a rural area southeast of JBLM and the community of Elk Plain. The Muck Creek Basin SPA is the second least populated of all the SPAs, after the Upper Puyallup SPA. The western portion of the SPA contains approximately 21 percent of JBLM, which has some flood risks in unbuilt and unpopulated areas along Muck Creek. This SPA has the second most farmland of any SPA, after Nisqually Basin SPA. Almost all the agriculture within the floodplain, 98 percent, is pastureland. Muck Creek Basin SPA has the lowest number of total employees in the floodplain extent at 101 and lowest amount of economic output in the floodplain at $22,916 per day.

Table ES- 7. Key Findings: Flooding in Mid Puyallup Basin SPA

	100-Year Floodplain	Sea Level Rise Floodplain	Total for SPA
Number of Acres	7,136	0	56,467
Population	3,109	0	29,289
Acres of Farmland	1,361	0	5,053
Number of Business Establishments	90	0	1,889
Number of Employees	101	0	13,973
Avg. Daily Labor Income	$29,277	$0	N/A
Avg. Daily Output	$88,442	$0	N/A
Total Assessed Value of Properties	$34.0 million	$0	N/A
Property Damage Estimate	$19.2 million	$0	N/A

Source: Created by ECONorthwest

Nisqually Basin SPA Impacts

The Nisqually Basin SPA is long and varied. It extends from Puget Sound near DuPont to Mount Rainier. It is the third largest SPA by land area but the third smallest SPA by population size. This SPA contains 44 percent of JBLM by land area and most of JBLM's buildings are within this SPA. The Nisqually Basin SPA also contains a portion of the Nisqually Indian Tribe Reservation Area. Along the coast there are multiple golf courses in this SPA, as well as the Billy Frank Jr. Nisqually National Wildlife Refuge. Sea level rise within this SPA is all contained within the Wildlife Refuge and does not affect any acres of built or agricultural lands. In addition to containing part of Mount Rainier National Park, this SPA is also home to SR-706, one of the primary access points to the park. In 2020, SR-706 closed for 16 days due to flood-related mudslides that restricted access to the National Park as well as for nearby residents.

The Nisqually Basin SPA is also home to Wilcox Farms, a large egg-producer. Riverine flooding does not affect the farm's buildings, but can inundate pastureland. The Nisqually Basin SPA has the highest number of total agricultural acres of all the SPAs at 6,996 and the highest number of acres in the floodplain at 2,317. Approximately 81 percent of the agricultural land in the floodplain is pasture. There are berry and vegetable acres in the floodplain as well.

Table ES- 8. Key Findings: Flooding in Mid Puyallup Basin SPA

	100-Year Floodplain	Sea Level Rise Floodplain	Total for SPA
Number of Acres	22,265	386	232,170
Population	3,682	576	30,179
Acres of Farmland	2,317	0	6,996
Number of Business Establishments	123	0	1,946
Number of Employees	222	0	29,911
Avg. Daily Labor Income	$59,372	$0	N/A
Avg. Daily Output	$181,932	$0	N/A
Total Assessed Value of Properties	$39.0 million	$0	N/A
Property Damage Estimate	$33.8 million	$0	N/A

Source: Created by ECONorthwest

Upper Puyallup Basin SPA Impacts

The Upper Puyallup Basin SPA is the largest of all the SPA. It is located in the eastern part of Pierce County and extends from Orting, northeast to Buckley, and southeast to Mount Rainier. In addition to the Upper Puyallup River this SPA also contains a large tributary, the Carbon River, as well as multiple creeks. This SPA is the least populated of all the SPAs. It also has the lowest percentage of its land located in a floodplain at 4.5 percent. There is only riverine flooding in this SPA, no groundwater, coastal, or sea level rise flooding. This SPA contains the Orting WWTP, located along the White River just upstream from the confluence with the Puyallup River. This SPA is also home to SR-165 which provides access to a portion of Mount Rainier National Park. The Upper Puyallup Basin SPA has 284 agricultural acres or 20 percent of total acres in the floodplain, primarily in nursery and pasture crops.

Table ES- 9. Key Findings: Flooding in Upper Puyallup Basin SPA

	100-Year Floodplain	Sea Level Rise Floodplain	Total for SPA
Number of Acres	11,354	0	253,310
Population	3,416	0	28,775
Acres of Farmland	284	0	1,477
Number of Business Establishments	93	0	1,464
Number of Employees	147	0	2,635
Avg. Daily Labor Income	$43,071	$0	N/A
Avg. Daily Output	$138,089	$0	N/A
Total Assessed Value of Properties	$127.2 million	$0	N/A
Property Damage Estimate	$80.4 million	$0	N/A

Source: Created by ECONorthwest

White River Basin SPA Impacts

The White River Basin SPA contains the White River, which is named as such due to the high amounts of sediment within the river that originates from the glaciers of Mount Rainier. The

White River SPA is the second largest SPA after the Upper Puyallup SPA, and has 4.8 percent of its total land acres in the 100-year floodplain (all riverine flooding). The White River SPA extends from Mount Rainier in the east through the northern portion of Pierce County and includes the City of Buckley and Lake Tapps before it ends at SR-161. This SPA contains a portion of the Muckleshoot Indian Tribe Reservation area.

This SPA is varied in that it has industrial, residential, rural, and forested land types throughout its extent. However, over the $222 million of total land value located within the floodplain $171 million or 77 percent is commercial and industrial land, most of which is located near Sumner. The White River Basin SPA has the second highest percentages of its populations that is located in the 100-year floodplain at 16.0 percent. This SPA contains Crystal Mountain as well as SR-410 which provides access to both Crystal Mountain and Mount Rainier National Park. In February 2020 a mudslide on SR-410 caused Crystal Mountain Resort to close for four days during the height of the winter recreation season.

Table ES- 10. Key Findings: Flooding in the White River Basin SPA

	100-Year Floodplain	Sea Level Rise Floodplain	Total for SPA
Number of Acres	11,546	0	241,706
Population	6,602	0	41,305
Acres of Farmland	572	0	2,769
Number of Business Establishments	131	0	3,794
Number of Employees	2,537	0	29,899
Avg. Daily Labor Income	$828,496	$0	N/A
Avg. Daily Output	$2.7 million	$0	N/A
Total Assessed Value of Properties	$561.5 million	$0	N/A
Property Damage Estimate	$43.9 million	$0	N/A

Source: Created by ECONorthwest

1 Introduction and Background

1.1 Purpose of the Report

This report, prepared for Pierce County Planning and Public Works, Surface Water Management Division (SWM) is a Flood Risk Assessment and Economic Analysis of the county-wide conditions associated with current and future flooding in Pierce County. The purpose of this analysis is to provide information to support implementing the 2023 Pierce County Comprehensive Flood Hazard Management Plan (FHMP). This assessment estimates the flood damage impacts of not implementing the FHMP as well as a hazard profile of current flood risks and past flood events and characteristics.

Although the economic impacts of flooding evaluated in this analysis are specific to the 100-year floodplain and a future sea level rise scenario, the information contained herein can inform the effects of other types of flooding that also results in disruption, damage, or other economic costs. Larger flood events, such as a 500-year flood with a 0.2 percent annual chance of occurrence, could result in additional costs beyond those calculated for the 100-year flood.

There is inherent uncertainty associated with modelling a natural event like a flood. Floods do not always behave predictably. A 100-year flood may not impact all areas simultaneously, so impacts may not occur in all areas. However, sometimes events are acute and can result in localized flooding that higher than estimates impacts for a smaller geographic area. In particular, levee breaches or overtopping may result in flood impacts in other locations and beyond the values estimated in this analysis. When the flood occurs is another source of uncertainty. Flooding during the work week will have different impacts than the weekend. Flooding during or outside of agricultural planting and harvest seasons will similarly have varying impacts. Recreation will be affected differently if flooding is during the winter ski season or when fields are needed for sports. While the values in this report provide estimates, they are most suited to be used for county-wide planning, rather than evaluating localized effects.

1.2 Organization of this Report

This report is organized into sections that describe the types of impacts that flooding could have on Pierce County's economy and economic resources. The subsequent chapters of the report are:

- **Chapter 2. Economic Resources in the Floodplain:** This section describes the economic resources located in each river basin, referred to as the Sub-Planning Area, and for each type of flooding.
- **Chapter 3. Economic Impacts of Flooding:** This section calculates the magnitude of economic resources that could be affected by flooding in terms of jobs, labor income, economic activity, and fiscal revenues. This section also describes the potential flood impacts to the agricultural sector of the County's economy.

- **Chapter 4. Distributional Effects of Flooding:** This section describes the socioeconomic and demographics of populations living in and around the floodplain to inform the potential vulnerability of different communities, as well as describe principles of equitable approaches for floodplain management.
- **Chapter 5. Flood Impacts to Properties:** report describes property and improvements located within the floodplain and estimates the monetary costs of potential damage to those physical resources.
- **Chapter 6. Transportation Impacts:** This section presents four road closure scenarios based on differing flood events and calculates the travel cost disruption that would occur. The section also addresses impacts to railroads that intersect with the floodplain.
- **Chapter 7. Sea Level Rise Transportation Impacts:** This section evaluates access to critical infrastructure of hospitals and fire stations based on road closures under a sea level rise flooding scenario. The section also evaluates railroads located within the floodplain and the impact of flooding.
- **Chapter 8. Flood Impacts to the Recreation Sector:** This section describes how flooding could impact visitation to four large recreation sites in Pierce County and evaluates the economic impacts in terms of reduced visitor spending.
- **Chapter 9. Flood Impacts to Wastewater Treatment Plants and Overflows:** This section identifies flood risks and impacts of flooding at four wastewater treatment plants in Pierce County.

1.3 Flooding Evaluated in this Report

There are two types of flood extents evaluated in this report: the 100-year floodplain and flooding from future sea level rise. The first, flooding that is within the **100-year floodplain** extent, is based on current conditions and represents the magnitude of flooding that has a 1 percent chance of happening in any year. The 100-year floodplain extent is further divided into three subcategories, representing the three sources of flooding: riverine, groundwater, and coastal flooding. These categories are based on floodplain categorization by FEMA.[3] Throughout this report, references to "the floodplain" refer to the current 100-year floodplain extent. Flooding due to sea level rise is denoted as "sea level rise flooding".

There are 75,645 acres of Pierce County that are within the 100-year floodplain, representing approximately 6.5 percent of the total area of Pierce County.[4] Table 1-1 summarizes the acres of flooding within the current 100-year floodplain for each of the three flooding types.

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[3] See Appendix A for additional detail on the data sources and detailed descriptions of floodplain extents.

[4] Calculation is based on an estimated area of 1,800 square miles in Pierce County, from: Vleming, J. (2021). *Pierce County Profile.* Washington Employment Security Department. Available at: https://media.esd.wa.gov/esdwa/Default/ESDWAGOV/labor-market-info/Libraries/Regional-reports/County-Profiles/Pierce%20County%20Profile%202020.pdf

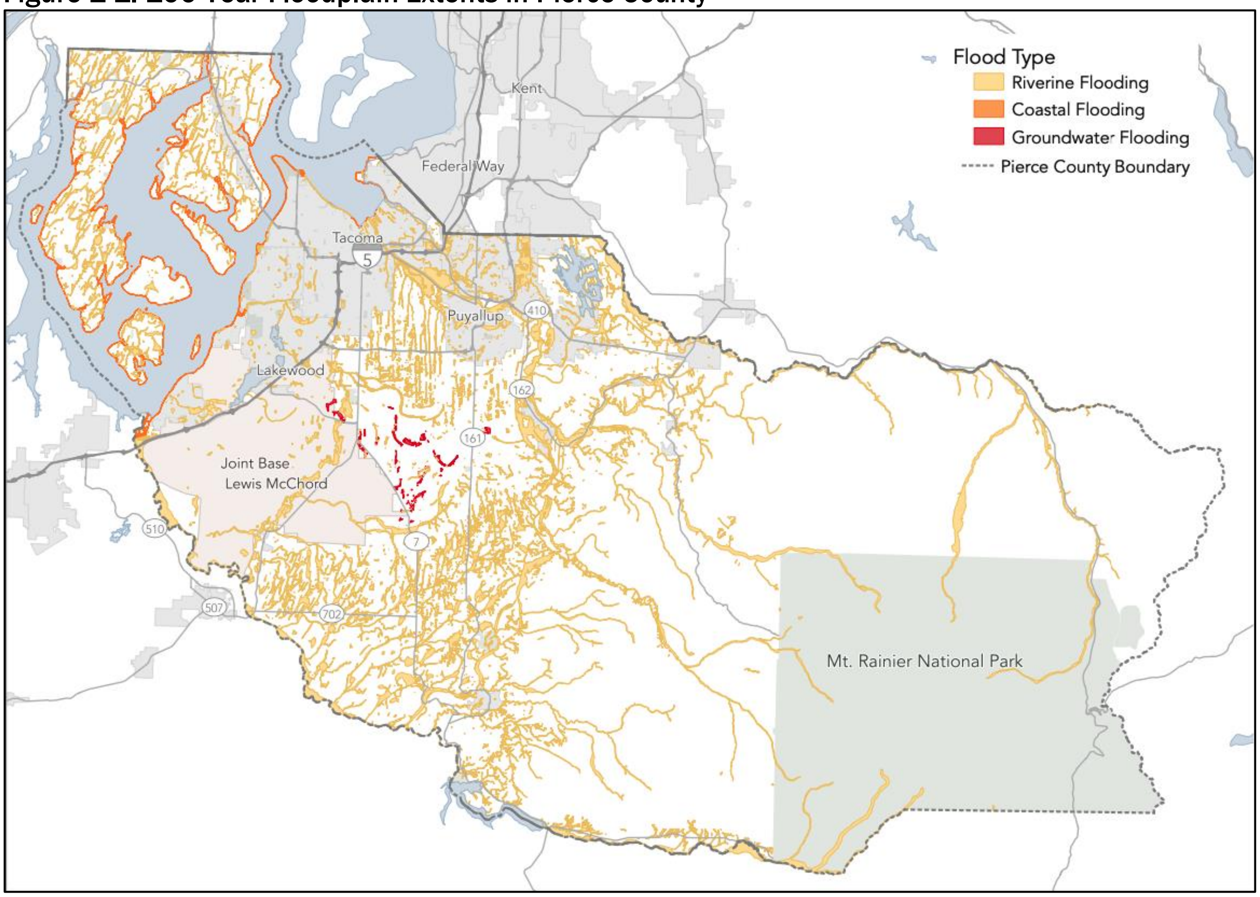
Table 1-1. Acres within 100-Year Floodplain in Pierce County, Washington

Flood Type	Total Acres of Floodplain in Pierce County	Percent of Total
Riverine	53,927	71.3%
Coastal	21,454	28.4%
Groundwater	264	0.3%
Total	**75,645**	**100%**

Source: ESA analysis of Pierce County Open GeoSpatial Data Portal. (2020). *Regulated Floodplain 2017*. Available at: https://gisdata- piercecowa.opendata.arcgis.com/datasets/regulated-floodplain-2017

Figure 1-1 displays the extents of each type of flooding associate with the 100-year floodplain. Riverine flooding occurs throughout Pierce County. Groundwater flooding is concentrated within the low-lying areas located southwest of the City of Puyallup and northeast of Joint Base Lewis McChord. Coastal flooding is throughout the shoreline with the Puget Sound, except in areas with high cliffs.

Figure 1-1. 100-Year Floodplain Extents in Pierce County

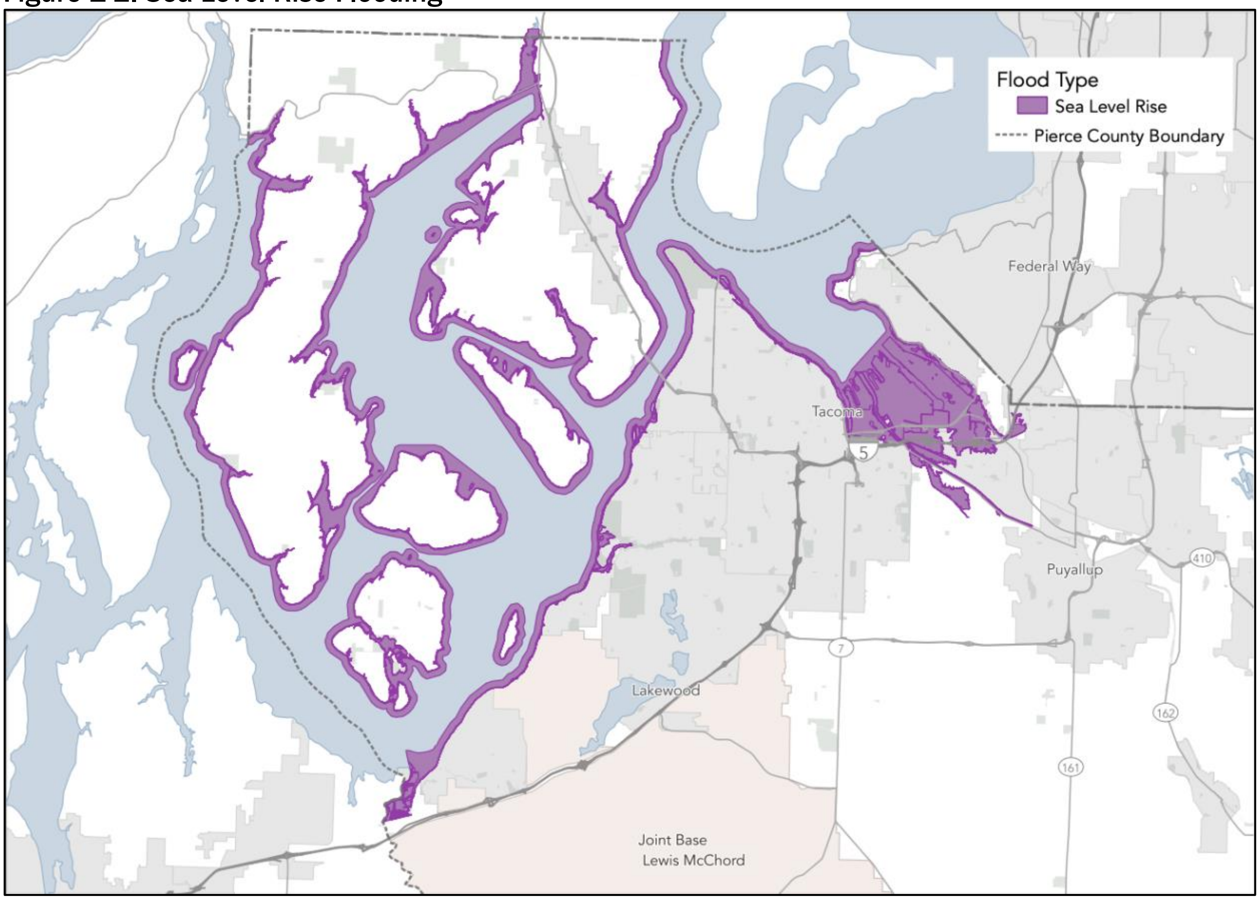


Source: Created by ECONorthwest

The second type of flooding evaluated in this analysis is flooding that is attributable to future potential sea level rise. The economic impacts of sea level rise have considerable uncertainty because they are modelling an event that would occur in the future. The sea level rise scenario that is used for this analysis is a four-foot rise above the current coastal high hazard base flood elevation determined by FEMA. The four-foot increase from the base flood elevation represents flooding in 2100 between the NOAA -2017 Intermediate and NOAA-2017 Intermediate High scenarios from the Sea-Level Change Curve Calculator (Version 2021.12).[5] This is the same sea level rise definition used for the *Costal Infrastructure* portion of Pierce County's 2023 Comprehensive Flood Hazard Management Plan. As the County and others plan for sea level rise by implementing measures to reduce its effect on economic resources, such as managed retreat of infrastructure, the effects evaluated in this analysis may not occur, but there will be costs associated with those investments.

Sea level rise flooding is concentrated on coastal areas and has the largest inland extent in the Port of Tacoma. Figure 1-2 depicts the extent of the sea level rise flooding used for this analysis.

Figure 1-2. Sea Level Rise Flooding



Source: Created by ECONorthwest

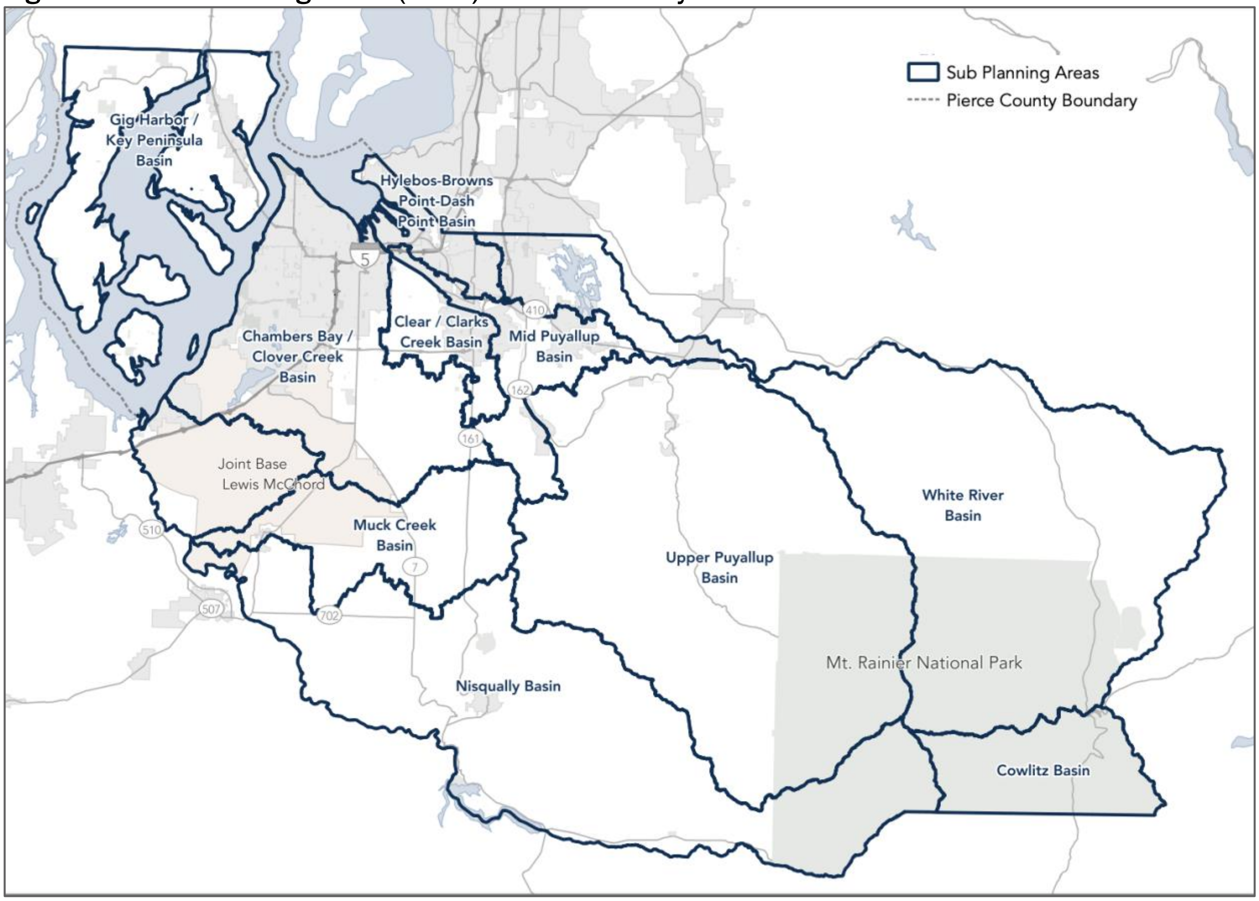
1.4 Sub-Planning Areas

Sub-planning areas (SPAs) correspond to the watersheds in Pierce County and are used throughout this analysis to provide regional descriptions of flood risk. There are nine SPAs

[5] U.S. Army Corps of Engineers. (2017). Sea-Level Change Curve Calculator (Version 2021.12). Available at: https://cwbi-app.sec.usace.army.mil/rccslc/slcc_calc.html

used for this analysis.[6] Figure 1-3 provides a map of Pierce County with the location of each SPA. Figure 1-4 depicts the 100-year floodplain extents overlaid with each SPA.

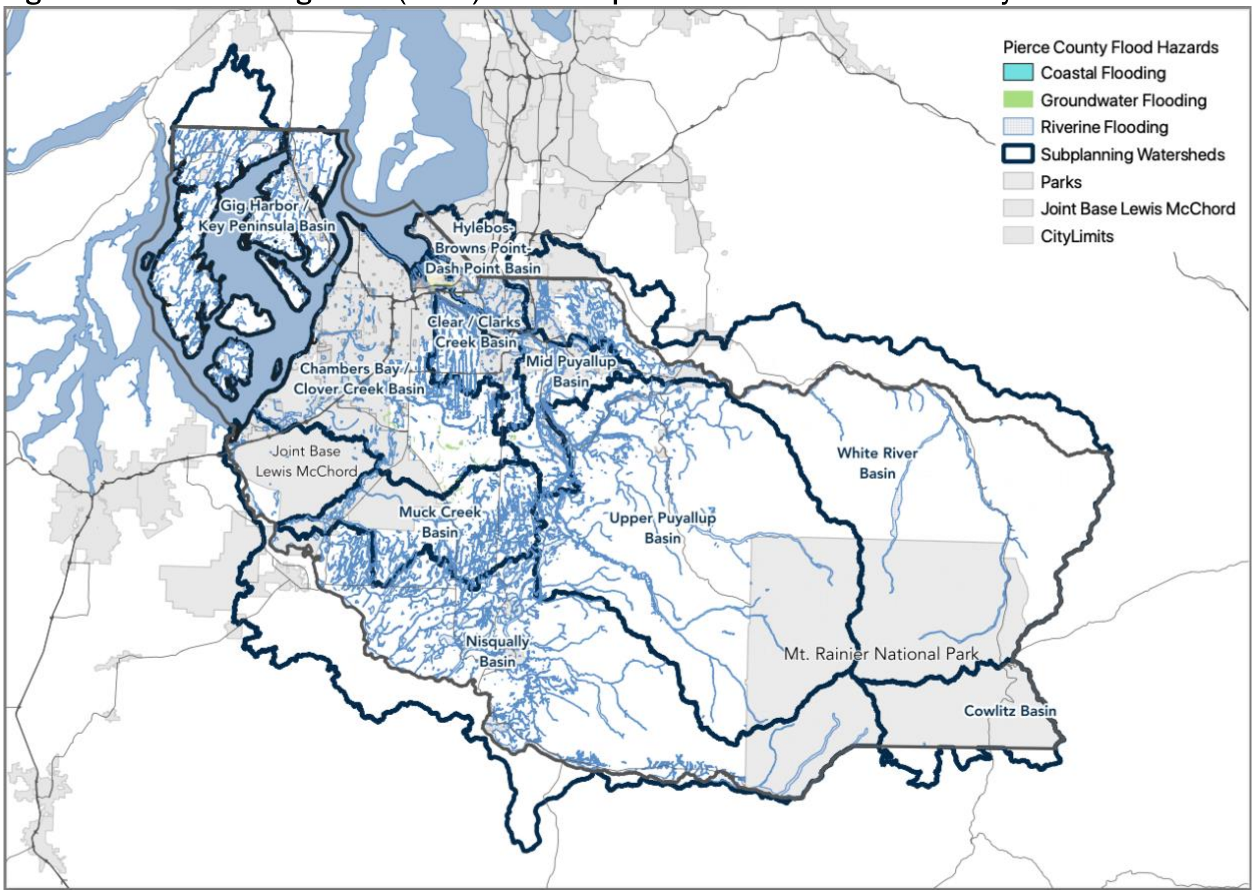
Figure 1-3. Sub-Planning Areas (SPAs) in Pierce County



Source: Created by ECONorthwest

[6] Cowlitz Basin, located in the southeast portion of Mt. Rainier National Park, does not have flooding and has a terminus outside of Pierce County, so it is not considered as a SPA.

Figure 1-4. Sub-Planning Areas (SPAs) and Floodplain Extents in in Pierce County



Source: Created by ECONorthwest

Table 1-2 summarizes the area of the SPA and the acres in the 100-year floodplain and in the sea level rise extent. The three largest SPAs are the Upper Puyallup Basin, Nisqually Basin, and White River Basin. The SPA with the highest percent of acres in the 100-year floodplain extent is the Mid-Puyallup Basin with 17.4 percent. Only the coastal SPAs have acres that are in the future sea level rise flood extent. Hylebos-Browns Point-Dash Point Basin SPA is the smallest SPA and has the highest total acres and percent of acres in the sea level rise floodplain extent.

Table 1-2. Area of SPA and Floodplain Extents (Acres)

SPA	Total Acres	Total Acres in 100-Year Floodplain	Percent of Total Acres in 100-Year Floodplain	Sea Level Rise Flood Area (Acres)	Percent of Total Acres in Sea Level Rise Flood Area
Chambers Bay/ Clover Creek Basin	106,798	7,314	6.8%	1,463	1.4%
Clear/Clarks Creek Basin	21,044	2,680	12.7%	353	1.7%
Gig Harbor/Key Peninsula Basin	79,292	6,794	8.6%	2,394	3.0%
Hylebos-Browns Point-Dash Point Basin	15,959	1,159	7.3%	4,127	25.9%
Mid Puyallup Basin	33,357	5,798	17.4%	585	1.8%
Muck Creek Basin	56,467	7,136	12.6%	0	0.0%
Nisqually Basin	232,170	22,265	9.6%	386	0.2%
Upper Puyallup Basin	253,310	11,354	4.5%	0	0.0%
White River Basin	241,706	11,546	4.8%	0	0.0%
SPA Total	**1,080,272**	**76,046**	**7.0%**	**9,307**	**0.9%**

Source: Created by ECONorthwest

[1] Totals with sea level rise are not additive to 100-year floodplain totals because areas are subject to both coastal flooding and sea level rise flooding.

Note: There are some areas of Pierce County, such as the Cowlitz Basin that encompasses Mt. Rainier National Park, that are not listed as an SPA but are included in the County totals.

2 Economic Resources in the Floodplain

2.1 Introduction

This section of the report describes the existing land uses and levels of economic activity in the floodplain for each sub-planning area for each flood type. The purpose of this section is to describe the location of economic resources in the floodplain, which is then used in the subsequent sections to calculate and describe the economic costs of flooding.

2.2 Existing Land Uses and Physical Infrastructure in the Floodplain

This subsection describes the use of land and existing physical infrastructure in the floodplain extents.

2.2.1 Flood-Impacted Areas

Table 2-1 shows the total land in each SPA as well as the amount of land contained within the floodplain extent. There are 1.08 million total acres in the nine SPAs in Pierce County.[7] The 100-year floodplain extents comprise the largest percentages of total area in Mid Puyallup Basin (17.4 percent of total area), followed by Clear/Clarks Creek Basin (12.7 percent), and Muck Creek Basin (12.6 percent). Sea level rise flooding has the largest extents in the Hylebos-Browns Point-Dash Point Basin and Chambers Bay/ Clover Creek Basin, which include the Port of Tacoma, as well as Gig Harbor/Key Peninsula which has the largest coastline of the SPAs.

Table 2-1. Acres in Floodplains, by flood type, by SPA

Area	Total Acres	Riverine Flooding (Acres)	Ground-water Flooding (Acres)	Coastal Flooding (Acres)	Total Acres in 100-Year Floodplain (% of total acres)	Sea Level Rise Flooding (Acres)	Total Acres (100-Year Floodplain and Sea Level Rise)[1]
Chambers Bay/ Clover Creek Basin	106,798	6,630	632	52	7,314 (6.8%)	1,463	8,601 (8.1%)
Clear/Clarks Creek Basin	21,044	2,680	0	0	2,680 (12.7%)	353	2,682 (12.7%)
Gig Harbor/Key Peninsula Basin	79,292	6,210	0	584	6,794 (8.6%)	2,394	8,398 (10.6%)
Hylebos-Browns Point-Dash Basin	15,959	1,137	0	22	1,159 (7.3%)	4,127	4,845 (30.4%)
Mid Puyallup Basin	33,357	5,746	52	0	5,798 (17.4%)	585	6,250 (18.7%)
Muck Creek Basin	56,467	7,044	92	0	7,136 (12.6%)	0	7,136 (12.6%)
Nisqually Basin	232,170	22,162	0	103	22,265 (9.6%)	386	22,548 (9.7%)

[7] Cowlitz Basin, located within Mt. Rainier National Park, is not one of the nine SPAs and is not included in the SPA totals.

Area	Total Acres	Riverine Flooding (Acres)	Ground-water Flooding (Acres)	Coastal Flooding (Acres)	Total Acres in 100-Year Floodplain (% of total acres)	Sea Level Rise Flooding (Acres)	Total Acres (100-Year Floodplain and Sea Level Rise)[1]
Upper Puyallup Basin	253,310	11,354	0	0	11,354 (4.5%)	0	11,354 (4.5%)
White River Basin	241,706	11,546	0	0	11,546 (4.8%)	0	11,546 (4.8%)
Pierce County Total	**1,080,272**	**74,525**	**777**	**762**	**76,046 (7.0%)**	**9,307**	**83,374 (7.7%)**

Source: ECONorthwest analysis

[1] Totals with sea level rise are not additive to 100-year floodplain totals because areas are subject to both coastal flooding and sea level rise flooding.

Note: There are some areas of Pierce County, such as the Cowlitz Basin that encompasses Mt. Rainier National Park, that are not listed as an SPA but are included in the County totals.

2.3 Population

The total population of Pierce County is approximately 877,013 as of 2019 (most recent data year available).[8] Table 2-2 shows the total population residing in each SPA as well as the population potentially located in the floodplain extent for each type of flooding. The population in the floodplain estimates are presented as population weighted averages. Using spatially weighted re-aggregation, block group populations are divided proportionally into component subarea and area within/out of the floodplain and then totaled by category to create demographic estimates for both the county and sub-planning area geographies. Additional information about the socioeconomic and demographic characteristics of this population is available in Chapter 4.

Table 2-2. Population in Floodplain Extent, by flood type, by SPA

Area	Total Population	Pop. in Riverine Flooding	Pop. in Ground-water Flooding	Pop. in Coastal Flooding	Population in 100-Year Floodplain	Pop. in Sea Level Rise Flooding
Chambers Bay/ Clover Creek Basin SPA	477,574	182	2,019	18,424	22,709 (4.8%)	2,660 (0.6%)
Clear/Clarks Creek Basin SPA	74,516	0	0	6,220	6,225 (8.4%)	316 (0.4%)
Gig Harbor/Key Peninsula Basin SPA	65,335	385	0	3,990	5,409 (8.3%)	1,514 (2.3%)
Hylebos-Browns Point-Dash Point Basin SPA	46,402	49	0	2,533	5,374 (11.6%)	3,446 (7.4%)
Mid Puyallup Basin SPA	78,181	0	92	12,982	13,268 (17.0%)	516 (0.7%)
Muck Creek Basin SPA	29,289	0	248	2,861	3,109 (10.6%)	0 (0%)
Nisqually Basin SPA	30,179	156	0	3,107	3,682 (12.2%)	576 (0%)
Upper Puyallup Basin SPA	28,775	0	0	3,416	3,416 (11.9%)	0 (0%)
White River Basin SPA	41,305	0	0	6,602	6,602 (16.0%)	0 (0%)
Pierce County SPA Total	**871,555**	**771**	**2,359**	**60,136**	**69,794 (8.0%)**	**9,028 (1.0%)**

[8] U.S. Census, American Community Survey, 5-year averages, 2014-2019.

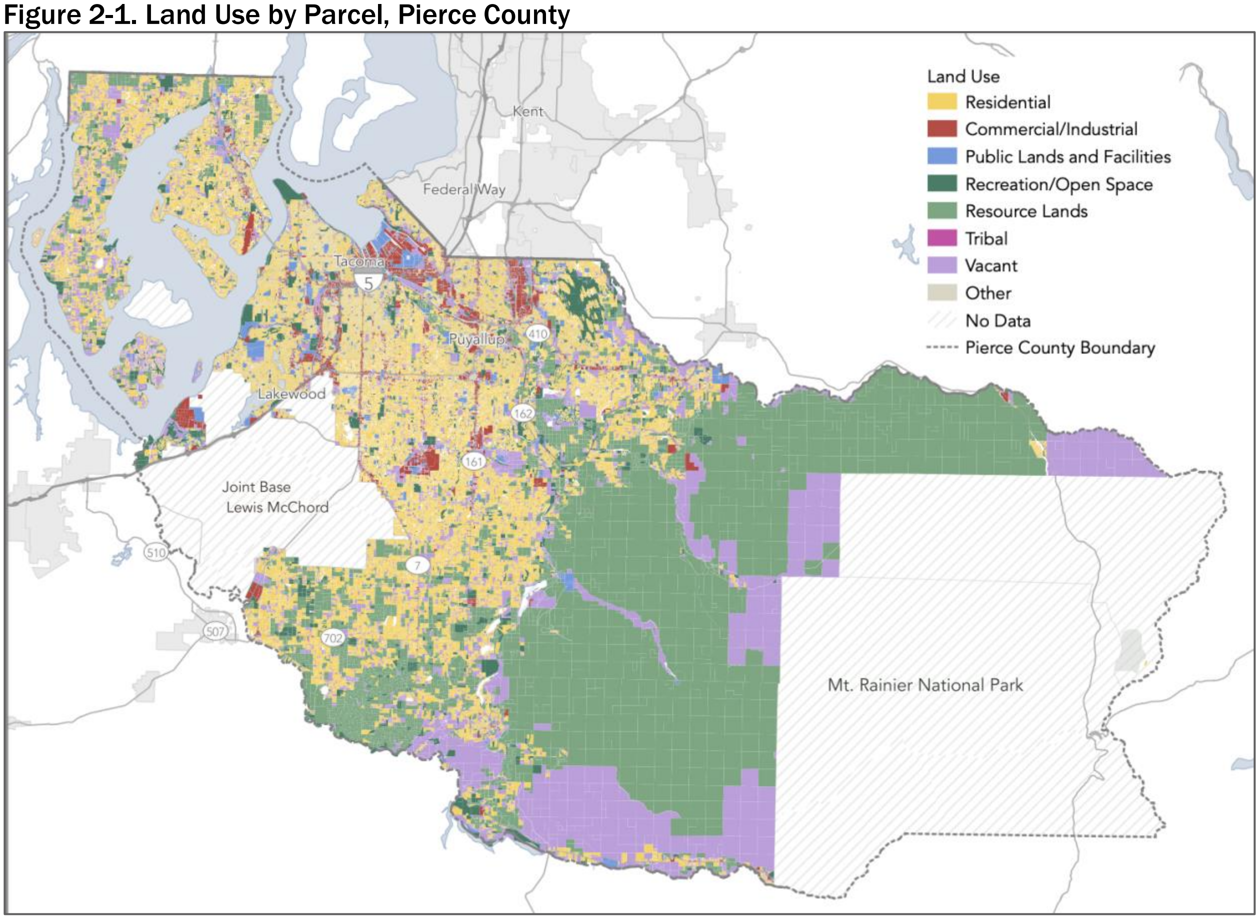
Source: ECONorthwest analysis of U.S. Census, American Community Survey, 5-year averages, 2014-2019.
Note: The total population does not sum to 877,013 due to the exclusion of the Cowlitz Basin and due to rounding.

Although having the largest total population levels, Chambers Bay/Clover Creek Basin SPA has the smallest percentage of the population that is potentially located in the 100-year floodplain. The Mid Puyallup SPA and White River SPA have the highest percentages of their populations that potentially are in the 100-year floodplain. Sea level rise flooding most affects the SPAs that have the largest coastlines as well as those that include the Port of Tacoma.

2.4 Land Use and Infrastructure

There are variations between and within the SPAs on the features and use of land. Some SPAs are more urban while others are more rural/agricultural. This section details existing landownership and land use patterns for each SPA from Pierce County Assessor data. Figure 2-1 displays the locations of the various land use types, by parcel, throughout Pierce County. The two land types that cover the largest amounts of area in the County are *Residential* and *Resource Lands*.

Figure 2-1. Land Use by Parcel, Pierce County



Source: Created by ECONorthwest using data from Pierce County Assessor Tax Parcels 2021

2.4.1 Land Ownership

Table 2-3 shows the total acres of land in each SPA by land type, regardless of whether the land is in a floodplain, based on tax parcel data from Pierce County's Assessor Office. More urban SPAs – such as Chambers Bay/ Clover Creek Basin, Clear/Clarks Creek Basin, and Hylebos-Browns Point-Dash Point Basin – have a larger portion of the area that is in residential and commercial/industrial use compared to the other SPAs. More rural SPAs – such as Nisqually Basin, White River Basin, and Upper Puyallup Basin – have higher percentages of resource lands, which include agricultural lands and timberlands. Note that because there are not existing land use coverage descriptions for all areas of Pierce County (see white area in Figure 2-1, including rivers and lakes) the 670,773 acres of land does not represent all acres within Pierce County.

Table 2-3. Total Acres of Land in Pierce County, by land type, by SPA

SPA	Resource Lands	Public Lands and Facilities	Recreation/ Open Space	Residential	Commercial/ Industrial	Tribal	Vacant	Other	Total
Chambers Bay/ Clover Creek Basin	572	6,480	6,392	38,539	7,218	0.71	6,695	1,167	**67,064**
Clear/Clarks Creek Basin	763	1,224	936	11,312	1,730	0	2,197	323	**18,485**
Gig Harbor/Key Peninsula Basin	10,597	1,493	5,076	36,354	1,374	0	16,126	239	**71,260**
Hylebos-Browns Point-Dash Point Basin	102	1,606	874	6,048	3,003	14	2,458	124	**14,229**
Mid Puyallup Basin	4,365	1,623	2,374	12,660	1,812	0	6,037	114	**28,986**
Muck Creek Basin	8,833	483	1,479	23,052	301	0	5,758	220	**40,126**
Nisqually Basin	78,123	1,273	7,962	26,056	855	7.6	49,384	64	**163,724**
Upper Puyallup Basin	135,452	965	3,285	12,081	751	0	35,361	9.3	**187,903**
White River Basin	46,445	1,642	4,355	8,970	2,297	0	15,206	79	**78,994**
Pierce County SPA Total	**285,253**	**16,788**	**32,733**	**175,071**	**19,341**	**23**	**139,223**	**2,340**	**670,773**

Source: ECONorthwest analysis of Pierce County Assessor Tax Parcels 2021
Note: The data source from Pierce County Assessor does not have data for all parts of Pierce County. Approximately 409,735 acres in the SPAs are not covered by this parcel data.

Table 2-4 shows the acres of land in each SPA that are in the 100-year floodplain by land use type. The floodplain extends across approximately 56,135 acres of land out of 670,773 total acres in Pierce County, representing approximately 8.4 percent.[9] Resource lands, residential areas, and vacant lands have the highest number of acres within the floodplain extent. Recreation/open space lands have the highest percentage of acres that are within the floodplain extent at 29.0 percent.

Table 2-4. Acres of Land in Pierce County in Floodplain, by land type, by SPA

SPA	Resource Lands	Public Lands and Facilities	Recreation/ Open Space	Residential	Commercial/ Industrial	Tribal	Vacant	Other	Total
Chambers Bay/ Clover Creek Basin	67	289	630	1,527	149	0	907	35	3,603
Clear/Clarks Creek Basin	313	181	208	888	129	0	350	18	2,087
Gig Harbor/Key Peninsula Basin	1,142	54	491	2,288	61	0	1,324	4.6	5,365
Hylebos-Browns Point-Dash Point Basin	19	19	58	294	76	0.079	165	0.68	631
Mid Puyallup Basin	956	184	841	1,349	260	0	1,083	0.55	4,673
Muck Creek Basin	1,887	22	387	2,586	9.2	0	935	45	5,872
Nisqually Basin	6,415	236	2,519	3,239	168	0	3,766	2.4	16,345
Upper Puyallup Basin	4,245	182	1,120	1,390	31	0	2,666	0.84	9,634
White River Basin	1,726	231	3,235	466	467	0	1,799	1.3	7,925
Pierce County SPA Total	**16,772**	**1,397**	**9,488**	**14,027**	**1,348**	**0.079**	**12,994**	**109**	**56,135**
Total in SPAs	**285,253**	**16,788**	**32,733**	**175,071**	**19,341**	**23**	**139,223**	**2,340**	**670,773**
Percent of Total	**5.9%**	**8.3%**	**29.0%**	**8.0%**	**7.0%**	**0.3%**	**9.3%**	**4.7%**	**8.4%**

Source: ECONorthwest analysis of Pierce County Assessor Tax Parcels 2021

Table 2-5 summarizes the land use types that are located within the sea level rise floodplain extent. The sea level rise extent covers 1,816 acres of land with land description data. The land use types of recreation/open space and residential have the highest number of acres in the sea level rise floodplain extent. Recreation/open space and tribal land types have the highest percentage of total acres within the sea level rise floodplain extent.

[9] Existing river extents without flooding are not included in the 670,773 acres of land because that area does not have a land description type.

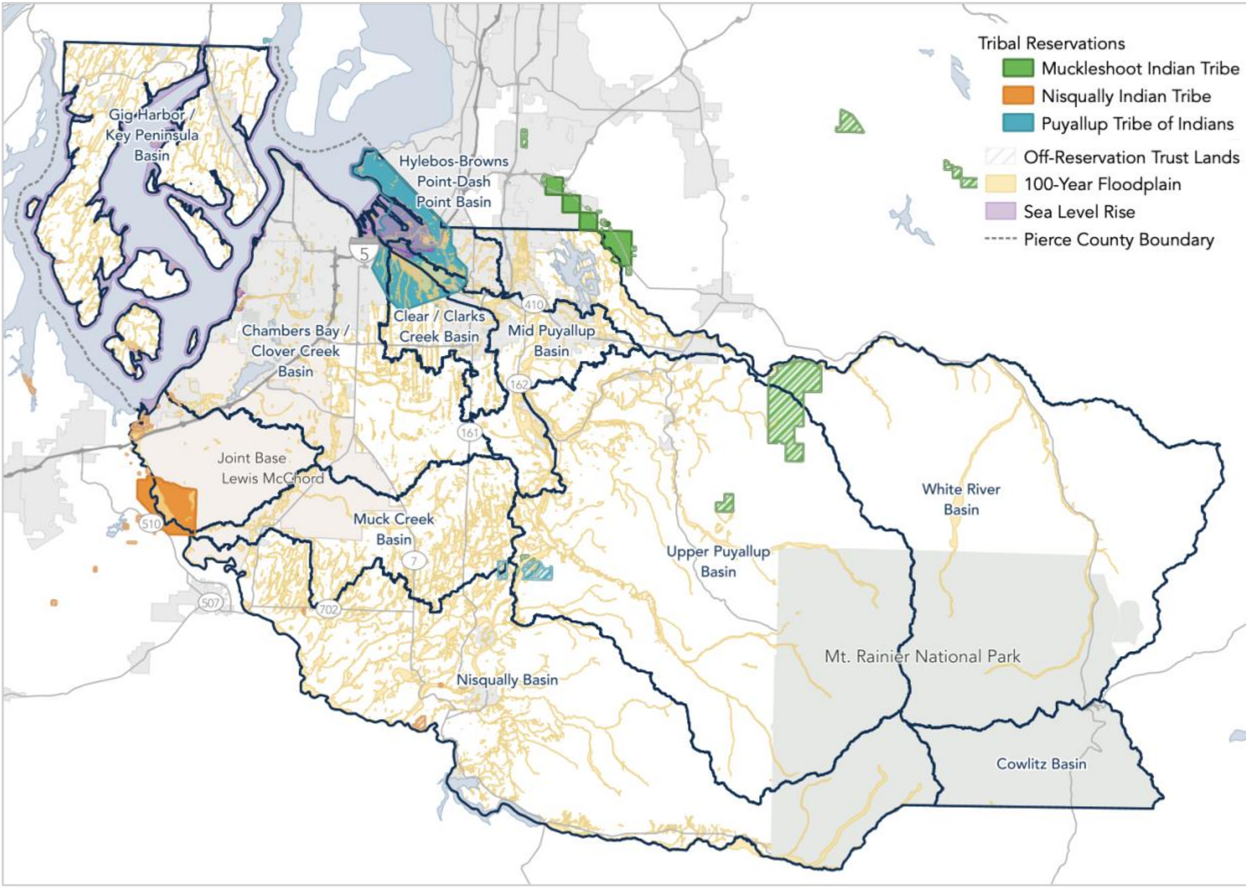
Table 2-5. Acres of Land in Pierce County in the Sea Level Rise Extent, by land type, by SPA

SPA	Resource Lands	Public Lands and Facilities	Recreat-ion/ Open Space	Residen-tial	Commer-cial/ Industrial	Tribal	Vacant	Other	Total
Chambers Bay / Clover Creek Basin	0	16	84	10	46	0	8.3	0	164
Clear / Clarks Creek Basin	49	4.9	164	84	16	0	23	0	342
Gig Harbor / Key Peninsula Basin	25	2.8	190	411	7.9	0	122	0.018	759
Hylebos-Browns Point-Dash Point Basin	0	93	39	30	150	0.35	122	1.1	435
Mid Puyallup Basin	0	1.1	12	0	1	0	0.99	0	15
Nisqually Basin	0	0	94	4.4	0	0	2.8	0	101
Total	**75**	**117**	**583**	**540**	**221**	**0.35**	**278**	**1.2**	**1,816**
Total in SPAs	**285,253**	**16,788**	**32,733**	**175,071**	**19,341**	**23**	**139,223**	**2,340**	**670,773**
Percent of Total	**0.0%**	**0.7%**	**1.8%**	**0.3%**	**1.1%**	**1.5%**	**0.2%**	**0.1%**	**0.3%**

Source: ECONorthwest analysis of Pierce County Assessor Tax Parcels 2021

There are three tribal reservation areas in Pierce County, as well as off-reservation trust land, for a total of 30,970 acres of land. Not all land within the reservation areas is tribally-owned, as some of it has been sold to non-tribal members. Figure 2-2 depicts the areas of tribal land by Tribe and SPA. Table 2-6 summarizes the areas of tribal land within reservations and off-reservation trust land for each Tribe and SPA.

Figure 2-2. Tribal Reservation and Off-Reservation Trust Land Areas in Pierce County



Source: Created by ECONorthwest with data from Washington Geospatial Open Data Portal, available at: https://geo.wa.gov/datasets/waecy::tribal-lands/about

Table 2-6. Acres of Tribal Land by SPA in Pierce County

	Nisqually Indian Tribe		Puyallup Tribe of Indians		Muckleshoot Indian Tribe	
SPA	**Reservation Land**	**Off-Reservation Trust Lands**	**Reservation Land**	**Off-Reservation Trust Lands**	**Reservation Land**	**Off-Reservation Trust Lands**
Chambers Bay / Clover Creek Basin	0	43	1,265	0	0	0
Clear / Clarks Creek Basin	0	0	4,359	3	0	0
Muck Creek Basin	19	0	0	177	0	0
Nisqually Basin	3,384	635	0	143	0	0
Upper Puyallup Basin	0	0	0	829	0	4,553
White River Basin	0	0	0	0	124	3,018
Hylebos-Browns Point-Dash Basin	0	0	10,040	0	0	0
Mid Puyallup Basin	0	0	2,378	0	0	0
Total	**3,403**	**678**	**18,042**	**1,152**	**124**	**7,571**

Source: Created by ECONorthwest with data from Washington Geospatial Open Data Portal, available at: https://geo.wa.gov/datasets/waecy::tribal-lands/about

2.4.2 Residential Properties

Table 2-7 shows the extent of residential land types based on parcel data for home type. Housing is categorized as single family, multi-family, and mobile home. Mobile homes are proportionately most affected by flooding – 10.2 percent of all properties with mobile homes are located within a floodplain. Approximately 7.9 percent of properties with single family-homes are in a floodplain. Approximately 4.4 percent of properties with multi-family-homes are in a floodplain.

Table 2-7. Residential Housing in Floodplain, by flood type, by SPA

	Single Family Residential		Multi-Family Residential		Mobile Home	
Area	**Total Acres**	**Acres in Floodplain (%)**	**Total Acres**	**Acres in Floodplain (%)**	**Total Acres**	**Acres in Floodplain (%)**
Chambers Bay/ Clover Creek Basin SPA	30,922	1,171 (3.8%)	4,277	169 (3.9%)	2,638	126 (4.8%)
Clear/Clarks Creek Basin SPA	9,343	743 (8%)	940	47 (5%)	744	144 (19.3%)
Gig Harbor/Key Peninsula Basin SPA	29,234	2,166 (7.4%)	630	7 (1.1%)	4,797	341 (7.1%)
Hylebos-Browns Point-Dash Point Basin SPA	5,288	261 (4.9%)	494	34 (7%)	100	19 (19.1%)
Mid Puyallup Basin SPA	10,461	1,002 (9.6%)	393	56 (14.3%)	1,349	212 (15.7%)
Muck Creek Basin SPA	16,049	1,796 (11.2%)	82	3 (3.7%)	5,906	623 (10.5%)
Nisqually Basin SPA	17,438	2,143 (12.3%)	79	1 (0.8%)	6,977	768 (11%)
Upper Puyallup Basin SPA	8,786	988 (11.2%)	41	1 (3.4%)	2,800	328 (11.7%)
White River Basin SPA	7,268	324 (4.5%)	381	4 (1.1%)	1,028	120 (11.7%)
Pierce County Total	**134,789**	**10,594 (7.9%)**	**7,317**	**322 (4.4%)**	**26,338**	**2,681 (10.2%)**

Source: ECONorthwest analysis of Pierce County Assessor Tax Parcels 2021

2.4.3 Agricultural Properties

Approximately 45,766 acres (7 percent of the land) in Pierce County is farmland, including cropland, pastureland, and woodlands.[10] Throughout Pierce County, approximately 37 percent of agricultural lands are pastureland. Cattle are the primary livestock that uses pasturelands, followed by horses and ponies. Table 2-8 summarizes the number of acres for the categories of agricultural lands in Pierce County.

Table 2-8. Acres of Agricultural Lands in Pierce County by Crop Type (2017)

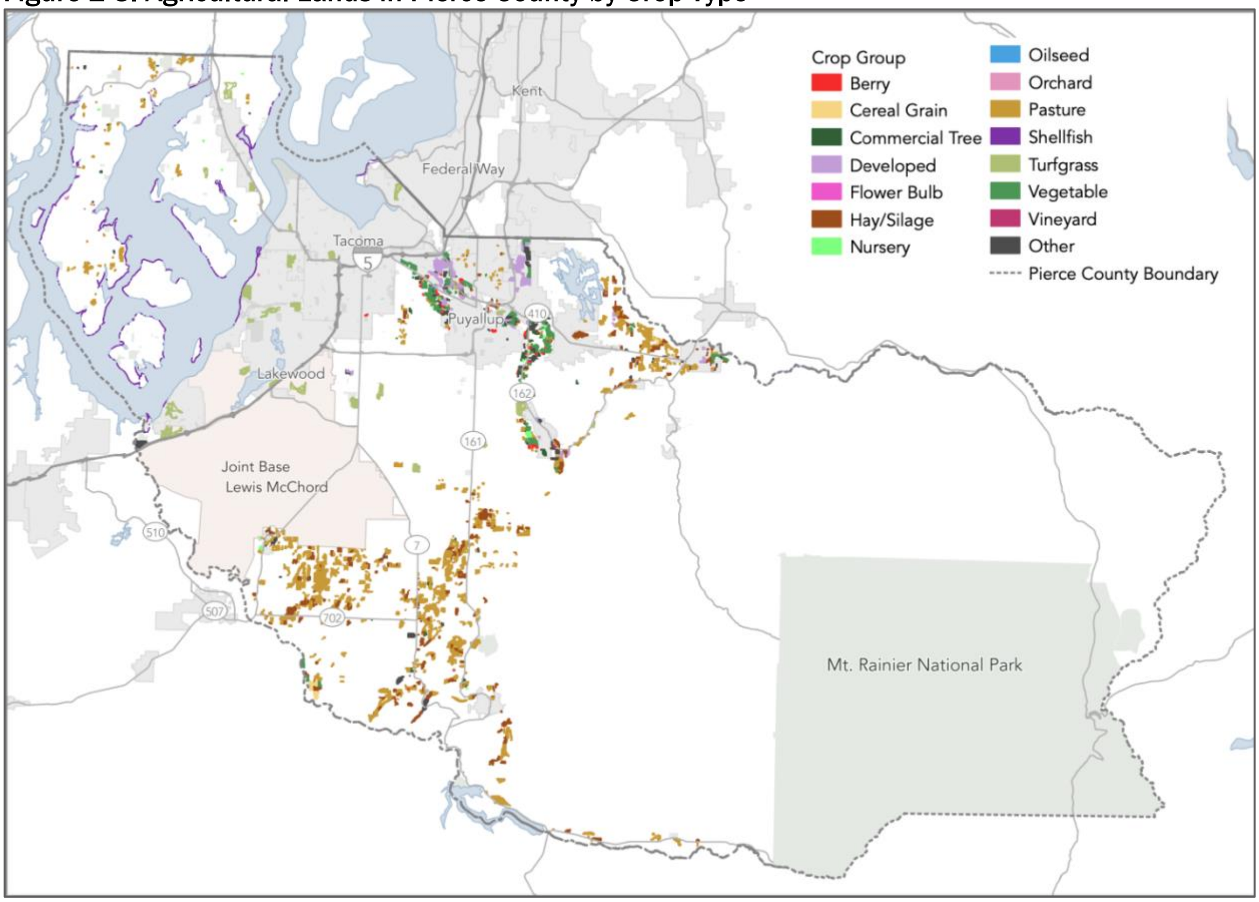
Agricultural Land Type	Approximate Acres	Percent of Total
Cropland	11,900	26%
Pastureland	16,930	37%
Woodland	10,980	24%
Aquaculture (Shellfish)	376	1%
Other	5,114	12%
Total	**45,766**	**100%**

[10] USDA Agricultural Statistics Service. *(2017). County Profile: Pierce County, Washington.*

Source: USDA Agricultural Statistics Service. *County Profile: Pierce County, Washington.*
Note: Totals do not sum due to rounding

Figure 2-3 displays the location of cropland and pastureland by crop type throughout Pierce County. Pasture and hay are most common crops in the valley lands west of the foothills of Mt. Rainer and east of the urbanized areas along the I-5 corridor. Pasture and hay is also common between Lake Tapps and the City of Buckley in the northern part of Pierce County. The Puyallup River area, extending from Tacoma to Orting, has a variety of more specialized crops, including vegetable, commercial trees, berry, flower bulbs, and nursery crops.

Figure 2-3. Agricultural Lands in Pierce County by Crop Type



Source: Created by ECONorthwest using data from Washington State Department of Agriculture Crop Distribution data (2019)

Table 2-9 summarizes the acres of farmland within the floodplain extent SPA for each flood type.[11] Spatial Washington State Department of Agriculture (WSDA) Crop Distribution data was intersected with the floodplain to calculate these areas. Pierce County has 24,287 acres of agriculture within its SPAs, of which 6,289 acres (26 percent) is in a floodplain. Approximately 484 acres or 2 percent of the total agricultural acres in Pierce County, are located in the sea level

[11] Farmland is defined based on the Washington State Department of Agriculture Crop Distribution data (2019) and includes the following categories: pasture, vegetable, hay/silage, other, commercial tree, shellfish, cereal grain, nursery, berry, vineyard, orchard, oilseed, flower bulb, and herb.

rise floodplain extent. Of the farmland in a floodplain, 93 percent is affected by riverine flooding, and the remaining 7 percent is from all other flooding types.

Table 2-9. Acres of Farmland in floodplain, by flood type, by SPA

SPA	Total Acres	Acres in 100-Year Floodplain	Acres in Riverine Flooding	Acres in Groundwater Flooding	Acres in Coastal Flooding	Acres in Sea Level Rise Flooding
Chambers Bay/ Clover Creek Basin	1,450	37	26	11	0.26	37
Clear/Clarks Creek Basin	882	406	406	0	0	44
Gig Harbor/Key Peninsula Basin	1,407	265	255	0	9.6	322
Hylebos-Browns Point-Dash Point Basin	923	105	105	0	0.063	20
Mid Puyallup Basin	3,330	942	942	0	0	61
Muck Creek Basin	5,053	1,361	1361	0	0	0
Nisqually Basin	6,996	2,317	2317	0	0	0
Upper Puyallup Basin	1,477	284	284	0	0	0
White River Basin	2,769	572	572	0	0	0
Pierce County SPA Total	**24,287**	**6,289**	**6268**	**11**	**9.9**	**484**

Source: ECONorthwest analysis of Washington State Department of Agriculture Crop Distribution data (2019)

Table 2-10 summarizes the acres of agricultural lands that are located in each type of floodplain extent, by crop type. Pasture lands and hay/silage have the highest numbers of acres located in the 100-year floodplain extent (excluding sea level rise flooding). The sea level rise flood extent includes areas with vegetable, berry, and other crop types.

Table 2-10. Acres of Agricultural Lands within Floodplain Extents

Crop Type	Total Ag. Acres in SPA Areas	Riverine Flooding (Acres)	Groundwater Flooding (Acres)	Coastal Flooding (Acres)	Acres in 100 Year Floodplain (% of Total Acres in Floodplain)	Sea Level Rise Flooding (Acres) (% of Total Acres in Floodplain)
Pasture	11,522	3,002	11	0.11	3,013 (26.2%)	2 (0.0%)
Hay/Silage	3,935	1,196	0	0	1,196 (30.4%)	6 (0.2%)
Vegetable	2,092	790	0	0	790 (37.8%)	83 (4.0%)
Developed	1,615	462	0	0	462 (28.6%)	3 (0.2%)
Other	1,252	335	0	0	335 (26.8%)	9 (0.7%)
Turfgrass	2,132	169	0	0	169 (7.9%)	0 (0.0%)
Berry	341	108	0	0	108 (31.7%)	6 (1.8%)
Nursery	217	94	0	0	94 (43.3%)	0 (0.0%)
Commercial Tree	362	51	0	0	51 (14.1%)	0 (0.0%)
Cereal Grain	231	48	0	0	48 (20.8%)	0 (0.0%)
Orchard	31	7	0	0	7 (23.2%)	0 (0.0%)
Oilseed	7.9	6	0	0	6 (81.0%)	0 (0.0%)
Shellfish	376	0	0	9.8	10 (2.7%)	375 (99.7%)

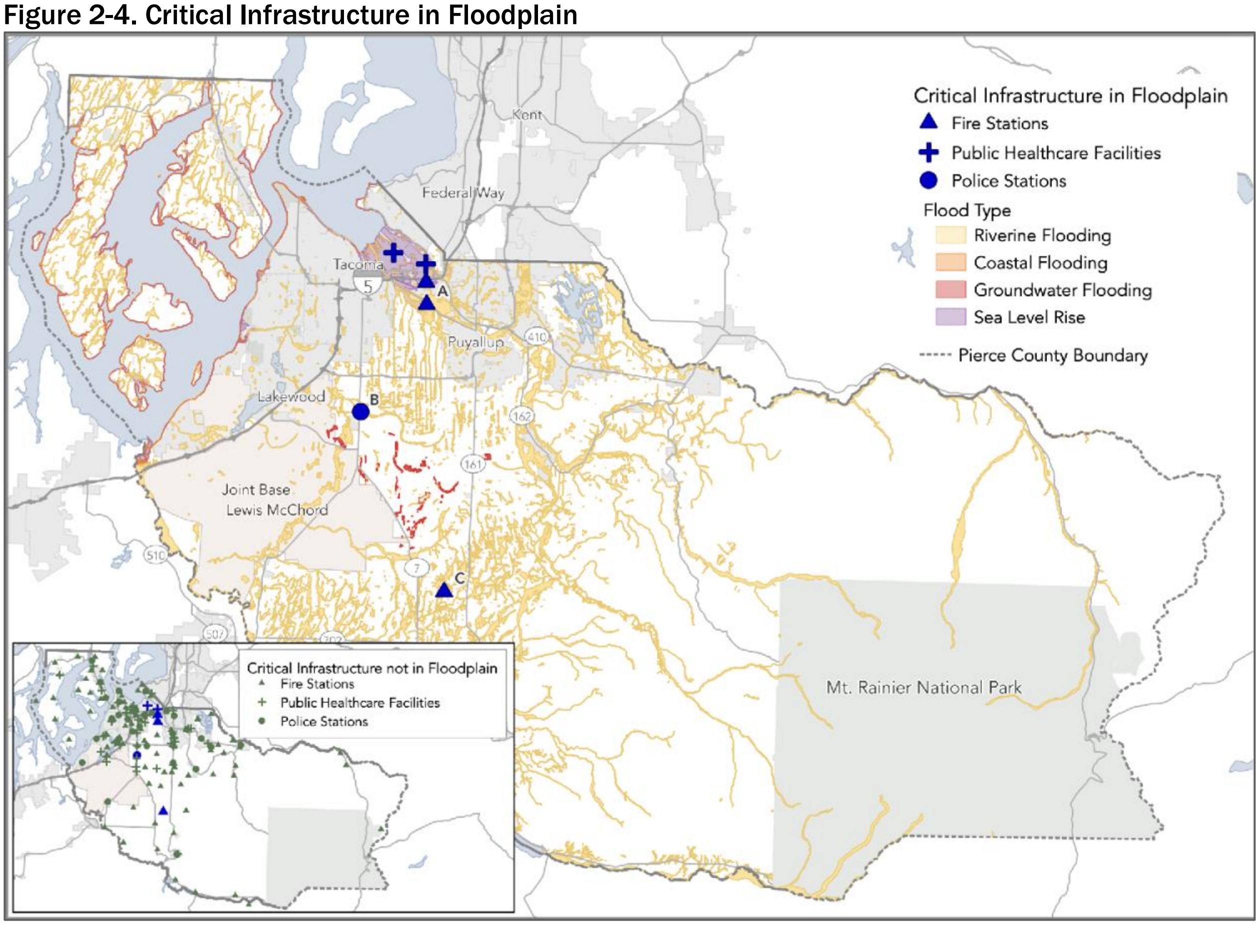
Crop Type	Total Ag. Acres in SPA Areas	Riverine Flooding (Acres)	Groundwater Flooding (Acres)	Coastal Flooding (Acres)	Acres in 100 Year Floodplain (% of Total Acres in Floodplain)	Sea Level Rise Flooding (Acres) (% of Total Acres in Floodplain)
Vineyard	9.5	0	0	0	0 (0.3%)	0 (0.0%)
Flower Bulb	16	0	0	0	0 (0.1%)	0 (0.0%)
Total	**24,139**	**6,268**	**11**	**9.9**	**6,289 (26.1%)**	**484 (2.0%)**

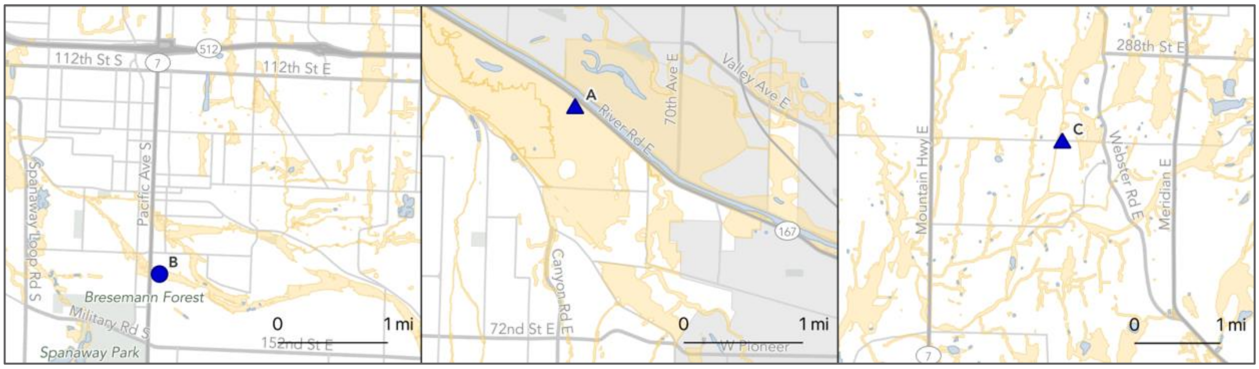
Source: Created by ECONorthwest

2.4.4 Emergency Response Infrastructure

In this report, emergency response infrastructure refers to health and social services infrastructure. Two public healthcare facilities and one fire station are located within the sea level rise floodplain extent, all within the Port of Tacoma area. Two additional fire stations and one police station are within the riverine floodplain extent. Figure 2-4 displays the map location of the emergency response infrastructure resources within the floodplain extents. Coastal flooding impacts to transportation that impair access to hospitals and fire stations are described further in Chapter 7.

Figure 2-4. Critical Infrastructure in Floodplain





Source: Created by ECONorthwest using data from Pierce County Open GeoSpatial Data Portal, available at: https://gisdata-piercecowa.opendata.arcgis.com/

2.4.5 Transportation Infrastructure

Transportation infrastructure within Pierce County that can be affected by flooding includes roads, bridges, railroads (including light rail), boat ports (including ferries), and pedestrian/bicycle networks. Flooding can cause route closures which have associated rerouting delays and costs, pose risks to public safety for access to critical infrastructure resources like hospitals, and result in damage to the transportation infrastructure itself, requiring clean up or repairs. This analysis focuses on roads, bridges, and rail lines. Flood impacts to these transportation resources and associated costs are described in detail in Chapter 6. Sea level rise flooding impacts to road and railroad infrastructure is described further in Chapter 7.

2.5 Economic Activity within the Floodplain Extents

2.5.1 Methodology

Employment, labor income, and output were calculated for each business in each SPA based on the location of the business as identified through business location data from the Washington State Department of Revenue (DOR).[12] This dataset from DOR has latitude, longitude, and industry classification information for the registered businesses in Pierce County. This dataset was used to identify which businesses are potentially located in the floodplain extent for each type of flooding. We assume that all businesses in this dataset are active with employees or sole proprietors. However, there are likely a small number of businesses which are no longer active but are included in the dataset. The DOR dataset is also limited because it is reported for the headquarters of the business, which is not always the same location as where the business activity is occurring if a business has multiple properties.[13]

Employment and revenues estimates for individual businesses are not available due to privacy considerations. To estimate employment, the DOR business data was combined with U.S.

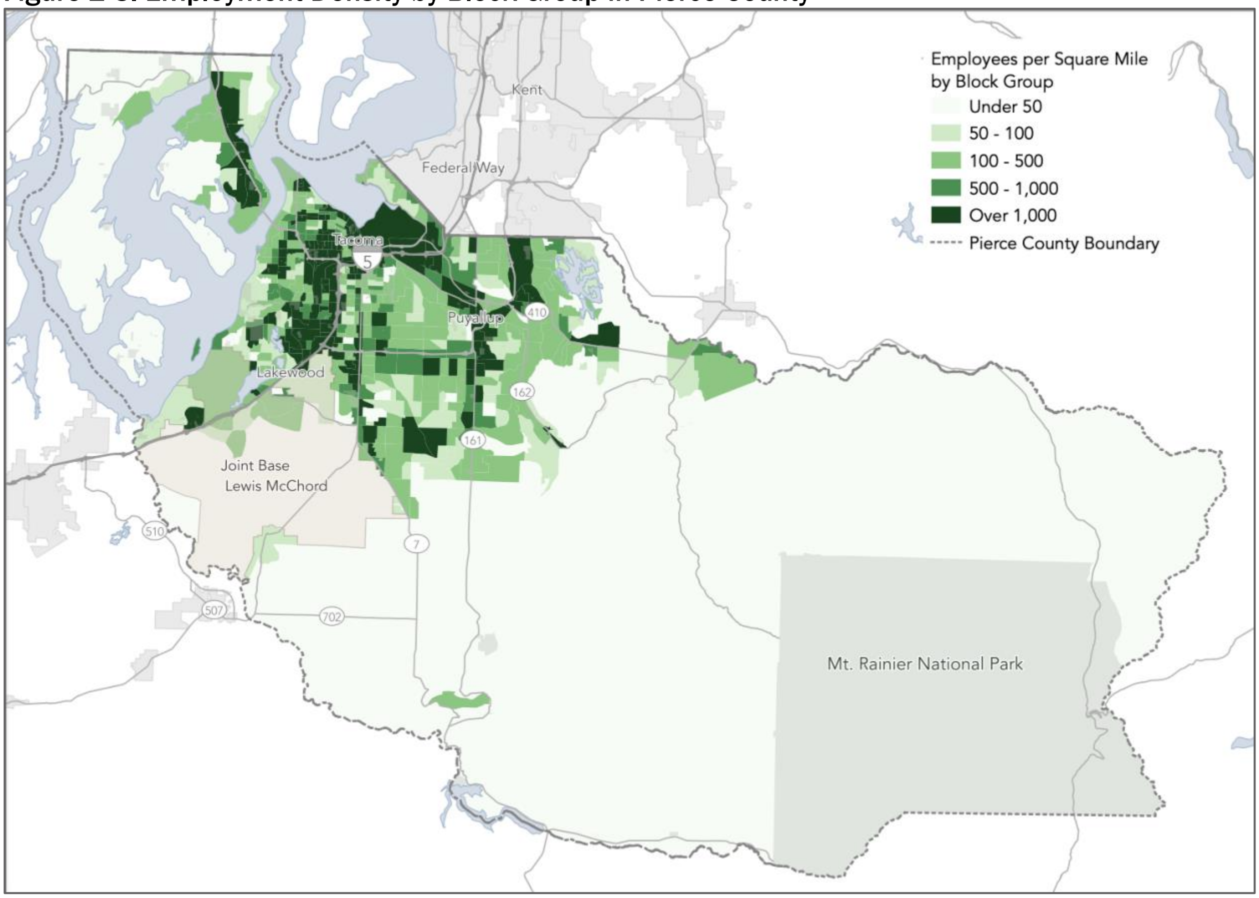
[12] Provided by Washington State Department of Revenue upon request. Data is as of December 31, 2020.

[13] For example, there is no business indicator for the Emerald Queen Hotel and Casino located at 5700 Pacific Hwy E, Fife, WA because that business is included in the entry for Puyallup Emerald Queen Casino at I-5 located at 2024 E 29th St, Tacoma, WA.

Census data,[14] which describes the number of jobs in each two-digit North American Industry Classification System (NAICS) code in each block group in Pierce County.[15] Under this methodology, the total employment in each block group and SPA is consistent, but the estimates of employment per business in the floodplain is based on the average for the two-digit NAICS industry for that block group.

A limitation to the U.S. Census Data is that it does not include civilian employees of the Department of Defense and Armed Forces. There is additional data suppression of some federal employees.[16] Given this data consideration, it is likely that there are large employment underestimates for Joint Base Lewis-McChord (JBLM). Figure 2-5 displays the employment density by block group for the U.S. Census Data that was used to calculate employment effects.

Figure 2-5. Employment Density by Block Group in Pierce County



Source: Created by ECONorthwest using data from U.S. Census Bureau, OnTheMap Application and LEHD Origin-Destination Employment Statistics (Beginning of Quarter Employment, 2nd Quarter of 2019). Retrieved from: https://onthemap.ces.census.gov/

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[14] U.S. Census Bureau, OnTheMap Application and LEHD Origin-Destination Employment Statistics (Beginning of Quarter Employment, 2nd Quarter of 2019). Retrieved from: https://onthemap.ces.census.gov/

[15] More information about NAICS codes is available at: https://www.census.gov/naics/

[16] More information about suppression of federal employment is located at: https://lehd.ces.census.gov/doc/help/onthemap/FederalEmploymentInOnTheMap.pdf

Due to the omission of JBLM from the US Census Data, the 54,000 jobs associated with JBLM are assigned to three SPAs based on the proportion of JBLM that falls into each. Jobs were further adjusted to account for other omissions. Because the 302,289 jobs in the U.S. Census Data is lower than the known 456,452 jobs from IMPLAN which includes all employment for the County, job estimates at the point level for businesses in the DOR data were adjusted up proportionally after subtracting the 54,000 jobs for JBLM.

To calculate labor income and output per business, values from IMPLAN were averaged within two-digit NAICS codes and converted to a per job estimate at the county scale.[17] Labor income and output values were then assigned based on NAICS code and multiplied by the number of jobs per business. Estimates of labor income and output are therefore based on a proportional average from the employment estimate for that industry. The result of this is an estimate of the employment, labor income, and output for each individual business within the DOR dataset.

The analysis identifies which businesses are potentially located in the floodplain or sea level rise flood extent based upon point-level data for the individual businesses. The estimates of number of businesses, employment, labor income, and output only describe the associated business activity that is within the floodplain extent. These businesses and levels of economic activity would not necessarily be impacted by flooding. Flooding may or may not cause damage to the physical assets (e.g., buildings, inventory, etc.) depending on the site-specific conditions and depth of flooding. Flooding may or may not disrupt business activities at the business site, also depending on site-specific conditions. Accordingly, all estimates of business activity and employment should be interpreted as potentially located within the floodplain, but not necessarily impacted should flooding occur.

2.6 Businesses in the Floodplain

2.6.1 Businesses in the 100-year Floodplain Extent

There are a total of approximately 70,872 total establishments in Pierce County as of 2018.[18] The Bureau of Labor Statistics shows that in 2018 there was an annual average of 22,605 employer establishments in Pierce County.[19] That same year, the Census Bureau's Non-Employer Statistics estimates there were 48,267 non-employer firms (i.e., sole proprietorships),[20] suggesting a total

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[17] IMPLAN, LLC. Model for Pierce County, Washington (2019).

[18] The DOR data that is used for this analysis has a total of 104,095 businesses. However, some of those businesses have closed, yet remained in the dataset. The DOR data is used for point-locations of businesses, but estimates of number of establishments are proportionally adjusted to total the known 70,875 total establishments for 2018.

[19] Bureau of Labor Statistics. (2018). *Number of Establishments in Private Total*. Series ID: ENU5305320510.

[20] U.S. Census Bureau. (2018). *All Sectors: Nonemployer Statistics by Legal Form of Organization and Receipts Size Class for the U.S., States, and Selected Geographies: 2018*. Series ID: NS1800NONEMP

of 70,872 total establishments.[21] Of these, a total of 1,958 establishments (2.8 percent) are located within the 100-year floodplain extent (excluding sea level rise).

The *Agriculture, Forestry, Fishing and Hunting* industry has the highest percentage of businesses located in the floodplain extent at 8.8 percent of total businesses. The *Construction* industry has the largest number of businesses located in the floodplain extent with 161 businesses. The *Health Care and Social Assistance* industry has the lowest percentage of businesses located in the floodplain extent. Table 2-11 summarizes the number of businesses located in the floodplain extent by flooding type and by industry. Of the businesses within the floodplain extent, 93 percent are in riverine flooding extents, compared to groundwater or coastal flooding areas.

[21] The most recent data year available at the writing of this report for the Census Bureau's Non-Employer Statistics is 2018.

Table 2-11. Number of Establishments in the 100-Year Floodplain Extent, by Flooding Type and Industry

NAICS Code	NAICS Description	Coastal Flooding	Groundwater Flooding	Riverine Flooding	Total in Floodplains	Total Establish-ments in Pierce County	% in Floodplain
11	Agriculture, Forestry, Fishing and Hunting	1	1	48	**51**	581	8.8%
21	Mining, Quarrying, & Oil and Gas Extr.	0	0	1	**1**	12	5.6%
22	Utilities	0	0	1	**1**	37	1.9%
23	Construction	2	5	154	**161**	4,833	3.3%
31	Manufacturing	0	1	7	**8**	348	2.3%
32	Manufacturing	0	2	13	**15**	307	4.9%
33	Manufacturing	0	1	16	**18**	552	3.2%
42	Wholesale Trade	1	2	52	**55**	1,012	5.4%
44	Retail Trade	2	1	74	**78**	2,964	2.6%
45	Retail Trade	4	2	71	**77**	3,463	2.2%
48	Transportation and Warehousing	1	3	62	**67**	1,618	4.1%
49	Transportation and Warehousing	0	0	14	**14**	353	4.1%
51	Information	0	1	9	**10**	537	1.8%
52	Finance and Insurance	3	0	18	**21**	1,137	1.9%
53	Real Estate and Rental and Leasing	4	3	52	**59**	2,119	2.8%
54	Professional, Scientific, and Technical Serv.	10	1	86	**97**	4,876	2.0%
55	Management of Companies and Enterprises	0	0	3	**3**	140	2.4%
56	Administrative, Support, Waste Mgmt ...	1	3	99	**103**	3,165	3.3%
61	Educational Services	0	0	20	**20**	878	2.3%
62	Health Care and Social Assistance	1	1	42	**45**	3,069	1.5%
71	Arts, Entertainment, and Recreation	3	1	29	**33**	1,073	3.1%
72	Accommodation and Food Services	7	1	50	**58**	1,853	3.1%
81	Other Services (except Public Administration)	7	5	86	**98**	4,690	2.1%
92	Public Administration	0	0	3	**3**	67	5.1%
Missing	Unknown	41	17	803	**861**	31,189	2.8%
	Total	**89**	**52**	**1,817**	**1,958**	**70,872**	**2.8%**

Source: Created by ECONorthwest

Table 2-12 summarizes the number of businesses in the floodplain extent for each SPA for each industry. The Mid-Puyallup Basin SPA has the most total businesses in the floodplain extent at 568, as well as the highest percent of total businesses at 9.3 percent. Chambers Bay/Clover Creek Basin SPA has the lowest percent of total businesses in the floodplain at 0.9 percent.

Table 2-12. Number of Businesses in the 100-Year Floodplain Extent, by SPA and Industry

NAICS Industry	Chambers Bay / Clover Creek Basin	Clear / Clarks Creek Basin	Gig Harbor / Key Peninsula Basin	Hylebos-Browns Point-Dash Point Basin	Mid Puyallup Basin	Muck Creek Basin	Nisqually Basin	Upper Puyallup Basin	White River Basin	Total
Agriculture, Forestry, Fishing and Hunting	3	8	7	3	9	1	14	3	3	51
Mining, Quarrying, & Oil and Gas Extr.	0	0	0	1	0	0	0	0	0	1
Utilities	0	0	0	0	0	0	1	0	0	1
Construction	26	15	8	17	55	10	8	10	12	161
Manufacturing (31)	2	0	1	0	3	1	0	1	1	8
Manufacturing (32)	3	3	0	3	5	0	1	0	0	15
Manufacturing (33)	4	1	0	0	7	3	1	1	1	18
Wholesale Trade	5	8	2	4	19	1	1	1	14	55
Retail Trade (45)	16	16	8	5	19	2	3	5	3	78
Retail Trade (48)	12	9	12	7	19	4	3	6	5	77
Transportation and Warehousing (49)	12	8	0	10	24	1	1	4	7	67
Transportation and Warehousing (51)	1	1	0	0	6	1	0	0	6	14
Information	3	3	1	0	1	1	0	0	1	10
Finance and Insurance	3	1	5	2	7	0	1	1	1	21
Real Estate and Rental and Leasing	12	4	9	3	19	3	4	1	4	59
Professional, Scientific, and Technical Serv.	12	5	19	10	33	5	5	5	5	97
Management of Companies and Enterprises	0	1	1	1	1	0	0	0	1	3
Administrative, Support, Waste Mgmt …	20	14	8	8	32	5	6	7	2	103
Educational Services	1	4	2	2	4	1	3	1	3	20
Health Care and Social Assistance	7	11	6	1	14	1	2	2	1	45
Arts, Entertainment, and Recreation	10	4	4	3	7	0	3	1	1	33
Accommodation and Food Services	9	7	12	3	16	1	3	1	6	58
Other Services (except Public Administration)	25	13	10	4	24	8	5	5	5	98
Public Administration	1	1	0	1	0	0	0	0	1	3
Unknown	146	131	95	57	244	43	57	39	50	861
Total in Floodplain	**330**	**269**	**210**	**144**	**568**	**90**	**123**	**93**	**131**	**1,958**
Total Businesses in SPA	**37,915**	**6,241**	**7,320**	**4,202**	**6,100**	**1,889**	**1,946**	**1,464**	**3,794**	**70,872**
Percent in Floodplain	**0.9%**	**4.3%**	**2.9%**	**3.4%**	**9.3%**	**4.8%**	**6.3%**	**6.4%**	**3.4%**	**2.8%**

Source: Created by ECONorthwest

2.6.2 Businesses in Sea Level Rise Floodplain Extent

Table 2-13 summarizes the number of businesses that located in the floodplain extent for sea level rise. Only five of the nine SPAs have businesses that are within the sea level rise floodplain extent. The types of businesses that are most commonly in the sea level rise floodplain extent are in the industries of *Real Estate and Rental and Leasing*, *Wholesale Trade*, and *Manufacturing*.

Table 2-13. Number of Businesses in the Sea Level Rise Floodplain Extent, by SPA and Industry

NAICS Code	NAICS Description	Chambers Bay / Clover Creek Basin	Clear / Clarks Creek Basin	Gig Harbor / Key Peninsula Basin	Hylebos-Browns Point-Dash Point Basin	Mid Puyallup Basin	Total
11	Agriculture, Forestry, Fishing and Hunting	5	1	6	7	0	19
22	Mining, Quarrying, & Oil and Gas Extr.	0	0	1	0	0	1
23	Utilities	11	2	13	47	5	78
31	Construction	3	0	2	1	1	7
32	Manufacturing	8	0	1	20	0	29
33	Manufacturing	6	0	1	15	2	24
42	Manufacturing	20	1	4	41	14	80
44	Wholesale Trade	12	1	13	50	11	86
45	Retail Trade	7	1	16	29	4	59
48	Retail Trade	10	0	0	38	7	54
49	Transportation and Warehousing	3	0	0	5	1	10
51	Transportation and Warehousing	0	0	1	1	2	4
52	Information	7	0	5	21	1	34
53	Finance and Insurance	12	1	14	31	4	62
54	Real Estate and Rental and Leasing	25	0	32	45	4	106
55	Professional, Scientific, and Technical Serv.	0	0	0	3	1	3
56	Management of Companies and Enterprises	5	1	6	30	1	43
61	Administrative, Support, Waste Mgmt	5	0	5	4	1	14
62	Educational Services	7	0	6	18	0	31
71	Health Care and Social Assistance	8	0	8	7	2	25
72	Arts, Entertainment, and Recreation	11	1	15	33	7	67
81	Accommodation and Food Services	16	1	16	33	10	75
92	Other Services (except Public Administration)	1	0	1	3	0	5
92	Public Administration	0	0	0	0	0	0
Missing	Unknown	135	10	118	351	46	662
	Total	**318**	**18**	**284**	**833**	**125**	**1,578**
	Total Businesses in SPA	**37,915**	**6,241**	**7,320**	**4,202**	**6,100**	**61,779**
	Percent of Total in SPA	**0.8%**	**0.3%**	**3.9%**	**19.8%**	**2.0%**	**2.6%**

Source: Created by ECONorthwest

2.7 Employment in the Floodplain

The largest employer in Pierce County is Joint Base Lewis-McChord. Additional large employers in the public sector include the State of Washington, Tacoma Public Schools, and the City of Tacoma (including Tacoma Public Utilities). The largest private employers are MultiCare Health System, CHI Franciscan Health, and Albertsons Companies. Table 2-14 lists the ten largest employers for both private and public employers in Pierce County.

Table 2-14. Ten Largest Employers in Pierce County, Private and Public Sectors (2020)

	Private		Public	
Rank	**Private Employers**	**Employment Level**	**Public Employer**	**Employment Level**
1	MultiCare Health System	8,264	Joint Base Lewis-McChord	54,000
2	CHI Franciscan Health	5,682	State of Washington	7,859
3	Albertsons Companies	2,153	Tacoma Public Schools	3,649
4	Fred Meyer Retail and Distribution Center	1,802	City of Tacoma & Tacoma Public Utilities	3,623
5	Amazon Distribution Centers	1,800	Pierce County Government	3,304
6	Boeing	1,550	Puyallup School District	2,711
7	Costco	1,318	Bethel School District	2,689
8	State Farm Insurance	1,219	Emerald Queen Casino	2,146
9	Pacific Maritime Association	1,028	Clover Park School District	1,782
10	Walmart	861	U.S. Postal Service	1,336

Source: Economic Development Board for Tacoma-Pierce County. (2020). *Pierce County Major Employers List, Annual Report*. Available at: https://choosetacomapierce.org/locating-your-business/major-employers/

2.7.1 Employment in the 100-year Floodplain

There are a total of approximately 456,452 employees in Pierce County as of 2019.[22] Of these, a total of approximately 15,416 employees (3.4 percent) are employed at businesses that are located within the 100-year floodplain extent (excluding sea level rise). This percent of employees is higher than the percent of businesses that are in the floodplain (2.8 percent of all business), suggesting that businesses within the floodplain employ higher levels of employees compared to businesses not located in the floodplain extent.

Table 2-15. Number of Employees in the 100-Year Floodplain Extent, by Flooding Type and Industry

NAICS Code	NAICS Description	Coastal Flooding	Groundwater Flooding	Riverine Flooding	Total in Floodplains	Total Employees in Pierce County	% in Floodplain
11	Agriculture, Forestry, Fishing and Hunting	3		143	147	770	19.1%
21	Mining, Quarrying, & Oil and Gas Extr.				0	8	0.0%
22	Utilities			12	12	302	4.0%
23	Construction	2	23	1,060	1,084	17,829	6.1%
31	Manufacturing			97	97	2,272	4.3%
32	Manufacturing		117	186	303	4,326	7.0%
33	Manufacturing		4	151	155	6,141	2.5%
42	Wholesale Trade	1	13	946	960	10,588	9.1%
44	Retail Trade	1	0	326	327	15,686	2.1%
45	Retail Trade	3	6	214	223	13,525	1.7%
48	Transportation and Warehousing	74	1	1,491	1,566	9,564	16.4%

[22] IMPLAN, LLC, Pierce County Region Overview, 2019.

NAICS Code	NAICS Description	Coastal Flooding	Groundwater Flooding	Riverine Flooding	Total in Floodplains	Total Employees in Pierce County	% in Floodplain
49	Transportation and Warehousing			508	508	2,631	19.3%
51	Information			10	10	2,187	0.5%
52	Finance and Insurance	1		31	32	6,811	0.5%
53	Real Estate and Rental and Leasing	4	5	74	84	4,090	2.0%
54	Professional, Scientific, and Technical Serv.	6	1	134	142	7,511	1.9%
55	Management of Companies and Enterprises			3	3	520	0.5%
56	Administrative, Support, Waste Mgmt ...	1	106	495	603	16,993	3.5%
61	Educational Services			310	310	21,511	1.4%
62	Health Care and Social Assistance		18	932	949	38,340	2.5%
71	Arts, Entertainment, and Recreation	22		1,584	1,606	5,921	27.1%
72	Accommodation and Food Services	31		431	462	20,858	2.2%
81	Other Services (except Public Administration)	7	2	160	170	8,473	2.0%
92	Public Administration			21	21	61,478	0.0%
Missing	Unknown	114	185	5,346	5,645	178,117	3.2%
	Total in Floodplain	**271**	**481**	**14,664**	**15,416**	**456,452**	**3.4%**

Source: Created by ECONorthwest

Table 2-16 summarizes the number of employees in the floodplain extent for each SPA for each industry. Hylebos-Browns Point-Dash Point Basin SPA has the most total employees in the floodplain extent at 4,179. Mid Puyallup Basin SPA has the highest percent of total employees located in the floodplain extent at 11.0 percent. Muck Creek Basin SPA has the lowest number of total employees in the floodplain extent at 101. Chambers Bay/Clover Creek Basin SPA has the lowest percent of employment located in the floodplain extent at 0.6 percent.

Table 2-16. Number of Employees in the 100-Year Floodplain Extent, by SPA and Industry

NAICS Industry	Chambers Bay / Clover Creek Basin	Clear / Clarks Creek Basin	Gig Harbor / Key Peninsula Basin	Hylebos-Browns Point-Dash Point Basin	Mid Puyallup Basin	Muck Creek Basin	Nisqually Basin	Upper Puyallup Basin	White River Basin	Total
Agriculture, Forestry, Fishing and Hunting	0	32	3	4	51	0	55		2	**147**
Mining, Quarrying, & Oil and Gas Extr.										
Utilities							12			**12**
Construction	100	132	7	188	334	10	12	26	274	**1,084**
Manufacturing (31)	0				26	5		17	49	**97**
Manufacturing (32)	117	20		92	71		2			**303**
Manufacturing (33)	27				52	2	0	19	55	**155**
Wholesale Trade	15	85	44	169	217	2	1	1	425	**960**
Retail Trade (45)	66	44	9	42	141	1	6	1	17	**327**
Retail Trade (48)	48	12	13	60	51	2	3	0	34	**223**
Transportation and Warehousing (49)	2	9		601	642	8		1	304	**1,566**
Transportation and Warehousing (51)	3	3			160	0			342	**508**
Information		5	0			4			1	**10**
Finance and Insurance	2	7	4	6	9		0		4	**32**
Real Estate and Rental and Leasing	34	7	7	0	13	2	0		19	**84**
Professional, Scientific, and Technical Serv.	6	8	10	32	42	1	16	0	26	**142**
Management of Companies and Enterprises				2	0				1	**3**
Administrative, Support, Waste Mgmt ...	132	86	10	119	222	3	5	2	22	**603**
Educational Services		5	1	262	1	2		9	31	**310**
Health Care and Social Assistance	59	824	14		33	1		4	14	**949**
Arts, Entertainment, and Recreation	23	5	3	1,465	28		3		78	**1,606**
Accommodation and Food Services	66	51	76	25	173	12	11		48	**462**
Other Services (except Public Administration)	29	12	17	35	54	3	3	3	14	**170**
Public Administration		21								**21**
Unknown	760	1,249	181	1,075	1,402	43	92	63	778	**5,645**
Total in Floodplain	**1,490**	**2,618**	**400**	**4,179**	**3,723**	**101**	**222**	**147**	**2,537**	**15,416**
Total Businesses in SPA	**248,582**	**36,205**	**22,705**	**38,737**	**33,806**	**13,973**	**29,911**	**2,635**	**29,899**	**456,452**
Percent in SPA	**0.6%**	**7.2%**	**1.8%**	**10.8%**	**11.0%**	**0.7%**	**0.7%**	**5.6%**	**8.5%**	**3.4%**

Source: Created by ECONorthwest

2.7.2 Employment in Sea Level Rise Floodplain

Table 2-17 summarizes the number of employees that are located in the floodplain extent for sea level rise. Hylebos-Browns Point-Dash Point Basin SPA has the highest number of employees located in the sea level rise floodplain extent at 20,804, many of which are within the Port of Tacoma which is largely within the sea level rise floodplain extent. This SPA also has the highest percent of employees located in the sea level rise floodplain extent at 54 percent.

Table 2-17. Number of Employees in the Sea Level Rise Floodplain Extent, by SPA and Industry

	NAICS Description	Chambers Bay / Clover Creek Basin	Clear / Clarks Creek Basin	Gig Harbor / Key Peninsula Basin	Hylebos-Browns Point-Dash Point Basin	Mid Puyallup Basin	Total in Sea Level Rise Floodplain
11	Agriculture, Forestry, Fishing and Hunting	16	1	7	14		39
21	Mining, Quarrying, & Oil and Gas Extr.						
22	Utilities	108	42	16	775	99	1,040
23	Construction	108	42	16	775	99	1,040
31	Manufacturing	31		3	19	39	93
32	Manufacturing	375			834		1,209
33	Manufacturing	281		1	581	58	922
42	Wholesale Trade	529	15	4	1,752	553	2,854
44	Retail Trade	21	2	22	699	177	921
45	Retail Trade	13	4	42	426	66	550
48	Transportation and Warehousing	515			1,856	319	2,690
49	Transportation and Warehousing	147			233	64	444
51	Information			0	194	290	484
52	Finance and Insurance	11		4	77	3	95
53	Real Estate and Rental and Leasing	56		13	178	28	275
54	Professional, Scientific, and Technical Serv.	65		46	186	16	313
55	Management of Companies and Enterprises				99	49	148
56	Administrative, Support, Waste	278	2	8	1,974	65	2,327
61	Educational Services	13		55	268	1	336
62	Health Care and Social Assistance	76		1	224		301
71	Arts, Entertainment, and Recreation	66		26	1,497	2	1,591
72	Accommodation and Food Services	127	2	153	640	158	1,079
81	Other Services (except Public Administration)	43		34	323	125	525
92	Public Administration	2			10		12
Missing	Unknown	1,951	78	265	7,945	1,111	11,351
	Total	**4,724**	**146**	**701**	**20,804**	**3,224**	**29,598**
	Total Employees in SPA	**248,582**	**36,205**	**22,705**	**38,737**	**33,806**	**380,035**
	Percent of Total in SPA	**1.9%**	**0.4%**	**3.1%**	**53.7%**	**9.5%**	**7.8%**

Source: Created by ECONorthwest

2.8 Labor Income in the Floodplain

This analysis uses the definition of labor income as defined by IMPLAN LLC. Labor income is the sum of wages and benefits to employees (i.e., employee compensation) as well as payments to self-employed individuals and business owners, excluding dividends, (i.e., proprietor income). Labor income data was obtained from IMPLAN and mapped to the NAICS industry categories based on values per employee of labor income by industry.

2.8.1 Labor Income in the 100-year Floodplain

There was a total of $29.7 billion in labor income in Pierce County in 2019. Of this total, 88.2 percent is employee compensation and 11.8 percent is proprietor income (Table 2-18). Employee compensation includes workers' wages and salaries, as well as other benefits such as health, disability, and life insurance, retirement payments, and non-cash compensation. Proprietor's income (i.e., business owner's income) consists of payments received by self-employed individuals and unincorporated business owners.

Table 2-18. Total Annual Labor Income in Pierce County (2019)

	Amount	Percent of Total Labor Income
1 - Employee Compensation	$26,196,552,053	88.2%
2 - Proprietor Income	$3,508,446,131	11.8%
Total Labor Income in Pierce County	**$29,704,998,184**	**100%**

Source: IMPLAN, LLC, Pierce County Region Overview, 2019.

Of the $29.7 billion in annual labor income in Pierce County, approximately 3.9 percent ($1.1 billion) is located in the 100-year floodplain extent. Table 2-19 summarizes annual labor income by industry and by floodplain type. The industries with the highest percent of total labor income located within the floodplain are the *Arts, Entertainment, and Recreation*, *Transportation and Warehousing*, and *Agriculture, Forestry, Fishing and Hunting* industries.

Table 2-20 describes the amount of annual labor income located in the floodplain extent for each SPA by industry. Mid Puyallup Basin SPA has both the highest amount of labor income in the floodplain extent at $297 million, as well as the highest percent of labor income at 11.9 percent. Chambers Bay/Clover Creek Basin SPA has the highest total labor income of all the SPAs, but the lowest percent of labor income located in the floodplain extent.

Table 2-19. Annual Labor Income in the 100-Year Floodplain Extent, by Flooding Type and Industry (2021 Dollars)

NAICS Code	NAICS Description	Coastal Flooding	Groundwater Flooding	Riverine Flooding	Total in Floodplains	Total Labor Income in Pierce County	Percent in Floodplain
11	Agriculture, Forestry, Fishing and Hunting	$210,932		$8,723,255	$8,934,187	$46,864,959	19.1%
21	Mining, Quarrying, & Oil				$0	$202,837	0.0%
22	Utilities			$2,039,028	$2,039,028	$50,726,561	4.0%
23	Construction	$141,145	$2,071,024	$95,308,782	$97,520,951	$1,603,681,162	6.1%
31	Manufacturing			$6,316,196	$6,316,196	$148,343,671	4.3%
32	Manufacturing		$11,793,674	$18,719,860	$30,513,534	$436,300,949	7.0%
33	Manufacturing		$375,971	$16,127,889	$16,503,860	$654,790,772	2.5%
42	Wholesale Trade	$87,392	$1,591,346	$113,533,409	$115,212,147	$1,271,040,488	9.1%
44	Retail Trade	$72,616	$2,048	$19,735,834	$19,810,497	$950,375,497	2.1%
45	Retail Trade	$108,927	$215,113	$7,356,457	$7,680,496	$465,118,705	1.7%
48	Transportation and Warehousing	$7,487,199	$71,009	$151,893,140	$159,451,348	$974,053,130	16.4%
49	Transportation and Warehousing			$36,328,858	$36,328,858	$188,273,720	19.3%
51	Information			$992,499	$992,499	$211,319,319	0.5%
52	Finance and Insurance	$107,614		$2,619,520	$2,727,134	$576,245,719	0.5%
53	Real Estate and Rental and Leasing	$295,194	$342,456	$4,883,594	$5,521,244	$270,420,949	2.0%
54	Professional, Scientific, and Technical Serv.	$473,114	$80,364	$10,040,178	$10,593,656	$561,671,602	1.9%
55	Management of Companies and Enterprises			$297,940	$297,940	$57,716,003	0.5%
56	Administrative, Support, Waste Mgmt ...	$61,920	$7,106,909	$33,047,474	$40,216,303	$1,134,265,880	3.5%
61	Educational Services			$14,343,021	$14,343,021	$994,565,585	1.4%
62	Health Care and Social Assistance		$1,707,479	$90,728,786	$92,436,265	$3,733,945,922	2.5%
71	Arts, Entertainment, and Recreation	$648,452		$45,873,539	$46,521,991	$171,520,955	27.1%
72	Accommodation and Food Services	$1,384,252		$19,372,069	$20,756,322	$937,338,798	2.2%
81	Other Services (except Public Administration)	$497,919	$164,050	$10,818,787	$11,480,755	$572,637,486	2.0%
92	Public Administration			$2,509,990	$2,509,990	$867,216,566	0.3%
Missing	Unknown	$8,216,149	$13,325,407	$384,948,575	$406,490,130	$12,826,361,084	3.2%
Total		**$19,792,823**	**$38,846,849**	**$1,096,558,679**	**$1,155,198,351**	**$29,704,998,319**	**3.9%**

Source: Created by ECONorthwest

Table 2-20. Annual Labor Income in the 100-Year Floodplain Extent, by SPA and Industry (in Thousands of Dollars, 2021 Dollars)

NAICS Industry	Chambers Bay / Clover Creek Basin	Clear / Clarks Creek Basin	Gig Harbor / Key Peninsula	Hylebos-Browns Point-Dash	Mid Puyallup Basin	Muck Creek Basin	Nisqually Basin	Upper Puyallup Basin	White River Basin	Total
Agriculture, Forestry, Fishing and Hunting	$14	$1,958	$184	$248	$3,104	$8	$3,325	$0	$94	$8,934
Mining, Quarrying, & Oil and Gas Extr.	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Utilities	$0	$0	$0	$0	$0	$0	$2,039	$0	$0	$2,039
Construction	$9,028	$11,887	$662	$16,911	$30,022	$938	$1,065	$2,369	$24,639	$97,521
Manufacturing (31)	$15	$0	$0	$0	$1,670	$345	$0	$1,113	$3,173	$6,316
Manufacturing (32)	$11,794	$2,014	$0	$9,310	$7,209	$0	$187	$0	$0	$30,514
Manufacturing (33)	$2,866	$0	$0	$0	$5,574	$176	$27	$1,997	$5,864	$16,504
Wholesale Trade	$1,824	$10,210	$5,242	$20,338	$26,020	$194	$166	$160	$51,059	$115,212
Retail Trade (45)	$4,011	$2,651	$566	$2,549	$8,528	$45	$338	$69	$1,054	$19,810
Retail Trade (48)	$1,651	$407	$437	$2,077	$1,750	$77	$102	$17	$1,162	$7,680
Transportation and Warehousing (49)	$158	$882	$0	$61,228	$65,359	$824	$0	$53	$30,948	$159,451
Transportation and Warehousing (51)	$186	$242	$0	$0	$11,438	$12	$0	$0	$24,452	$36,329
Information	$0	$515	$42	$0	$0	$363	$0	$0	$73	$992
Finance and Insurance	$202	$583	$316	$505	$730	$0	$22	$0	$370	$2,727
Real Estate and Rental	$2,277	$491	$463	$31	$871	$100	$32	$0	$1,257	$5,521
Professional, Scientific, and Technical Serv.	$436	$588	$774	$2,402	$3,165	$110	$1,182	$15	$1,922	$10,594
Management of Companies	$0	$0	$0	$167	$46	$0	$0	$0	$86	$298
Administrative, Support, Waste Mgmt	$8,793	$5,760	$695	$7,924	$14,833	$198	$347	$166	$1,500	$40,216
Educational Services	$0	$229	$27	$12,110	$48	$80	$0	$414	$1,434	$14,343
Health Care and Social Assistance	$5,791	$80,239	$1,349	$0	$3,247	$117	$0	$378	$1,316	$92,436
Arts, Entertainment, and Recreation	$678	$140	$93	$42,446	$813	$0	$89	$0	$2,263	$46,522
Accommodation and Food Services	$2,944	$2,285	$3,422	$1,117	$7,767	$542	$513	$0	$2,167	$20,756
Other Services	$1,939	$818	$1,143	$2,366	$3,671	$172	$232	$206	$934	$11,481
Public Administration	$0	$2,510	$0	$0	$0	$0	$0	$0	$0	$2,510
Unknown	$54,744	$89,951	$13,022	$77,443	$100,981	$3,112	$6,638	$4,548	$56,051	$406,490
Total	**$109,353**	**$214,357**	**$28,437**	**$259,170**	**$296,844**	**$7,414**	**$16,303**	**$11,504**	**$211,816**	**$1,155,198**
Total Labor Income	**$16,985,791**	**$2,559,743**	**$1,619,847**	**$2,971,874**	**$2,484,216**	**$173,259**	**$425,088**	**$191,971**	**$2,293,210**	**$29,704,998**
Percent in Floodplain	**0.6%**	**8.4%**	**1.8%**	**8.7%**	**11.9%**	**4.3%**	**3.8%**	**6.0%**	**9.2%**	**3.9%**

Source: Created by ECONorthwest

2.8.2 Labor Income in Sea Level Rise Floodplain

Table 2-21 summarizes the amount of labor income that is located in the floodplain extent for sea level rise. The Hylebos-Browns Point-Dash Point Basin SPA has the highest amount of labor income located in the sea level rise floodplain extent at $1.6 billion, representing 53.4 percent of the total labor income in the SPA. The total annual labor income in the sea level rise floodplain is $2.3 billion.

Table 2-21. Annual Labor Income in the Sea Level Rise Floodplain Extent, by SPA and Industry (in Thousands of Dollars, 2021 Dollars)

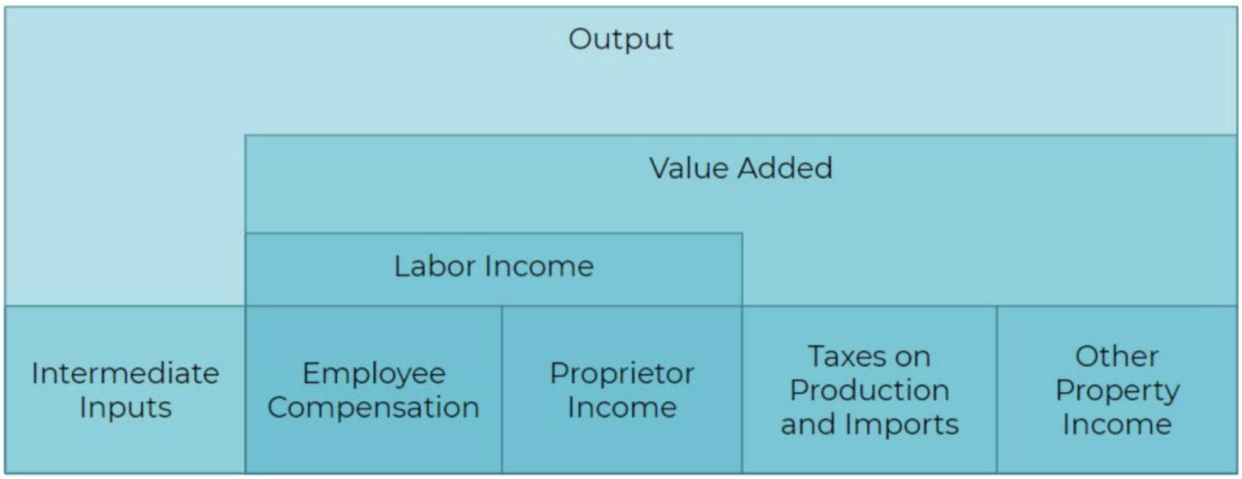
NAICS Code	NAICS Description	Chambers Bay / Clover Creek Basin	Clear / Clarks Creek Basin	Gig Harbor / Key Peninsula Basin	Hylebos-Browns Point-Dash Point Basin	Mid Puyallup Basin	Total in Sea Level Rise Floodplain
11	Agriculture, Forestry, Fishing and Hunting	$992	$60	$446	$868	$0	**$2,365**
21	Mining, Quarrying, & Oil and Gas Extr.	$0	$0	$0	$0	$0	**$0**
22	Utilities	$0	$0	$0	$0	$0	**$0**
23	Construction	$9,711	$3,807	$1,470	$69,679	$8,885	**$93,552**
31	Manufacturing	$2,056	$0	$192	$1,269	$2,539	**$6,056**
32	Manufacturing	$37,829	$0	$0	$84,071	$0	**$121,901**
33	Manufacturing	$29,996	$0	$139	$61,981	$6,218	**$98,334**
42	Wholesale Trade	$63,537	$1,858	$527	$210,302	$66,442	**$342,666**
44	Retail Trade	$1,289	$112	$1,343	$42,341	$10,714	**$55,799**
45	Retail Trade	$433	$127	$1,432	$14,644	$2,280	**$18,917**
48	Transportation and Warehousing	$52,410	$0	$0	$189,038	$32,496	**$273,944**
49	Transportation and Warehousing	$10,522	$0	$0	$16,679	$4,567	**$31,768**
51	Information	$0	$0	$42	$18,707	$28,060	**$46,809**
52	Finance and Insurance	$932	$0	$305	$6,522	$252	**$8,011**
53	Real Estate and Rental and Leasing	$3,697	$0	$862	$11,778	$1,877	**$18,214**
54	Professional, Scientific, and Technical Serv.	$4,863	$0	$3,445	$13,924	$1,169	**$23,401**
55	Management of Companies and Enterprises	$0	$0	$0	$11,010	$5,422	**$16,432**
56	Administrative, Support, Waste Mgmt …	$18,530	$132	$558	$131,747	$4,344	**$155,312**
61	Educational Services	$595	$0	$2,544	$12,372	$45	**$15,557**
62	Health Care and Social Assistance	$7,375	$0	$77	$21,836	$0	**$29,288**
71	Arts, Entertainment, and Recreation	$1,906	$0	$747	$43,379	$46	**$46,078**
72	Accommodation and Food Services	$5,695	$82	$6,892	$28,746	$7,079	**$48,494**
81	Other Services (except Public Administration)	$2,885	$0	$2,271	$21,829	$8,463	**$35,448**
92	Public Administration	$236	$0	$0	$1,178	$0	**$1,414**
Missing	Unknown	$140,506	$5,593	$19,099	$572,145	$80,032	**$817,376**
	Total in Floodplain	**$395,995**	**$11,772**	**$42,392**	**$1,586,047**	**$270,930**	**$2,307,137**
	Total Labor Income in SPA	**$16,985,791**	**$2,559,743**	**$1,619,847**	**$2,971,874**	**$2,484,216**	**$26,621,470**
	Percent of Total in SPA	**2.3%**	**0.5%**	**2.6%**	**53.4%**	**10.9%**	**8.7%**

Source: Created by ECONorthwest

2.9 Output in the Floodplain

This analysis uses the definition of output as defined by IMPLAN LLC. Output represents the value of goods and services produced and is the broadest measure of economic activity. Output includes labor income, as well as taxes on production and imports, other property income, and the cost of intermediate inputs (Figure 2-6). There was a total of $77.7 billion in annual output in Pierce County in 2019. Annual total value added, a component of output that is also referred to as Gross Regional Product, was $47.8 billion in 2019.

Figure 2-6. Components of Output



Source: IMPLAN, LLC

2.9.1 Output in the 100-year Floodplain

Table 2-22 summarizes annual output with the floodplain extent by flood type. The industry of *Wholesale Trade* has the largest amount of annual output located in the floodplain extent, followed by *Transportation and Warehousing*.

Table 2-23 provides annual output within the floodplain extent for each SPA. Mid Puyallup Basin SPA has both the highest amount of output in the floodplain extent at $893 million, as well as the highest percent of output at 13.0 percent. Mid Puyallup Basin and Hylebos-Browns Point-Dash Point Basin SPAs have large portions of output located in the floodplain extent for the *Transportation and Warehousing* industry. The White River Basin SPA has a large portion of output located in the floodplain extent for the *Wholesale Trade* industry.

Table 2-22. Annual Output in the 100-Year Floodplain Extent, by Flooding Type and Industry (2021 Dollars)

NAICS Code	NAICS Description	Coastal Flooding	Groundwater Flooding	Riverine Flooding	Total in Floodplains	Total Output in Pierce County	Percent of Total in Floodplain
11	Agriculture, Forestry, Fishing and Hunting	$354,670		$14,667,656	$15,022,326	$78,800,760	19.1%
21	Mining, Quarrying, & Oil and Gas Extr.				$0	$2,158,360	0.0%
22	Utilities			$16,385,768	$16,385,768	$407,642,070	4.0%
23	Construction	$295,635	$4,337,865	$199,629,064	$204,262,563	$3,358,991,289	6.1%
31	Manufacturing			$56,263,122	$56,263,122	$1,321,409,059	4.3%
32	Manufacturing		$80,644,841	$128,005,933	$208,650,774	$2,983,414,835	7.0%
33	Manufacturing		$1,422,820	$61,034,157	$62,456,977	$2,477,980,939	2.5%
42	Wholesale Trade	$462,948	$8,429,975	$601,430,452	$610,323,376	$6,733,193,797	9.1%
44	Retail Trade	$143,749	$4,054	$39,068,591	$39,216,394	$1,881,341,016	2.1%
45	Retail Trade	$289,370	$571,461	$19,542,878	$20,403,709	$1,235,616,339	1.7%
48	Transportation and Warehousing	$25,611,090	$242,896	$519,573,242	$545,427,227	$3,331,894,899	16.4%
49	Transportation and Warehousing			$50,270,351	$50,270,351	$260,525,281	19.3%
51	Information			$4,929,662	$4,929,662	$1,049,606,433	0.5%
52	Finance and Insurance	$375,817		$9,148,118	$9,523,935	$2,012,415,613	0.5%
53	Real Estate and Rental and Leasing	$1,662,217	$1,928,350	$27,499,211	$31,089,778	$1,522,723,505	2.0%
54	Professional, Scientific, and Technical Serv.	$1,124,078	$190,937	$23,854,597	$25,169,612	$1,334,483,264	1.9%
55	Management of Companies and Enterprises			$552,920	$552,920	$107,109,850	0.5%
56	Administrative, Support, Waste Mgmt ...	$116,744	$13,399,395	$62,307,847	$75,823,986	$2,138,549,574	3.5%
61	Educational Services			$21,265,626	$21,265,626	$1,474,588,858	1.4%
62	Health Care and Social Assistance		$2,328,221	$123,712,600	$126,040,821	$5,091,395,712	2.5%
71	Arts, Entertainment, and Recreation	$1,892,748		$133,899,051	$135,791,799	$500,647,923	27.1%
72	Accommodation and Food Services	$3,115,755		$43,603,768	$46,719,523	$2,109,816,093	2.2%
81	Other Services (except Public Administration)	$876,753	$288,865	$19,050,111	$20,215,728	$1,008,320,704	2.0%
92	Public Administration			$3,609,709	$3,609,709	$1,247,176,054	0.3%
Missing	Unknown	$21,751,723	$35,278,152	$1,019,126,434	$1,076,156,309	$33,956,960,550	3.2%
Total		**$58,073,298**	**$149,067,830**	**$3,198,430,866**	**$3,405,571,994**	**$77,626,762,775**	**4.4%**

Source: Created by ECONorthwest

Table 2-23. Annual Output in the 100-Year Floodplain Extent, by SPA and Industry (in Thousands of Dollars, 2021 Dollars)

NAICS Industry	Chambers Bay / Clover Creek Basin	Clear / Clarks Creek Basin	Gig Harbor / Key Peninsula Basin	Hylebos-Browns Point-Dash Point Basin	Mid Puyallup Basin	Muck Creek Basin	Nisqually Basin	Upper Puyallup Basin	White River Basin	Total
Agriculture, Forestry, Fishing and Hunting	$23	$3,292	$309	$417	$5,219	$13	$5,592	$0	$158	$15,022
Mining, Quarrying, & Oil and Gas Extr.	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Utilities	$0	$0	$0	$0	$0	$0	$16,386	$0	$0	$16,386
Construction	$18,909	$24,898	$1,387	$35,421	$62,882	$1,965	$2,231	$4,961	$51,607	$204,263
Manufacturing (31)	$130	$0	$0	$0	$14,877	$3,071	$0	$9,917	$28,268	$56,263
Manufacturing (32)	$80,645	$13,772	$0	$63,659	$49,293	$0	$1,282	$0	$0	$208,651
Manufacturing (33)	$10,844	$0	$0	$0	$21,095	$668	$102	$7,558	$22,190	$62,457
Wholesale Trade	$9,665	$54,084	$27,771	$107,737	$137,836	$1,028	$877	$847	$270,479	$610,323
Retail Trade (45)	$7,941	$5,247	$1,120	$5,045	$16,883	$90	$668	$137	$2,086	$39,216
Retail Trade (48)	$4,386	$1,082	$1,162	$5,518	$4,650	$205	$270	$44	$3,087	$20,404
Transportation and Warehousing (49)	$541	$3,015	$0	$209,440	$223,569	$2,818	$0	$182	$105,861	$545,427
Transportation and Warehousing (51)	$258	$334	$0	$0	$15,827	$16	$0	$0	$33,835	$50,270
Information	$0	$2,559	$207	$0	$0	$1,804	$0	$0	$361	$4,930
Finance and Insurance	$707	$2,036	$1,102	$1,764	$2,548	$0	$76	$0	$1,291	$9,524
Real Estate and Rental and Leasing	$12,821	$2,764	$2,606	$173	$4,906	$562	$178	$0	$7,079	$31,090
Professional, Scientific, & Technical	$1,037	$1,396	$1,840	$5,706	$7,521	$262	$2,808	$35	$4,566	$25,170
Management of Companies	$0	$0	$0	$309	$85	$0	$0	$0	$159	$553
Administrative, Support, Waste Mgmt	$16,579	$10,859	$1,310	$14,940	$27,966	$373	$655	$313	$2,829	$75,824
Educational Services	$0	$340	$41	$17,955	$71	$119	$0	$614	$2,127	$21,266
Health Care and Social Assistance	$7,896	$109,409	$1,840	$0	$4,427	$159	$0	$515	$1,794	$126,041
Arts, Entertainment, and Recreation	$1,979	$408	$273	$123,894	$2,372	$0	$259	$0	$6,607	$135,792
Accommodation and Food Services	$6,627	$5,143	$7,702	$2,514	$17,482	$1,220	$1,154	$0	$4,877	$46,720
Other Services (except Public Administration)	$3,415	$1,440	$2,012	$4,166	$6,464	$302	$408	$363	$1,645	$20,216
Public Administration	$0	$3,610	$0	$0	$0	$0	$0	$0	$0	$3,610
Unknown	$144,932	$238,139	$34,475	$205,025	$267,341	$8,239	$17,574	$12,039	$148,391	$1,076,156
Total in Floodplain	**$329,336**	**$483,827**	**$85,156**	**$803,684**	**$893,313**	**$22,916**	**$50,520**	**$37,525**	**$699,295**	**$3,405,572**
Total Output in SPA	**$42,169,895**	**$6,051,215**	**$4,175,735**	**$9,267,218**	**$6,893,138**	**$447,905**	**$1,186,452**	**$524,811**	**$6,910,394**	**$77,626,763**
Percent in Floodplain	**0.8%**	**8.0%**	**2.0%**	**8.7%**	**13.0%**	**5.1%**	**4.3%**	**7.2%**	**10.1%**	**4.4%**

Source: Created by ECONorthwest

2.9.2 Output in Sea Level Rise Floodplain

Table 2-24 summarizes the amount of annual output that is located in the floodplain extent for sea level rise. The Hylebos-Browns Point-Dash Point Basin SPA has the highest amount of output located in the sea level rise floodplain extent at $5.2 billion representing 55.6 percent of the total output in the SPA.

Table 2-24. Annual Output in the Sea Level Rise Floodplain Extent, by SPA and Industry (in Thousands of Dollars, 2021 Dollars)

NAICS Code	NAICS Description	Chambers Bay / Clover Creek Basin	Clear / Clarks Creek Basin	Gig Harbor / Key Peninsula Basin	Hylebos-Browns Point-Dash Point Basin	Mid Puyallup Basin	Total in Sea Level Rise Floodplain
11	Agriculture, Forestry, Fishing and Hunting	$1,667	$102	$750	$1,459	$0	$3,977
21	Mining, Quarrying, & Oil and Gas Extr.	$0	$0	$0	$0	$0	$0
22	Utilities	$0	$0	$0	$0	$0	$0
23	Construction	$20,339	$7,975	$3,078	$145,947	$18,610	$195,950
31	Manufacturing	$18,315	$0	$1,712	$11,308	$22,615	$53,949
32	Manufacturing	$258,677	$0	$0	$574,877	$0	$833,554
33	Manufacturing	$113,518	$0	$527	$234,559	$23,530	$372,134
42	Wholesale Trade	$336,578	$9,842	$2,794	$1,114,054	$351,967	$1,815,234
44	Retail Trade	$2,552	$222	$2,659	$83,817	$21,209	$110,458
45	Retail Trade	$1,150	$338	$3,805	$38,904	$6,058	$50,255
48	Transportation and Warehousing	$179,278	$0	$0	$646,633	$111,157	$937,067
49	Transportation and Warehousing	$14,560	$0	$0	$23,079	$6,320	$43,959
51	Information	$0	$0	$208	$92,915	$139,373	$232,496
52	Finance and Insurance	$3,254	$0	$1,064	$22,777	$882	$27,977
53	Real Estate and Rental and Leasing	$20,815	$0	$4,853	$66,323	$10,571	$102,562
54	Professional, Scientific, and Technical Serv.	$11,555	$0	$8,184	$33,083	$2,776	$55,599
55	Management of Companies and Enterprises	$0	$0	$0	$20,433	$10,062	$30,495
56	Administrative, Support, Waste Mgmt	$34,937	$250	$1,052	$248,397	$8,190	$292,825
61	Educational Services	$883	$0	$3,772	$18,343	$67	$23,065
62	Health Care and Social Assistance	$10,056	$0	$105	$29,775	$0	$39,936
71	Arts, Entertainment, and Recreation	$5,563	$0	$2,181	$126,616	$136	$134,496
72	Accommodation and Food Services	$12,818	$184	$15,514	$64,704	$15,933	$109,152
81	Other Services (except Public Administration)	$5,081	$0	$3,999	$38,437	$14,903	$62,419
92	Public Administration	$339	$0	$0	$1,694	$0	$2,033
Missing	Unknown	$371,980	$14,807	$50,564	$1,514,718	$211,880	$2,163,950
	Total in Floodplain	**$1,423,914**	**$33,720**	**$106,820**	**$5,152,851**	**$976,238**	**$7,693,544**
	Total Output in SPA	**$42,169,895**	**$6,051,215**	**$4,175,735**	**$9,267,218**	**$6,893,138**	**$68,557,201**
	Percent in Floodplain	**3.4%**	**0.6%**	**2.6%**	**55.6%**	**14.2%**	**11.2%**

Source: Created by ECONorthwest

2.10 Fiscal Revenues in the Floodplain

There are three types of taxes relevant to potential flooding impacts in Pierce County:

1. Sales and Use Tax
2. Business and Occupation Tax
3. Property Tax

2.10.1 Sales and Use Tax

The sales and use tax rate in Pierce County varies by taxing jurisdiction. There is a 6.5 percent sales and use tax at the state level throughout the county. The local tax rate varies from a low of 1.5 percent to a high of 3.8 percent.[23] Since 2008, Washington has had a destination-based sales tax system. Sales and use tax is levied at the destination of the merchandise (i.e., the point of delivery or where the buyer receives or takes possession). In other words, the tax rate that is owed depends on the location of the sale/delivery, not the location of the business or shipping warehouse. In fiscal year 2020, sales and use tax revenue for Pierce County was $102.6 million.[24] Approximately 29 percent of county revenues are from sales and use taxes.

2.10.2 Business and Occupation Tax

Washington's business and occupation tax rate for services is 0.015 of gross receipts (i.e., the value of products, gross proceeds of sale, or gross income of the business).[25] Pierce County does not receive funds from the business and occupation tax, however, local cities do implement their own business and occupation taxes. For example, the City of Tacoma has local business and occupation taxes that vary by industry (e.g., a rate of 0.0011 for manufacturing).[26]

2.10.3 Property Tax

Property taxes are a primary source of revenue for Pierce County. In fiscal year 2020, property tax revenue for Pierce County was $146.9 million, representing 42 percent of total county revenues. Property taxes funds for city and county government services, including school districts, fire districts, emergency medical service, parks, libraries, roads, Port of Tacoma, Sound Transit, and flood control activities. Certain properties are exempt from property tax, including churches, government entities, and many nonprofit agencies. There are additional programs that certain people can apply for to receive property tax exemptions. For example, the Current Use Open Space Taxation Act program may reduce a parcel's property tax liability for properties used for forestry and agriculture.

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[23] Detailed information about local sales and use taxes are available at: https://dor.wa.gov/taxes-rates/sales-and-use-tax-rates/local-sales-and-use-tax

[24] Pierce County. (2020). *Annual Comprehensive Financial Report For the Year Ended December 31, 2020*.

[25] More information about Washington's Business and Occupation tax is available from Washington Department of Revenue: https://dor.wa.gov/taxes-rates/business-occupation-tax

[26] More information about local business and occupation tax rates can be found at: https://wacities.org/docs/default-source/resources/bando-taxes/botaxrates.pdf

The total assessed value of taxable property in Pierce County was $137.7 billion for fiscal year 2020. The 2020 property tax rate averaged $12.66 per $1,000 of assessed value, but varies by individual taxing district.[27] Properties and assessed values in the floodplain and sea level rise extents are discussed further in Chapter 7.

2.11 Agricultural Economic Activity

Table 2-25 displays the market value of agricultural products sold (e.g., gross revenue, gross sales) by crop type for 2017. The largest categories of agricultural products are animal products, include poultry and eggs, cattle and calves, milk from cows and shellfish, as well as high-value nursery, greenhouse, floriculture, sod products. Pierce County is notable for its aquaculture industry as well as Wilcox Farms, which is a 1,600-acre egg producer in the Nisqually Basin SPA.

Table 2-25. Market Value of Agricultural Products Sold by Crop Type, Pierce County Total (2017)

Agricultural Product	Total Annual Ag. Revenue
Poultry and eggs, cattle and calves, milk from cows	$24,666,000
Nursery, greenhouse, floriculture, sod	$14,641,000
Shellfish	$9,028,000
Vegetables, melons, potatoes, sweet potatoes	$7,922,000
Fruits, tree nuts, berries	$5,456,000
Other crops and hay	$771,000
Horses, ponies, mules, burros, donkeys	$664,000
Other animals and animal products	$562,000
Cultivated Christmas trees, short rotation woody crops	$455,000
Sheep, goats, wool, mohair, milk	$438,000
Grains, oilseeds, dry beans, dry peas	$181,000
Hogs and pigs	$93,000
Total	**$64,877,000**

Source: USDA Agricultural Statistics Service. *(2017). County Profile: Pierce County, Washington.*

Table 2-26 provides estimates of how much on-farm revenue is generated by the farmland located in a floodplain. On-farm revenue from all Pierce County SPAs totals $64.9 million,[28] of which $17.9 million (27.7 percent) is revenue generated from land in the 100-year floodplain and $9.4 million (14.5 percent) is revenue generated from land in the sea level rise floodplain. See Table 2-9 for acres of farmland in the floodplain that was used to calculate the revenue estimates.

[27] Pierce County. (2020). *Annual Comprehensive Financial Report For the Year Ended December 31, 2020*. Schedule 6.

[28] U.S. Department of Agriculture, National Agricultural Statistical Service, Value of Sales (2017), Pierce County.

Table 2-26. Annual On-Farm Revenues in the 100-Year Floodplain and Sea Level Rise Floodplain Extents, by Flood Type and SPA (2021 Dollars)

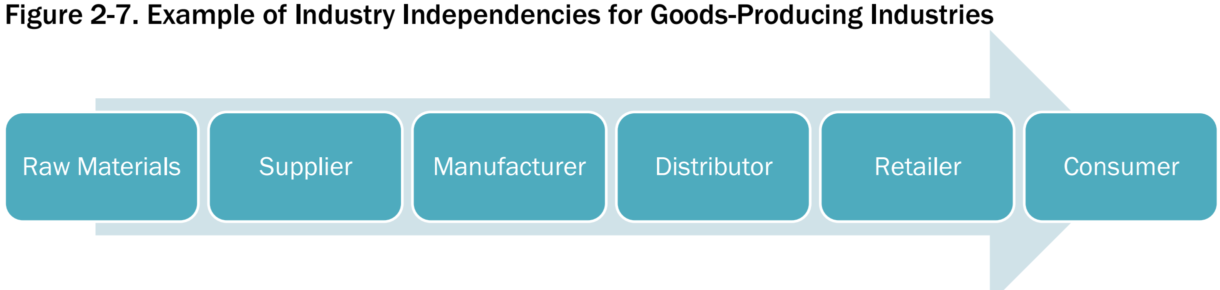
SPA	Total Revenue	Revenue: Acres in Coastal Flooding	Revenue: Acres in Groundwater Flooding	Revenue: Acres in Riverine Flooding	Revenue for Acres in Floodplain (% in Floodplain)	Revenue: Acres in Sea Level Rise Flooding (% in Floodplain)
Chambers Bay/ Clover Creek Basin	$1,607,705	$6,204	$21,918	$3,576	$31,698 (2.0%)	$884,264 (55.0%)
Clear/Clarks Creek Basin	$3,438,853	$0	$0	$2,111,661	$2,111,661 (61.4%)	$160,674 (4.7%)
Gig Harbor/Key Peninsula Basin	$10,880,445	$228,388	$0	$624,877	$853,265 (7.8%)	$7,705,353 (70.8%)
Hylebos-Browns Point-Dash Point Basin	$2,534,196	$1,515	$0	$394,975	$396,490 (15.6%)	$410,989 (16.2%)
Mid Puyallup Basin	$16,113,585	$0	$0	$6,258,786	$6,258,786 (38.8%)	$232,287 (1.4%)
Muck Creek Basin	$9,753,329	$0	$0	$2,086,306	$2,086,306 (21.4%)	$0
Nisqually Basin	$10,470,723	$0	$0	$3,242,764	$3,242,764 (31.0%)	$0
Upper Puyallup Basin	$3,643,549	$0	$0	$2,001,461	$2,001,461 (54.9%)	$0
White River Basin	$6,434,615	$0	$0	$987,307	$987,307 (15.3%)	$0
Total in SPAs	**$64,877,000**	**$236,108**	**$21,918**	**$17,711,712**	**$17,969,738 (27.7%)**	**$9,393,566 (14.5%)**

Source: ECONorthwest analysis of Washington State Department of Agriculture Crop Distribution data (2019) and USDA Agricultural Statistics Service. *(2017). County Profile: Pierce County, Washington.*

2.12 Industry Interdependencies

Industry interdependencies refers to the ways in which businesses within Pierce County are dependent upon one another. In other words, the output from one business or industry is an input to another. Figure 2-7 provides an example of the types of interdependencies for industries that produce goods. An example of interdependencies that would follow this pattern are food processors – farmers grow crops, such as vegetables and berries, which are then supplied to manufactures to process them into things like packaged goods, which are then distributed and sold in places like grocery stores. All of this could occur within Pierce County or could be exported out of the County to other locations further down the supply chain process.

Figure 2-7. Example of Industry Independencies for Goods-Producing Industries



Source: Created by ECONorthwest

Similar interdependencies occur through industries that supply services, rather than goods. Service providers are dependent on suppliers of finished goods and services provided by other industries. For example, an office needs to purchase paper and printing ink, as well as purchase services for cleaning, telecommunications, etc.

All of these industry independencies are present in small and large scales within Pierce County. The analysis in the subsequent Chapter identifies supply-chain and consumption effects of spending by businesses and their employees provides a quantitative evaluation of these effects. The section below qualitatively describes a large business and employer in Pierce County that is highly dependent on the interrelated dynamics of business within Pierce County – the Port of Tacoma.

2.12.1 Port of Tacoma

The Port of Tacoma is a significant driver of economic activity in Pierce County. It operates container shipping terminals, breakbulk and bulk terminals, and leases real estate. Since the establishment of the Northwest Seaport Alliance (NWSA) in 2015 which merged business between the Ports of Seattle and Tacoma, the NWSA has become the sixth largest container port in the U.S..[29] The Port of Tacoma is a source of 42,100 jobs and almost $3 billion dollars of economic activity.[30]

Potential flood risks to the Port of Tacoma include riverine flooding risks in select areas and along major transportation routes, and risk of sea level rise flooding across the entire Port area. The major transportation avenues in and out of the Port are also subject to sea level rise flooding risk. These risks from future sea level rise affect both the Port as well as both shippers and receivers who depend on the Port to play its role within the regional supply chain.

Potential disruptions to Port operations due to flooding could have impacts on not only the Port's business, but on the region's and country's economic activity due to the volume of goods moving through the Port of Tacoma. In 2020, 3.3 million Twenty-foot Equivalent Container Units (TEUs) were processed through the Port, 2.6 million of which were international and 0.68 million TEUs were domestic.[31] These estimates were 12.1 percent higher in 2019, prior to the decrease in volume due to the COVID-19 pandemic. In 2020, over $65.8 billion in total value of cargo passed through NWSA. Table 2-27 summarizes the top imports and exports by commodity type that passed through the NWSA in 2020.

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[29] Container News. (2021). *Top 10: The busiest container ports in the United States*. Available at: https://container-news.com/top-10-the-busiest-container-ports-in-the-united-states/.

[30] Port of Tacoma, *About*, available at: https://www.portoftacoma.com/about.

[31] NWSA. (2020). *2020 NWSA Annual Cargo Report*. Available at: https://s3.us-west-2.amazonaws.com/nwseaportalliance.com.if-us-west-2/prod/2021-04/2020%20NWSA%20Annual%20Cargo%20Report.pdf

Table 2-27. NSWA Top 20 Commodities, by Imports and Exports and Vessel Value

NWSA Import Commodities (Vessel Value)		NWSA Export Commodities (Vessel Value)	
Other machinery	$10,835M	Soybeans	$2,087M
Motor vehicle parts	$8,611M	Other machinery	$1,190M
Apparel	$3,526M	Corn	$771M
Small appliances	$2,888M	Frozen potato products	$760M
Furniture	$2,610M	Hay & forage	$713M
Toys & games	$1,799M	Chemicals	$681M
footwear	$1,517M	Dairy products	$630M
Other textiles	$1,339M	Other foodstuffs	$537M
Other plastic articles	$1,242M	Paper & paperboard	$531M
Other base metals	$1,066M	Fish	$494M
Iron or steel products	$1,024M	Scrap metal	$481M
Medical & optical devices	$1,014M	Mineral products	$425M
Chemicals	$1,012M	Apples	$403M
Outdoor & sports equipment	$988M	Pork	$394M
Aerospace parts	$762M	Legumes (peas, beans, lentils)	$311M
White goods	$637M	Aerospace parts	$268M
Home & kitchen	$629M	Beef	$235M
Hardware & tools	$611M	Animal feed	$215M
Motor vehicles	$554M	Stone, plaster, cement articles	$194M
Other foodstuffs	$548M	Lumber	$183M
Other imports	$7,896M	Other exports	$3,235M
Total	**$51,108M**	**Total**	**$14,738M**

Source: NWSA. (2020). *2020 NWSA Annual Cargo Report*. Available at: https://s3.us-west-2.amazonaws.com/nwseaportalliance.com.if-us-west-2/prod/2021-04/2020%20NWSA%20Annual%20Cargo%20Report.pdf

In 2021, NWSA made a strong comeback compared to 2020 with 22.5 percent increase in inbound loaded TEUs compared to 2020 volumes. This rate of growth was comparable to the Port of Los Angeles (25.4%) and the Port of Long Beach (23.8%), the top two ports in the United States by volume.[32]

The Port of Tacoma can compete with other ports by providing better facilities, more affordable services and transportation, and better access to the western region and country. Its proximity to Interstate 5 and Interstate 90, as well as SR 509 and SR 167 make it very well suited for intermodal transportation with trucking. Access to the Burlington Northern Santa Fe (BNSF) Railyard and the Union Pacific Railyard allow customers to connect to rail transportation options. Both railyards are outside of the 100-year floodplain but within the sea level rise floodplain.

As a significant driver of economic activity Pierce County, the Port of Tacoma and the NWSA marine cargo directly supported $5.9 billion in business output in 2017.[33] In terms of labor, the

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[32] Pacific Merchant Shipping Association. (2021). *West Coast Trade Report*. https://www.pmsaship.com/wp-content/uploads/2021/11/West-Coast-Trade-Report-November-2021.pdf

[33] NWSA. (2019). *The NWSA Marine Cargo Economic Impact Analysis*. Available at: https://www.nwseaportalliance.com/sites/default/files/cai.nwsa_marine_cargo_economic_impacts.2019_0123.pdf

NWSA directly supported 20,100 jobs and $1.9 billion in wages in 2017. Factoring in indirect and induced jobs, the NWSA supported 58,400 jobs and $4 billion in labor income.[34, 35] Overall this economic activity resulted in nearly $136 million in tax revenue for Washington state.

The Port of Tacoma and the NWSA are important sources of employment and economic activity in the region. Risk of flooding at the Port or nearby on the critical transportation routes negatively impacts the Ports ability to conduct business with certainty and compete with other west coast ports. Should Port operations be impacted by flooding, it could have potentially adverse impacts not only on Pierce County but on the region, as well as on key importers and exporters utilizing the Port's services currently.

2.13 Average Daily Levels of Economic Activity within the Floodplain Extent

Impacts from flooding generally do not last as long as a full year. For this reason, average daily estimates of economic activity are more useful to understand impacts to businesses and economic activity due to flooding. Some flooding may cause infrastructure damage that could impair operations, in full or in part, for longer periods of time. The tables below summarize average daily values for the economic activity within the 100-year floodplain and sea level rise floodplain extents. These values were calculated by dividing the annual values by 365 and thus represent annual average values for any day within the year. Average daily employment does not have average annual values that differ from the annual values reported above because employment is generally static, rather than cumulative like labor income, value added, output, and agricultural revenues.

Table 2-28 summarizes average daily labor income within the floodplain extents for each industry. The sea level rise floodplain extent has a higher average daily value due to the large amount of economic activity within the Port of Tacoma that could be impacted by future sea level rise. Table 2-29 provides the same calculations for output.

Table 2-28. Average Daily Values of Labor Income within the Floodplain, by Industry (2021 Dollars)

		Average Daily Labor Income in the Floodplain Extent	
NAICS Code	NAICS Description	100-Year Floodplain	Sea Level Rise Floodplain
11	Agriculture, Forestry, Fishing and Hunting	$24,477	$6,479
21	Mining, Quarrying, & Oil	$0	$0
22	Utilities	$5,586	$0
23	Construction	$267,181	$256,307
31	Manufacturing	$17,305	$16,592
32	Manufacturing	$83,599	$333,975

[34] NWSA. (2019). *The NWSA Marine Cargo Economic Impact Analysis.* Available at: https://www.nwseaportalliance.com/sites/default/files/cai.nwsa_marine_cargo_economic_impacts.2019_0123.pdf

[35] NSWA. (2019). Economic Impact, available at: https://www.nwseaportalliance.com/about-us/do-business-us/economic-impact

		Average Daily Labor Income in the Floodplain Extent	
NAICS Code	NAICS Description	100-Year Floodplain	Sea Level Rise Floodplain
33	Manufacturing	$45,216	$269,408
42	Wholesale Trade	$315,650	$938,811
44	Retail Trade	$54,275	$152,874
45	Retail Trade	$21,042	$51,827
48	Transportation and Warehousing	$436,853	$750,532
49	Transportation and Warehousing	$99,531	$87,036
51	Information	$2,719	$128,244
52	Finance and Insurance	$7,472	$21,948
53	Real Estate and Rental and Leasing	$15,127	$49,901
54	Professional, Scientific, and Technical Serv.	$29,024	$64,112
55	Management of Companies and Enterprises	$816	$45,019
56	Administrative, Support, Waste Mgmt ...	$110,182	$425,512
61	Educational Services	$39,296	$42,622
62	Health Care and Social Assistance	$253,250	$80,241
71	Arts, Entertainment, and Recreation	$127,458	$126,241
72	Accommodation and Food Services	$56,867	$132,860
81	Other Services (except Public Administration)	$31,454	$97,118
92	Public Administration	$6,877	$3,874
Missing	Unknown	$1,113,672	$2,239,386
Total		**$3,164,927**	**$6,320,923**

Source: Created by ECONorthwest

Table 2-29. Average Daily Values of Output within the Floodplain, by Industry (2021 Dollars)

		Average Daily Output in the Floodplain Extent	
NAICS Code	NAICS Description	100-Year Floodplain	Sea Level Rise Floodplain
11	Agriculture, Forestry, Fishing and Hunting	$41,157	$10,896
21	Mining, Quarrying, & Oil	$0	$0
22	Utilities	$44,893	$0
23	Construction	$559,623	$536,849
31	Manufacturing	$154,146	$147,805
32	Manufacturing	$571,646	$2,283,710
33	Manufacturing	$171,115	$1,019,545
42	Wholesale Trade	$1,672,119	$4,973,244
44	Retail Trade	$107,442	$302,625
45	Retail Trade	$55,901	$137,685
48	Transportation and Warehousing	$1,494,321	$2,567,307
49	Transportation and Warehousing	$137,727	$120,436
51	Information	$13,506	$636,975
52	Finance and Insurance	$26,093	$76,649
53	Real Estate and Rental and Leasing	$85,177	$280,992
54	Professional, Scientific, and Technical Serv.	$68,958	$152,326

		Average Daily Output in the Floodplain Extent	
NAICS Code	NAICS Description	100-Year Floodplain	Sea Level Rise Floodplain
55	Management of Companies and Enterprises	$1,515	$83,548
56	Administrative, Support, Waste Mgmt ...	$207,737	$802,260
61	Educational Services	$58,262	$63,192
62	Health Care and Social Assistance	$345,317	$109,414
71	Arts, Entertainment, and Recreation	$372,032	$368,482
72	Accommodation and Food Services	$127,999	$299,047
81	Other Services (except Public Administration)	$55,386	$171,011
92	Public Administration	$9,890	$5,570
Missing	Unknown	$2,948,373	$5,928,630
Total		**$9,330,334**	**$21,078,203**

Source: Created by ECONorthwest

Table 2-30 displays the average daily on-farm revenues for each floodplain type. Some businesses may be highly seasonal, particularly agricultural businesses, which would result in larger deviations from the average values depending on the time of year when flooding occurs. Average daily values are higher for the 100-year floodplain extent compared to the sea level rise floodplain extent.

Table 2-30. Average Daily On-Farm Revenue within the Floodplain (2021 Dollars)

	Average Daily On-Farm Revenue in the Floodplain Extent	
NAICS Code	100-Year Floodplain	Sea Level Rise Floodplain
On-Farm Agricultural Revenue	$49,232	$25,736

Source: Created by ECONorthwest

2.14 Summary of Economic Resources in the Floodplain

This Chapter provides baseline information about economic activity within the floodplain extents by industry and for each SPA. Flooding within Pierce County is as diverse as the County itself. In more rural areas there can be more floodplain covered, but a lower density of people and economic activity in the floodplain extent. Some urban areas can have both large extents of flooding as well as high densities of economic activity that is located in the floodplain extent – particularly for future sea level rise. Other urban areas have high concentrations of economic activity but smaller areas of the floodplain. The information about the resources within the floodplain extents detailed in this Chapter is the foundation for the evaluation of economic effects of flooding explored further in the subsequent chapters.

3 Economic Impacts of Flooding

3.1 Introduction

This section informs the potential economic impact of flooding by describing the amount of total economic activity located within each floodplain type for each SPA. To the extent a flood impairs a business from operating, there would be short-term effects on business productivity and economic activity. For example, short-term flood impacts to businesses could be caused by inaccessible roads to the business, impairing access for both customers and commuting employees. Flooding could also cause a lack of employees who are able to work because they are dealing with emergency situations related to flooding elsewhere or business impacts from supplies not being delivered due to flooding. The analysis focuses on levels of economic activity for one-day.

These findings can be scaled up, if needed, to inform the effects of flooding over a longer period. For example, longer-term impacts to businesses could occur if businesses are physically damaged by flooding. In these instances, there would be larger and longer impacts from flooding. Businesses may also incur costs associated with flooding. Costs of flooding in terms of damage to physical infrastructure, including inventories, are discussed further in Chapter 5.

3.2 Methodology

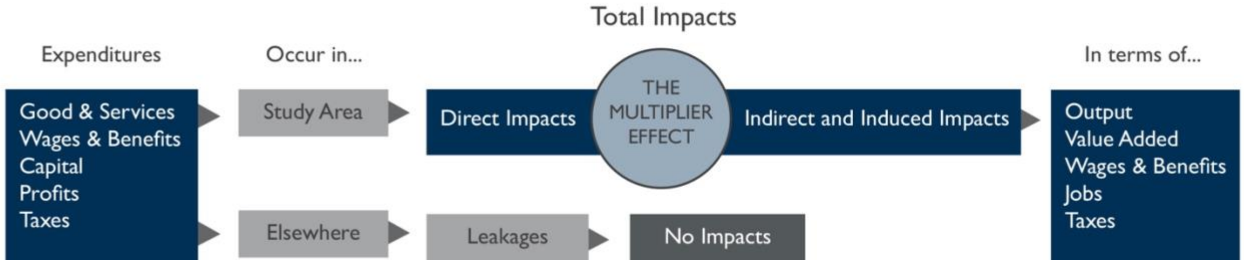
This analysis evaluates potential impacts from flooding for both direct and secondary impacts over a one-day period. The analysis is performed using the input-output modelling software IMPLAN, developed and distributed by the Minnesota IMPLAN Group, Inc. All effects are calculated using the 2019 Model for Pierce County, with dollar values inflated to 2021.

The inputs to the model of the estimates of number of businesses and economic activity located within the floodplain extents (i.e., the direct effects) are from the estimates provided in Chapter 2. See Section 2.5.1 for more information about the data sources and methods behind these calculations.

3.2.1 IMPLAN Input-Output Model

In general terms, the IMPLAN model works by tracing how spending associated with an industry circulates through an economy or study area. Changes in one sector or multiple sectors trigger changes in demand and supply throughout the economy. Initial changes in the model propagate through the economy via supply- and demand-chain linkages, altering the equilibrium quantities of inputs and outputs and associated jobs, income, and value-added components. These multiplier effects continue until the initial change in final demand leaks out of the economy in the form of savings, taxes, and imports. In summary, IMPLAN traces the interdependencies of economic activity within a regional economy. Figure 3-1 summarizes the components of the multiplier effect.

Figure 3-1. Components of the Multiplier Effect



Source: Created by ECONorthwest

Economic impact analyses use specific terminology to identify different types of economic effects that can be modeled using input-output tools. Economic impacts are categorized into three types of effects:

- **Direct effects** are the economic effects directly attributable to industry. For example, the number of employees directly employed, amount of gross revenues, and costs of inputs, for all businesses within an industry. Direct effects can be considered the "inputs" to the model.
- **Indirect effects** are the economic effects supported by spending in the local economy due to increases in supply chain purchases. Suppliers to the directly involved industry will also purchase additional goods and services; spending leads to additional rounds of indirect impacts (i.e., the multiplier effect). Indirect effects are also referred to as “supply chain effects”.
- **Induced effects** are the economic effects caused by changes in household income. The direct and indirect increases in employment and income enhance the overall purchasing power in the economy, thereby inducing further consumption- and investment-driven stimulus. Induced effects are also referred to as “consumption effects.”

Total economic impacts are based on the sum of the direct, indirect, and induced effects. These three types of economic impacts are measured in terms of output, labor income, and employment resulting from spending in the study area:

- **Output** represents the value of goods and services produced and is the broadest measure of economic activity.

- **Labor Income** consists of employee compensation and proprietor income and is a subset of output.

    - *Employee compensation* includes workers’ wages and salaries, as well as other benefits such as health, disability, and life insurance, retirement payments, and non-cash compensation.

- *Proprietor's income* (business owner's income) consists of payments received by self-employed individuals and unincorporated business owners. More specifically, it represents the current-production income of sole proprietorships, partnerships, and tax-exempt cooperatives. Business income would include, for example, income received by private business owners, doctors, accountants, and lawyers.

- **Employment** is measured in terms of full-year-equivalents (FYE) jobs. One FYE job equals work over twelve months in each industry (this is the same definition used by the federal government's Bureau of Economic Analysis). For example, two jobs that last six months each count as one FYE job. A job can be full-time or part-time, seasonal or permanent. IMPLAN counts jobs based on the duration of employment, not the number of hours a week worked. Job impacts from operations are for one year of normal operation.

IMPLAN reports results for 546 industries, known as the IMPLAN Industry Schemes. These industries are based on North American Industry Classification System (NAICS) industries, but do not follow the same categorization scheme. All results herein are reported by two-digit NAICS code, which is based on the crosswalk between the IMPLAN and NAICS industry schemes. Indirect and induced effects are calculated using industry averages from IMPLAN.

3.2.2 Model Limitations

This analysis evaluates businesses and their corresponding economic activity based on the businesses' physical location within the 100-year or sea level rise floodplain extents.[36] Being located within the floodplain does not necessarily mean that the business will experience impacts from flooding that would result in a full loss of business activity for that day. This analysis describes average daily values for employment, labor income, and output. Accordingly, those values should be considered the upper bound of the potential loss in business activity values, assuming a total loss of economic activity for that day. IMPLAN also does not consider price effects, so changes in prices will result in changes in economic activity affected by flooding.

Because this analysis is based on the location of the business relative to the floodplain, it does not take into consideration any impacts on workers who may be unable to commute to or otherwise participate in their employment for that day due to flooding. This analysis also does not consider any temporary increases in economic activity that could arise to respond to or clean up from a flood event. This analysis also does not include any costs to businesses associated with response or clean up from flooding. Impacts to businesses due to increased travel time for suppliers, distributors, and customers due to road closures and reroutes is discussed in *Chapter 6. Transportation Impacts*.

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[36] The location of the business was identified by the Washington State Department of Revenue (DOR data). See Section 2.5.1 for more information about this data source.

The study area for the model is Pierce County, meaning all economic activity effects are only those that remain within the Pierce County area. Because businesses in Pierce County also rely on imports from and exports to businesses outside the county, the indirect and induced effects would be larger if the analysis was for a larger geography, such as statewide.

The SPAs in the study area comprise almost all of the economic activity within Pierce County. This factor complicates the analysis because there is potential for double counting within the indirect and induced effects. For example, a business located in the floodplain may have indirect and induced effects that support employment, labor income, and output for another business within Pierce County, in which case those values would be included in the direct effects for that business and industry. This type of relationship would result in double counting. Accordingly, the total effects across industries and SPAs may not be additive to the extent that double counting is occurring.

This analysis uses the 2019 IMPLAN model for Pierce County. However, it is being used to estimate impacts on economic activity that would occur in the future. Conditions in the future may be different than conditions in the 2019 model. This model does not account for structural changes in the economy that occur in the future. Flood impacts happening sooner in the future will more closely resemble the estimates herein compared to impacts happening in the more distant future. This consideration is especially relevant for sea level rise impacts, as the sea level rise scenario is as of the year 2100.

3.3 Overview of Economic Activity in Pierce County

3.3.1 Total Economic Activity in Pierce County

On an annual basis, total output in Pierce County is $77.6 billion, total labor income is $29.7 billion, and total employment is 456,452. Table 3-1 coverts these values into daily estimates and summarizes them by industry for all of Pierce County. The conversion to daily estimates is done by dividing the annual values by 365. This approach does not allow for nuances on how daily economic activity varies by weekday versus weekend, seasonality, or any other measures that would result in actual daily values meaningfully deviating from these calculated averages. Employment does not vary between daily estimates and annual estimates.

Table 3-1. Average Daily Measures of Economic Activity in Pierce County

NAICS Code	Industry	Total Employment	Total Labor Income	Total Output	Average Employee Compensation per Employee	Average Proprietor Income per Proprietor
11	Agriculture, Forestry, Fishing and Hunting	2,051	$261,064	$479,093	$123	$201
21	Mining, Quarrying, & Oil and Gas Extr.	420	$60,184	$264,485	$195	$6
22	Utilities	667	$242,482	$2,122,298	$372	$154
23	Construction	31,140	$6,151,930	$14,213,704	$187	$247
31	Manufacturing	3,386	$516,999	$3,909,468	$164	$88
32	Manufacturing	7,908	$1,816,772	$16,143,493	$232	$132

NAICS Code	Industry	Total Employment	Total Labor Income	Total Output	Average Employee Compensation per Employee	Average Proprietor Income per Proprietor
33	Manufacturing	8,314	$1,870,058	$7,808,673	$257	$14
42	Wholesale Trade	13,696	$3,125,272	$12,850,898	$264	$281
44	Retail Trade	19,540	$2,466,865	$5,765,974	$126	$324
45	Retail Trade	20,356	$1,655,172	$4,967,973	$101	$38
48	Transportation and Warehousing	14,370	$2,353,116	$5,373,412	$269	$156
49	Transportation and Warehousing	14,798	$2,083,724	$3,951,032	$185	$7
51	Information	3,043	$568,033	$3,265,640	$215	$69
52	Finance and Insurance	15,849	$2,643,021	$13,182,945	$357	$39
53	Real Estate and Rental and Leasing	21,584	$2,013,708	$29,513,998	$189	$133
54	Professional, Scientific, and Technical Serv.	22,678	$4,243,099	$10,410,558	$214	$93
55	Management of Companies and Enterprises	1,067	$260,008	$560,015	$307	$12
56	Administrative, Support, Waste Mgmt	27,701	$3,947,975	$7,577,608	$164	$115
61	Educational Services	6,385	$644,262	$1,160,082	$127	$31
62	Health Care and Social Assistance	56,713	$13,320,590	$21,366,186	$166	$720
71	Arts, Entertainment, and Recreation	8,001	$482,252	$1,538,313	$88	$84
72	Accommodation and Food Services	34,200	$2,827,685	$7,886,584	$102	$82
81	Other Services (except Public Administration)	32,506	$4,221,494	$7,370,875	$145	$144
92	Public Administration	89,910	$23,607,791	$30,992,754	$261	N/A
Total		**456,452**	**$81,383,557**	**$212,676,062**	**$211** (Average)	**$125** (Average)

Source: IMPLAN LLC

3.3.2 Regional Coefficients for Pierce County

Regional Purchase Coefficients (RPCs) represent the proportion of local demand that is estimated to be purchased from local producers. For example, an RPC of 0.50 percent for a given industry means that for each $1 of demand, $0.50 will be purchased from local producers. **Regional Supply Coefficients (RSCs)**, also known as the Local Use Ratios, indicate the proportion of local supply of a commodity that goes to meet local demands. For example, an RSC of 0.50 percent for a given industry means that 50 percent total supply produced in Pierce County goes to satisfy demand in Pierce County (and not exported out).

Table 3-2 summarizes the RPCs and RSCs for each NAICS industry. These values were weighted using the Total Commodity Supply for the IMPLAN industry.[37] Some of the highest RPCs are for industries that rely heavily on local labor and face high transportation costs, such as *Construction* and *Public Administration*. RSCs are lowest in industries with high amounts of exports, including *Agriculture, Forestry, Fishing and Hunting*, and *Manufacturing*.

Table 3-2. Weighted Average RPC and RSC for Pierce County

NAICS	NAICS Description	Weighted Average RPCs	Weighted Average RSCs
11	Agriculture, Forestry, Fishing and Hunting	15.0%	12.7%
21	Mining, Quarrying, & Oil and Gas Extr.	1.3%	28.4%
22	Utilities	59.8%	68.4%
23	Construction	100.0%	100.0%
31	Manufacturing	4.5%	2.8%
32	Manufacturing	30.9%	20.8%
33	Manufacturing	3.4%	2.6%
42	Wholesale Trade	51.2%	32.2%
44	Retail Trade	79.7%	95.4%
45	Retail Trade	69.0%	58.5%
48	Transportation and Warehousing	46.3%	34.2%
49	Transportation and Warehousing	98.9%	45.8%
51	Information	17.0%	34.2%
52	Finance and Insurance	51.1%	68.5%
53	Real Estate and Rental and Leasing	90.9%	87.3%
54	Professional, Scientific, and Technical Serv.	41.8%	64.6%
55	Management of Companies and Enterprises	7.1%	38.3%
56	Administrative, Support, Waste Mgmt …	90.8%	73.3%
61	Educational Services	40.8%	70.6%
62	Health Care and Social Assistance	91.8%	86.4%
71	Arts, Entertainment, and Recreation	42.2%	56.3%
72	Accommodation and Food Services	80.3%	81.2%
81	Other Services (except Public Administration)	94.8%	95.2%
92	Public Administration	93.7%	90.4%
	Average (Not Weighted)	**54.3%**	**56.2%**

Source: Created by ECONorthwest using RPC and RSC by IMPLAN Industry from IMPLAN 2019

3.4 Economic Impacts of Flooding

The following sections describe economic impacts of flooding, including both direct and secondary (indirect and induced) effects. The results are presented as summaries for all businesses located within the floodplain extent, for each floodplain type and for each SPA. Agricultural impacts are then singled out for a special review of potential impacts to agricultural economic activity. Agricultural businesses are included in the total business estimates.

The information for this section is based on the analysis of businesses located within the floodplain extent and businesses in Pierce County as reflected in the DOR data set. See Section

[37] Total Commodity Supply is the total amount of a Commodity that is available for purchase in a local area value.

2.5.1 for descriptions of the DOR data set and how businesses were identified as being within the floodplain extents.

3.4.1 100-Year Flood Extent

The 100-year flood extent includes riverine, groundwater, and coastal flooding. The 'Total' field for employment, labor income, and output is calculated as the sum of direct, indirect, and induced effects.

3.4.1.1 Employment

Table 3-3 summarizes employment for businesses located in the floodplain extent in terms of direct jobs and total jobs for each industry. The average jobs multiplier is 1.37, meaning for every one direct job another 0.37 jobs are supported in Pierce County through indirect and induced effects. The highest employment multipliers are in industries that have a high labor to capital ratio, pay higher wages, and/or have higher expenses. The industries with the highest multipliers are *Wholesale Trade*, *Finance and Insurance*, and *Real Estate and Rental and Leasing*.

Table 3-3. Average Daily Employment Impacts for Businesses Located in the 100-Year Flood Extent, by Industry

NAICS	NAICS Description	Direct Jobs	Total Jobs	Multiplier
11	Agriculture, Forestry, Fishing and Hunting	147	204	1.39
21	Mining, Quarrying, & Oil and Gas Extr.	0	0	N/A
22	Utilities	12	18	1.56
23	Construction	1,084	1,556	1.43
31	Manufacturing	101	116	1.14
32	Manufacturing	286	406	1.42
33	Manufacturing	155	214	1.39
42	Wholesale Trade	960	1,770	1.84
44	Retail Trade	307	412	1.34
45	Retail Trade	193	237	1.23
48	Transportation and Warehousing	1,566	2,274	1.45
49	Transportation and Warehousing	508	691	1.36
51	Information	10	15	1.38
52	Finance and Insurance	32	56	1.75
53	Real Estate and Rental and Leasing	84	134	1.60
54	Professional, Scientific, and Technical Serv.	140	207	1.48
55	Management of Companies and Enterprises	3	4	1.50
56	Administrative, Support, Waste Mgmt ...	624	815	1.30
61	Educational Services	310	393	1.27
62	Health Care and Social Assistance	949	1,275	1.34
71	Arts, Entertainment, and Recreation	1,606	1,928	1.20
72	Accommodation and Food Services	462	550	1.19
81	Other Services (except Public Administration)	170	214	1.26
92	Public Administration	0	0	N/A
0	Missing	5,709	7,556	1.32
Total		**15,416**	**21,044**	**1.37**

Source: Created by ECONorthwest

Table 3-4 summarizes employment located within the floodplain extent for each SPA. The Hylebos-Browns Point-Dash Point Basin and Mid Puyallup Basin SPAs have the highest number of direct jobs and total jobs located within the floodplain extents. Multipliers by SPA are consistent, with the exception of the White River Basin which has an average multiplier of 1.47 due to the high proportion of employment in the floodplain for high-multiplier industries, such as *Wholesale Trade*.

Table 3-4. Average Daily Employment Impacts for Businesses Located in the 100-Year Flood Extent, by SPA

SPA	Direct Jobs	Total Jobs	Multiplier
Chambers Bay / Clover Creek Basin	1,490	2,013	1.35
Clear / Clarks Creek Basin	2,618	3,528	1.35
Gig Harbor / Key Peninsula Basin	400	550	1.38
Hylebos-Browns Point-Dash Point Basin	4,179	5,427	1.30
Mid Puyallup Basin	3,723	5,161	1.39
Muck Creek Basin	101	136	1.35
Nisqually Basin	222	308	1.39
Upper Puyallup Basin	147	196	1.33
White River Basin	2,537	3,724	1.47
Total	**15,416**	**21,044**	1.37

Source: Created by ECONorthwest

3.4.1.2 Labor Income

Table 3-5 summarizes average daily labor income for businesses located in the floodplain extent in terms of direct labor income and total labor income for each industry. The average labor income multiplier is 1.38, meaning for every $1 in direct labor income another $0.38 in labor income is supported in Pierce County through indirect and induced effects. The *Transportation and Warehousing* industry has the highest amount of total labor income located within the floodplain extent. Labor income multipliers are generally higher in industries that pay higher wages. The industries with the highest multipliers include *Information*, *Real Estate and Rental and Leasing*, and *Finance and Insurance*.

Table 3-5. Average Daily Labor Income Impacts for Businesses Located in the 100-Year Flood Extent, by Industry

NAICS	NAICS Description	Direct Labor Income	Total Labor Income	Multiplier
11	Agriculture, Forestry, Fishing and Hunting	$24,477	$30,233	1.24
21	Mining, Quarrying, & Oil and Gas Extr.	$0	$0	N/A
22	Utilities	$5,586	$7,022	1.26
23	Construction	$267,181	$357,616	1.34
31	Manufacturing	$18,531	$22,406	1.21
32	Manufacturing	$78,990	$108,926	1.38
33	Manufacturing	$45,216	$59,985	1.33
42	Wholesale Trade	$315,650	$492,380	1.56
44	Retail Trade	$50,993	$70,213	1.38
45	Retail Trade	$18,189	$26,491	1.46
48	Transportation and Warehousing	$436,853	$615,789	1.41
49	Transportation and Warehousing	$99,531	$140,120	1.41
51	Information	$2,719	$5,010	1.84
52	Finance and Insurance	$7,472	$12,550	1.68
53	Real Estate and Rental and Leasing	$15,127	$28,678	1.90

NAICS	NAICS Description	Direct Labor Income	Total Labor Income	Multiplier
54	Professional, Scientific, and Technical Serv.	$28,720	$40,424	1.41
55	Management of Companies and Enterprises	$816	$1,089	1.33
56	Administrative, Support, Waste Mgmt	$117,058	$156,644	1.34
61	Educational Services	$39,296	$53,988	1.37
62	Health Care and Social Assistance	$253,250	$320,423	1.27
71	Arts, Entertainment, and Recreation	$127,458	$175,535	1.38
72	Accommodation and Food Services	$56,867	$75,255	1.32
81	Other Services (except Public Administration)	$31,454	$40,042	1.27
92	Public Administration	$0	$0	N/A
0	Missing	$1,123,494	$1,522,135	1.35
Total		**$3,164,927**	**$4,362,954**	**1.38**

Source: Created by ECONorthwest

Table 3-6 summarizes average daily labor income for businesses located in the floodplain extent for each SPA. Mid Puyallup Basin and Hylebos-Browns Point-Dash Point Basin SPAs have the highest amounts of labor income located within the floodplain extents. Labor income multipliers are more varied by SPA (i.e., have a higher standard deviation) compared to the employment multipliers.

Table 3-6. Average Daily Labor Income Impacts for Businesses Located in the 100-Year Flood Extent, by SPA

SPA	Direct Labor Income	Total Labor Income	Multiplier
Chambers Bay / Clover Creek Basin	$299,597	$409,019	1.37
Clear / Clarks Creek Basin	$587,279	$779,533	1.33
Gig Harbor / Key Peninsula Basin	$77,910	$109,613	1.41
Hylebos-Browns Point-Dash Point Basin	$710,055	$975,529	1.37
Mid Puyallup Basin	$813,273	$1,129,045	1.39
Muck Creek Basin	$20,311	$29,277	1.44
Nisqually Basin	$44,665	$59,372	1.33
Upper Puyallup Basin	$31,519	$43,071	1.37
White River Basin	$580,318	$828,496	1.43
Total	**$3,164,927**	**$4,362,954**	**1.38**

Source: Created by ECONorthwest

3.4.1.3 Output

Table 3-7 summarizes average daily output for businesses located in the floodplain extent in terms of direct output and total output for each industry. The average output multiplier is 1.44, meaning for every $1 in direct output another $0.44 in output is supported in Pierce County through indirect and induced effects. Output multipliers are more consistent by industry (i.e., have a lower standard deviation) compared to labor income and employment multipliers.

Table 3-7. Average Daily Output Impacts for Businesses Located in the 100-Year Flood Extent, by Industry

NAICS	NAICS Description	Direct Output	Total Output	Multiplier
11	Agriculture, Forestry, Fishing and Hunting	$41,157	$63,190	1.54
21	Mining, Quarrying, & Oil and Gas Extr.	$0	$0	N/A

NAICS	NAICS Description	Direct Output	Total Output	Multiplier
22	Utilities	$44,893	$50,073	1.12
23	Construction	$559,623	$805,620	1.44
31	Manufacturing	$162,534	$187,292	1.15
32	Manufacturing	$540,129	$708,709	1.31
33	Manufacturing	$171,115	$219,569	1.28
42	Wholesale Trade	$1,672,119	$2,409,704	1.44
44	Retail Trade	$100,944	$151,122	1.50
45	Retail Trade	$48,320	$74,218	1.54
48	Transportation and Warehousing	$1,494,321	$2,370,530	1.59
49	Transportation and Warehousing	$137,727	$220,128	1.60
51	Information	$13,506	$16,572	1.23
52	Finance and Insurance	$26,093	$39,664	1.52
53	Real Estate and Rental and Leasing	$85,177	$121,597	1.43
54	Professional, Scientific, and Technical Serv.	$68,236	$100,195	1.47
55	Management of Companies and Enterprises	$1,515	$2,264	1.50
56	Administrative, Support, Waste Mgmt ...	$217,627	$319,229	1.47
61	Educational Services	$58,262	$90,564	1.55
62	Health Care and Social Assistance	$345,317	$523,790	1.52
71	Arts, Entertainment, and Recreation	$372,032	$572,735	1.54
72	Accommodation and Food Services	$127,999	$176,859	1.38
81	Other Services (except Public Administration)	$55,386	$83,622	1.51
92	Public Administration	$0	$0	N/A
0	Missing	$2,986,303	$4,092,980	1.37
Total		**$9,330,334**	**$13,400,225**	**1.44**

Source: Created by ECONorthwest

Table 3-8 summarizes average daily output for businesses located in the floodplain extent for each SPA. In total, up to $9.4 million in daily output is located within the 100-year floodplain extent in Pierce County. The Mid Puyallup Basin and Hylebos-Browns Point-Dash Point Basin SPAs have the highest amounts of output located within the floodplain extents.

Table 3-8. Average Daily Output Impacts for Businesses Located in the 100-Year Flood Extent, by SPA

SPA	Direct Output	Total Output	Multiplier
Chambers Bay / Clover Creek Basin	$902,292	$1,241,968	1.38
Clear / Clarks Creek Basin	$1,325,554	$1,893,741	1.43
Gig Harbor / Key Peninsula Basin	$233,303	$333,102	1.43
Hylebos-Browns Point-Dash Point Basin	$2,201,873	$3,235,655	1.47
Mid Puyallup Basin	$2,447,433	$3,540,373	1.45
Muck Creek Basin	$62,783	$88,442	1.41
Nisqually Basin	$138,410	$181,932	1.31
Upper Puyallup Basin	$102,809	$138,089	1.34
White River Basin	$1,915,877	$2,746,924	1.43
Total	**$9,330,334**	**$13,400,225**	**1.44**

Source: Created by ECONorthwest

3.4.2 Sea Level Rise Flood Extent

This analysis evaluates economic activity located in the floodplain extent for sea level rise flooding, which is a future event modelled as conditions for the year 2100. Because this timeframe is so far off in the future, there would likely be different businesses and different relationships between industries compared to the 2019 IMPLAN model used for this analysis – both of which would change the estimates described herein.

3.4.2.1 Employment

Table 3-9 summarizes employment for businesses located in the sea level rise floodplain extent in terms of direct jobs and total jobs for each industry. The industries with the highest total jobs located within the floodplain extent are *Wholesale Trade* and *Transportation and Warehousing*. The average jobs multiplier is 1.45, meaning for every one direct job another 0.45 jobs are supported in Pierce County through indirect and induced effects. The industries with the highest multipliers are *Wholesale Trade, Finance and Insurance,* and *Real Estate and Rental and Leasing.*

Table 3-9. Average Daily Employment Impacts for Businesses Located in the Sea Level Rise Flood Extent, by Industry

NAICS	NAICS Description	Direct Jobs	Total Jobs	Multiplier
11	Agriculture, Forestry, Fishing and Hunting	39	53	1.38
21	Mining, Quarrying, & Oil and Gas Extr.	0	0	N/A
22	Utilities	0	0	N/A
23	Construction	1,040	1,484	1.43
31	Manufacturing	73	109	1.49
32	Manufacturing	1,209	2,155	1.78
33	Manufacturing	883	1,297	1.47
42	Wholesale Trade	2,854	5,336	1.87
44	Retail Trade	899	1,231	1.37
45	Retail Trade	547	678	1.24
48	Transportation and Warehousing	2,690	4,432	1.65
49	Transportation and Warehousing	444	594	1.34
51	Information	484	1,250	2.58
52	Finance and Insurance	95	159	1.68
53	Real Estate and Rental and Leasing	266	440	1.66
54	Professional, Scientific, and Technical Serv.	310	458	1.48
55	Management of Companies and Enterprises	148	232	1.57
56	Administrative, Support, Waste Mgmt ...	2,272	2,973	1.31
61	Educational Services	336	426	1.26
62	Health Care and Social Assistance	301	411	1.36
71	Arts, Entertainment, and Recreation	1,591	1,907	1.20
72	Accommodation and Food Services	1,079	1,302	1.21
81	Other Services	525	666	1.27
92	Public Administration	2	3	2.00
0	Missing	11,512	15,238	1.32
Total		**29,598**	**42,833**	**1.45**

Source: Created by ECONorthwest

Table 3-10 summarizes average daily employment for businesses located within the sea level rise floodplain by SPA. Only five of the nine SPAs have businesses located within the floodplain. Hylebos-Browns Point-Dash Point Basin SPA, which includes the Port of Tacoma, has the highest number of direct and total jobs located within the sea level rise floodplain extent.

Table 3-10. Average Daily Employment Impacts for Businesses Located in the Sea Level Rise Flood Extent, by SPA

SPA	Direct Jobs	Total Jobs	Multiplier
Chambers Bay / Clover Creek Basin	4,724	7,001	1.48
Clear / Clarks Creek Basin	146	204	1.39
Gig Harbor / Key Peninsula Basin	701	913	1.30
Hylebos-Browns Point-Dash Point Basin	20,804	29,872	1.44
Mid Puyallup Basin	3,224	4,842	1.50
Total	**29,598**	**42,833**	**1.45**

Source: Created by ECONorthwest

3.4.2.2 Labor Income

Table 3-11 summarizes average daily labor income for businesses located within the sea level rise floodplain by industry. The *Wholesale Trade* and *Transportation and Warehousing* industries have the highest amount of labor income located within the sea level rise floodplain extent.

Table 3-11. Average Daily Labor Income Impacts for Businesses Located in the Sea Level Rise Flood Extent, by Industry

NAICS	NAICS Description	Direct Labor Income	Total Labor Income	Multiplier
11	Agriculture, Forestry, Fishing and Hunting	$6,481	$7,989	1.23
21	Mining, Quarrying, & Oil and Gas Extr.	$0	$0	N/A
22	Utilities	$0	$0	N/A
23	Construction	$256,307	$341,045	1.33
31	Manufacturing	$13,115	$18,842	1.44
32	Manufacturing	$333,974	$484,331	1.45
33	Manufacturing	$258,052	$347,857	1.35
42	Wholesale Trade	$938,811	$1,481,170	1.58
44	Retail Trade	$149,205	$203,066	1.36
45	Retail Trade	$51,565	$80,189	1.56
48	Transportation and Warehousing	$750,532	$1,081,829	1.44
49	Transportation and Warehousing	$87,035	$122,912	1.41
51	Information	$128,244	$262,809	2.05
52	Finance and Insurance	$21,948	$37,769	1.72
53	Real Estate and Rental and Leasing	$48,187	$90,645	1.88
54	Professional, Scientific, and Technical Serv.	$63,442	$89,334	1.41
55	Management of Companies and Enterprises	$45,020	$60,046	1.33
56	Administrative, Support, Waste Mgmt ...	$416,839	$558,844	1.34
61	Educational Services	$42,621	$58,556	1.37
62	Health Care and Social Assistance	$80,242	$99,603	1.24
71	Arts, Entertainment, and Recreation	$126,241	$171,468	1.36
72	Accommodation and Food Services	$132,859	$178,096	1.34
81	Other Services (except Public Administration)	$97,119	$122,544	1.26
92	Public Administration	$646	$1,049	1.62
0	Missing	$2,272,438	$3,078,749	1.35
Total		**$6,320,923**	**$8,978,742**	**1.42**

Source: Created by ECONorthwest

Table 3-12 summarizes average daily labor income impacts for businesses located in the sea level rise floodplain. Hylebos-Browns Point-Dash Point Basin SPA, which includes the Port of Tacoma, has the highest amount of direct and total labor income located within the sea level rise floodplain extent.

Table 3-12. Average Daily Labor Income Impacts for Businesses Located in the Sea Level Rise Flood Extent, by SPA

SPA	Direct Labor Income	Total Labor Income	Multiplier
Chambers Bay / Clover Creek Basin	$1,084,918	$1,530,879	1.41
Clear / Clarks Creek Basin	$32,253	$44,442	1.38
Gig Harbor / Key Peninsula Basin	$116,142	$160,496	1.38
Hylebos-Browns Point-Dash Point Basin	$4,345,335	$6,172,221	1.42
Mid Puyallup Basin	$742,275	$1,070,703	1.44
Total	**$6,320,923**	**$8,978,742**	**1.42**

Source: Created by ECONorthwest

3.4.2.3 Output

Table 3-13 summarizes average daily labor income for businesses located within the sea level rise floodplain by industry. Like with labor income, the *Wholesale Trade* and *Transportation and Warehousing* industries have the highest amount of output located within the sea level rise floodplain extent.

Table 3-13. Average Daily Output Impacts for Businesses Located in the Sea Level Rise Flood Extent, by Industry

NAICS	NAICS Description	Direct Output	Total Output	Multiplier
11	Agriculture, Forestry, Fishing and Hunting	$10,897	$16,504	1.51
21	Mining, Quarrying, & Oil and Gas Extr.	$0	$0	N/A
22	Utilities	$0	$0	N/A
23	Construction	$536,848	$774,096	1.44
31	Manufacturing	$116,827	$143,288	1.23
32	Manufacturing	$2,283,709	$2,850,409	1.25
33	Manufacturing	$976,568	$1,242,938	1.27
42	Wholesale Trade	$4,973,244	$7,031,260	1.41
44	Retail Trade	$295,363	$440,461	1.49
45	Retail Trade	$136,984	$211,077	1.54
48	Transportation and Warehousing	$2,567,308	$4,074,827	1.59
49	Transportation and Warehousing	$120,436	$190,781	1.58
51	Information	$636,977	$902,371	1.42
52	Finance and Insurance	$76,649	$116,416	1.52
53	Real Estate and Rental and Leasing	$271,338	$392,384	1.45
54	Professional, Scientific, and Technical Serv.	$150,734	$220,168	1.46
55	Management of Companies and Enterprises	$83,549	$124,890	1.49
56	Administrative, Support, Waste Mgmt ...	$784,465	$1,174,908	1.50
61	Educational Services	$63,192	$98,227	1.55
62	Health Care and Social Assistance	$109,414	$166,269	1.52
71	Arts, Entertainment, and Recreation	$368,482	$573,224	1.56
72	Accommodation and Food Services	$299,047	$412,024	1.38
81	Other Services (except Public Administration)	$171,010	$266,182	1.56
92	Public Administration	$928	$1,296	1.40
0	Missing	$6,044,233	$8,284,129	1.37
Grand Total		**$21,078,202**	**$29,708,131**	**1.41**

Source: Created by ECONorthwest

Table 3-14 summarizes average daily output impacts for businesses located in the sea level rise floodplain. Hylebos-Browns Point-Dash Point Basin SPA, which includes the Port of Tacoma, has the highest amount of direct and total output located within the sea level rise floodplain extent.

Table 3-14. Average Daily Output Impacts for Businesses Located in the Sea Level Rise Flood Extent, by SPA

SPA	Direct Output	Total Output	Multiplier
Chambers Bay / Clover Creek Basin	$3,901,134	$5,415,676	1.39
Clear / Clarks Creek Basin	$92,382	$131,116	1.42
Gig Harbor / Key Peninsula Basin	$292,658	$412,882	1.41
Hylebos-Browns Point-Dash Point Basin	$14,117,401	$19,920,382	1.41
Mid Puyallup Basin	$2,674,625	$3,828,076	1.43
Total	**$21,078,202**	**$29,708,131**	**1.41**

Source: Created by ECONorthwest

3.5 Agricultural Impacts

There is approximately $17.9 million in annual agricultural revenue located within the 100-year floodplain extent in Pierce County (see Table 2-26). On an average day, agricultural revenues average $49,232 among agricultural acres within the floodplain. Impacts from flooding on agricultural lands can vary significantly by time of year, type of agriculture, and site-specific conditions. Crop washouts and livestock deaths are two particularly costly impacts of flooding. In particular, flooding during planting and harvesting times can cause larger revenue losses for farms due to declines in yields and crop losses.

Table 3-15 summarizes agricultural revenues located in the 100-year floodplain extent as well as the total economic activity supported in Pierce County by the daily revenue values. Total daily jobs, labor income, and output include direct, indirect, and induced effects and were calculated using IMPLAN. Table 3-16 summarizes the same information for sea level rise flooding. Almost all sea level rise impacts to agriculture are in the Clear/Clarks Creek Basin SPA.

Table 3-15. Agricultural Revenues Located in the 100-Year Floodplain Extent

SPA	Annual Revenue	Daily Revenue	Total Daily Jobs	Total Daily Labor Income	Total Daily Output
Chambers Bay/ Clover Creek Basin	$31,698	$87	1	$89	$130
Clear/Clarks Creek Basin	$2,111,661	$5,785	48	$5,906	$8,645
Gig Harbor/Key Peninsula Basin	$853,265	$2,338	20	$2,386	$3,493
Hylebos-Browns Point-Dash Point Basin	$396,490	$1,086	9	$1,109	$1,623
Mid Puyallup Basin	$6,258,786	$17,147	143	$17,505	$25,625
Muck Creek Basin	$2,086,306	$5,716	48	$5,835	$8,542
Nisqually Basin	$3,242,764	$8,884	74	$9,069	$13,276

SPA	Annual Revenue	Daily Revenue	Total Daily Jobs	Total Daily Labor Income	Total Daily Output
Upper Puyallup Basin	$2,001,461	$5,483	46	$5,598	$8,194
White River Basin	$987,307	$2,705	23	$2,761	$4,042
Total in SPAs	**$17,969,738**	**$49,232**	**412**	**$50,258**	**$73,571**

Source: Created by ECONorthwest

Table 3-16. Average Agricultural Revenues Located in the Sea Level Rise Floodplain Extent

SPA	Annual Revenue	Daily Revenue	Total Jobs	Total Labor Income	Total Output
Chambers Bay/ Clover Creek Basin	$884,264	$2,423	20	$2,473	$3,620
Clear/Clarks Creek Basin	$160,674	$440	4	$449	$658
Gig Harbor/Key Peninsula Basin	$7,705,353	$21,111	177	$21,551	$31,547
Hylebos-Browns Point-Dash Point Basin	$410,989	$1,126	9	$1,149	$1,683
Mid Puyallup Basin	$232,287	$636	5	$650	$951
Muck Creek Basin	$0	$0	0	$0	$0
Nisqually Basin	$0	$0	0	$0	$0
Upper Puyallup Basin	$0	$0	0	$0	$0
White River Basin	$0	$0	0	$0	$0
Total in SPAs	**$9,393,566**	**$25,736**	**216**	**$26,272**	**$38,459**

Source: Created by ECONorthwest

Disruption to farm activity from flooding could also affect local and regional agricultural processors because the raw agricultural goods are inputs to the processors – so if they are damaged the processors would need to find alternative inputs or delay or defer production. Agricultural processors themselves can also be affected by flooding through damage to property or equipment. Farmland is affected by flooding because it can destroy crops, erode soil, and require clean-up. Clean-up costs to restore impacted fields can be as high as $500 per acre based on estimates for the Chehalis River Basin, with additional costs for reseeding and any lost farm income.[38] The aquaculture industry is also at risk of losses due to flooding because water quality can be impaired by contaminants in runoff that can come into contact with the shellfish.

There are seven fish hatcheries operated by Washington State Department of Fish and Wildlife in Pierce County.[39] The Minter Creek and Hupp Springs fish hatcheries are both located in the 100-year and the sea level rise floodplain. None of the other five hatcheries are located within a floodplain extent. Flooding can cause mortality for the species due to sedimentation and other impacts to water quality, trauma from high velocity water, and early release to avoid the effects of flooding in the facility. Flooding can also damage fish hatchery infrastructure by clogging

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[38] EES Consulting. (2016). *Chehalis Basin Strategy. Draft Economics Study Update: Reducing Flood Damage and Restoring Aquatic Species Habitat.* Appendix F.

[39] Washington State Department of Fish and Wildlife, *Hatchery facilities*, available at: https://wdfw.wa.gov/fishing/management/hatcheries/facilities?county=43

intake valves from sediment in the floodwaters. Loss of fish populations can impact commercial, recreational, and tribal fisheries.

Many agricultural processors in Pierce County are concentrated in the seafood and meat processing industries. Large agricultural processors located in Pierce County include:

- Wilcox Farm
- Medallion Foods
- Gruma (Diane's Foods)
- Brown & Haley
- Keurig Green Mountain
- Verone's Sausage Company Inc
- Goldbelt Seafoods, LLC
- Shining Ocean
- Trident Seafoods Corp

In addition to these large processors there are also smaller-scale fruit and vegetable canning operations in Pierce County. Flooding is not likely to impact seafood processors unless there is direct damage to their operation. Too much freshwater in fish farming areas could also impair operations for salt-water species. Regional meat and produce processors are unlikely to be significantly impacted by flood damage to Pierce County farms. They source almost all of their inputs from farm operations located outside Pierce County. Similarly, crop processors would only be impacted to they extent that they source their crops from Pierce County producers who are impacted by flooding.[40]

3.6 Summary of Economic Impacts of Flooding

This Chapter describes how total economic activity could be affected by flooding in Pierce County by detailing the indirect and induced effects associated with the businesses that are located within the floodplain extents for the 100-year and sea level rise floodplains. Businesses can be impacted by flooding in a variety of ways, and specific impacts will depend on the way in which the business is impacted, which is a function of the flood severity and site-specific conditions for the business. While all businesses can be affected by flooding, the total impact on economic activity in Pierce County is largest for businesses that are highly dependent on inputs that are sourced from within Pierce County, including labor, as well as those that could easily have their assets damaged by flooding, such as agricultural producers.

[40] The Regional Purchase Coefficients, the proportion of local demand that is estimated to be purchased from local producers, for the *Agriculture, Forestry, Fishing and Hunting* industry is only 15% for Pierce County, suggesting 85% of inputs for this industry are from outside the region.

4 Distributional Effects of Flooding

4.1 Introduction

Economic equity, along with economic value and economic impacts, is one of the three pillars of economic analysis. Economic equity is evaluated by using the distribution of economic value and impacts to answer the question: who is receiving the benefit or incurring the cost, and are they the same or different to those who have historically been impacted?

The purpose of this section is to describe the demographic and socioeconomic characteristics of the people living in the floodplain. This section also compares those characteristics to the people living outside the floodplain to identify differences between those within and outside of floodplain.

The information contained in this section represents only a first step towards understanding the potential ways in which certain areas and populations in Pierce County might be more or less vulnerable to flood risks and/or adverse outcomes from flooding. However, socioeconomics and demographics themselves are not indicative that a community is more vulnerable to adverse outcomes from flooding. The U.S. Water Alliance recommends that a series of five actions are taken to support efficient, resilient, and equitable water systems (Figure 4-1). What this report is doing – using data to identify risks, assets, and community vulnerabilities – represents only step one of the recommended actions.

Figure 4-1. Priority Actions for Equitable Water Management Recommended by U.S. Water Alliance

Priority Action #1: Use data to identify risks, assets, and community vulnerabilities.
Priority Action #2: Commit to ongoing and meaningful community engagement.
Priority Action #3: Set a proactive vision and build strategic alignment.
Priority Action #4: Fully incorporate equity into resilience planning processes.
Priority Action #5: Target Investments in vulnerable communities.

Source: U.S. Water Alliance. (2020). Water Rising: Equitable Approaches to Urban Flooding. Available at: http://uswateralliance.org/sites/uswateralliance.org/files/publications/Final_USWA_Water%20Rising_0.pdf

4.2 Flood Risk Vulnerability and Equity Factors

This section and the data analysis that follows is focused on the vulnerability of individuals and households. However, note that businesses have varying degrees of vulnerability as well. For example, smaller businesses tend to occupy riskier structures, concentrate in retail and service sectors more likely to experience disruption, have smaller cash reserves, and are less likely to distribute risk through insurance against property damage and business interruptions.[41,42,43]

4.2.1 Vulnerability Overview

Income, minority status, and other socioeconomic and demographic factors can contribute to flood-related vulnerability. Although a household might have certain demographic characteristics, it does not mean that it necessarily experiences the challenges described below, only that it is at higher risk of experiencing them compared to households without the factors.

For purposes of this technical memorandum, the term "vulnerability" is applied broadly with respect to multiple vulnerability factors, including:

- Vulnerability due to being at higher risk of being impacted by a flood event, either directly through residential location that increases the risk of damage to persons and property, or indirectly through transportation disruption or business/workplace closures.
- Vulnerability due to factors that make it more challenging to respond to and recover following a flood event (i.e., factors that limit resilience).
- Vulnerability that creates barriers to participation in decisions about policies and investments that could preemptively reduce flood risks.
- Vulnerability to experiencing adverse outcomes as a result of actions taken by the county to reduce flood risk (e.g., property acquisitions, infrastructure installation, etc.)

This list of vulnerability factors is not exhaustive. Households could also be considered vulnerable for reasons that do not fit into one of the above categories of vulnerability. Vulnerability factors often occur in tandem with socioeconomic inequities, many which are the result of complex and historical social injustices including systemic disadvantages and historical discriminatory policies.[44]

4.2.2 Equity Overview

Equity is related to but very different from vulnerability. Vulnerability factors consider only who is at risk. Equity builds upon that information to also understand who is protected by existing flood protection measures. An equity evaluation requires identifying who is living in

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[41] Wasileski, G., H. Rodruguez, & W. Diaz (2011). Business closure and relocation: a comparative analysis of the Loma Prieta earthquake and Hurricane Andrew. *Disasters*. 2011, 35(1): 102–129.

[42] Brown, C., Seville, E., Hatton, T., et al. 2019. "Accounting for Business Adaptations in Economic Disruption Models. *Journal of Infrastructure Systems.*

[43] Chang, S.E., & Rose, A. (2012). Towards a Theory of Economic Recovery from Disasters. *International Journal of Mass Emergencies and* Disasters, 32(2), 171-181.

[44] Donner & Rodríguez (2008) assert that "scholars widely acknowledge socio-economic inequality as one of the root causes of vulnerability to disasters" (p.1090). Donner, W., & Rodríguez, H. (2008). Population composition, migration and inequality: The influence of demographic changes on disaster risk and vulnerability. *Social forces*, 87(2), 1089-1114.

the floodplain and what is located there, as well as who and what are protected from flooding from existing infrastructure and policies, such as levees and prior buyout programs.

4.3 Literature on Vulnerability

4.3.1 Flood Risk Vulnerability

Nationally, historical development practices often placed low-income people and communities of color in flood-prone areas.[45] Systematic biases in housing, transportation, and land use – the most extreme of which including policies like redlining – have relegated many vulnerable populations to neighborhoods with lower quality services and more environmental hazards, including flooding.[46] Inequitable opportunities, lower levels of resources, and higher exposure to risks can make some community members more vulnerable than others, particularly to natural disasters.[47, 48] Nationally, low-income residents are more likely to live in floodplains and less likely to purchase earthquake or flood insurance,[49] which are not covered by most homeowner policies. Evidence from Hurricane Katrina suggests that low-income, elderly, and disabled residents might disproportionately lack access to transportation needed to evacuate away from areas expected to flood,[50] and thus are more vulnerable in their response to disasters. **Understanding who is at risk and who is protected by current flood protections informs how flood risk vulnerability is correlated with socio-demographic factors.**

4.3.2 Flood Resilience

After a disaster, low-income and minority populations could take longer to repair or rebuild due to higher levels of damage, limited personal financial resources, or challenges in navigating public and private bureaucratic processes to access aid.[51] Evidence from Hurricane Andrew in Florida and Louisiana documented more damage and slower recovery for neighborhoods with higher portions of minority residents, low income residents, rental housing, and multifamily

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[45] U.S. Water Alliance. (2020). *Water Rising: Equitable Approaches to Urban Flooding*. Available at http://uswateralliance.org/sites/uswateralliance.org/files/publications/Final_USWA_Water%20Rising_0.pdf

[46] U.S. Water Alliance. (2020). *Water Rising: Equitable Approaches to Urban Flooding*.

[47] Juntunen (2004) states that "Because there is unequal access to opportunity in pre-existing patterns of community settlement, and unequal exposure to risk due to the location of development, some people are inherently more vulnerable to disasters than others." (p.4). Juntunen, L. (2004). Addressing social vulnerability to hazards. Disaster Safety Review, v. 4, no. 2, p. 3-10.

[48] Fothergill, A., & Peek, L. A. (2004). Poverty and disasters in the United States: A review of recent sociological findings. *Natural Hazards*, 32(1), 89-110.

[49] Ibid.

[50] Masozera, M., Bailey, M., & Kerchner, C. (2007). Distribution of impacts of natural disasters across income groups: A case study of New Orleans. *Ecological Economics*, 63(2-3), 299-306.

[51] Fothergill, A., & Peek, L. A. (2004). Poverty and disasters in the United States: A review of recent sociological findings. *Natural hazards*, 32(1), 89-110.

housing.[52] Because there are inequities in the extent of damage and ability to recover, vulnerable populations can also experience severe and long-lasting post-traumatic stress, depression, and physical health problems following a disaster.[53] **Knowledge about a community's capacity to recover quickly from a flood event provides information that could be used to prioritize the location of investments to reduce flood risk.**

4.3.3 Barriers to Participation

One of the largest barriers to participation in policies like rebates and buyout programs is having a language barrier. Language barriers increase the costs, time, and effort needed to obtain information – putting those people at a disadvantage. **Knowing the languages of people in the community and producing materials in those languages can reduce language related participation barriers.**

Beyond language barriers, which can be fairly easily overcome, there can be larger barriers to participation affecting some communities. Public perceptions about government institutions can also create a barrier to participation. A study by Nance and Johnson[54] found that flood buyout programs were not seen as a beneficial supportive program, but instead as a predatory attempt to "take away" homes from people who do not have the means to replace them. This belief was especially prevalent in low-income communities. **Developing long-term relationships in low-income communities, paying fair market value, offering relocation assistance, and acknowledgement of the emotional loss of home and community can help ease concerns for wary homeowners.**

4.3.4 Potential for Adverse Outcomes from Participation

Potential adverse outcomes are those that are associated with participating in programs to reduce flood risk, particularly in buyout programs. Relocating from a home due to a buyout program is a disruption that some households may be better able to adjust to than others. Low-income households are also more likely to suffer from adverse outcomes of relocating including disruption for children, difficulty maintaining social relations, and health and bureaucratic difficulties.[55] Children in particular who move have higher rates of earlier initiation of drug use, earlier onset of depression, and increased risk of premarital sexual behavior and teenage pregnancy; however, there is no evidence of a causal relationship between moving and these outcomes because of the many factors that could be contributing to both moving and these

[52] Zhang, Y., & Peacock, W. G. (2009). Planning for housing recovery? Lessons learned from Hurricane Andrew. *Journal of the American Planning Association*, 76(1), 5-24.

[53] Substance Abuse and Mental Health Services Administration. (2017). *Disaster Technical Assistance Center Supplemental Research Bulletin: Greater Impact: How disasters affect people of low socioeconomic status.* US Department of Health & Human Services.

[54] Earthea Nance and Jamila Johnson. (2020). "Barriers to Equity in Flood Mitigation Buyouts". Available at http://works.bepress.com/nanceea/28/

[55] Bartlett, S. (1997). The significance of relocation for chronically poor families in the USA. *Environment and Urbanization*, 9(1), 121-132.

outcomes.[56] Relocating can result in a loss of social capital, particularly for adolescents.[57] Lack of stable housing due to relocation may lead to a shift from home-owner to renter. **Although there are mechanisms that can be used to ease the burden of relocation (e.g., increased compensation, relocation specialists, favorable terms, etc.), having to move from a home is a life disruption that should be treated as such in the buyout process.**

Navigating bureaucratic processes can be more difficult for people with less educational training or experience – a consideration that is relevant for buyout programs where ability to negotiate and understand real estate markets can influence the outcomes for the seller. These vulnerabilities to adverse outcomes can be partially mitigated through third-party advocates, but only if does not impose a financial burden on the seller to do so (i.e., free to the seller to use that resource). Financial burdens associated with some of the local flood protection action programs can disproportionately affect low-income households because expending costs associated with flood protection represent a larger share of their household wealth. Financial burdens can also occur from local flood protections action if they increase household utility costs. **Providing additional resources for sellers who are most at risk of disruption (e.g., low-income, elderly, etc.) could reduce the risk of adverse outcomes for those participants.**

4.4 Existing Measures of Risks and Vulnerabilities

There are two existing measures of risks and vulnerabilities relevant to flooding that have been developed by federal agencies. They are the **National Risk Index (NRI)** developed by the Federal Emergency Management Agency (FEMA**)** and the **Social Vulnerability Index (SVI)** developed by the Centers for Disease Control and Prevention (CDC).

4.4.1 FEMA NRI

The Federal Emergency Management Agency (FEMA) has recently released the National Risk Index for Natural Hazards (NRI) that documents risk to 18 natural hazards based on expected annual losses, social vulnerabilities, and community resilience.[58] NRI data is available at the census tract level.

The NRI is comprised of three risk components: social vulnerability, community resilience, and expected annual loss.

- **Social vulnerability** is measured by a sub-index, the University of South Carolina's Hazards and Vulnerability Research Institute (HVRI) Social Vulnerability Index (SoVI). The SoVI utilizes 29 socioeconomic variables to represent a community’s ability to prepare for, respond to, and recover from hazards.

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[56] Jelleyman, T., & Spencer, N. (2008). Residential mobility in childhood and health outcomes: A systematic review. *Journal of Epidemiology and Community Health* (1979-), 62(7), 584-592.

[57] Tønnessen, M., Telle, K., & Syse, A. (2016). Childhood residential mobility and long-term outcomes. Acta Sociologica, 59(2), 113-129.

[58] More information about the NRI is available at: https://hazards.fema.gov/nri

- **Community resilience** is measured by the University of South Carolina's HVRI Baseline Resilience Indicators for Communities (BRIC) index. HVRI BRIC uses a set of 49 indicators that represent six types of resilience: social, economic, community capital, institutional capacity, housing/infrastructure, and environmental.
- **Expected annual loss** is the average economic loss in dollars resulting from natural hazards each year, based upon historic losses. The NRI evaluates 18 natural hazards, the most common of which is drought, followed by flooding, wildfire, and earthquakes.

The NRI is a national model so it characterizes risk level as compared to national averages. Pierce County ranks as "relatively high" for all natural hazards (i.e., avalanche, drought, hurricane, tsunami, and additional 14 natural hazards). The county ranks as "relatively moderate" for coastal flooding and "relatively low" for riverine flooding.

4.4.2 CDC SVI

The Centers for Disease Control and Prevention (CDC) offers another type of vulnerability index, the Social Vulnerability Index (SVI). The SVI uses 15 socio-demographic variables (Figure 4-2) from the U.S. Census to help local officials identify communities that may need support before, during, or after disasters.[59]

Figure 4-2. U.S. Center for Disease Control Social Vulnerability Index (SVI) Variables

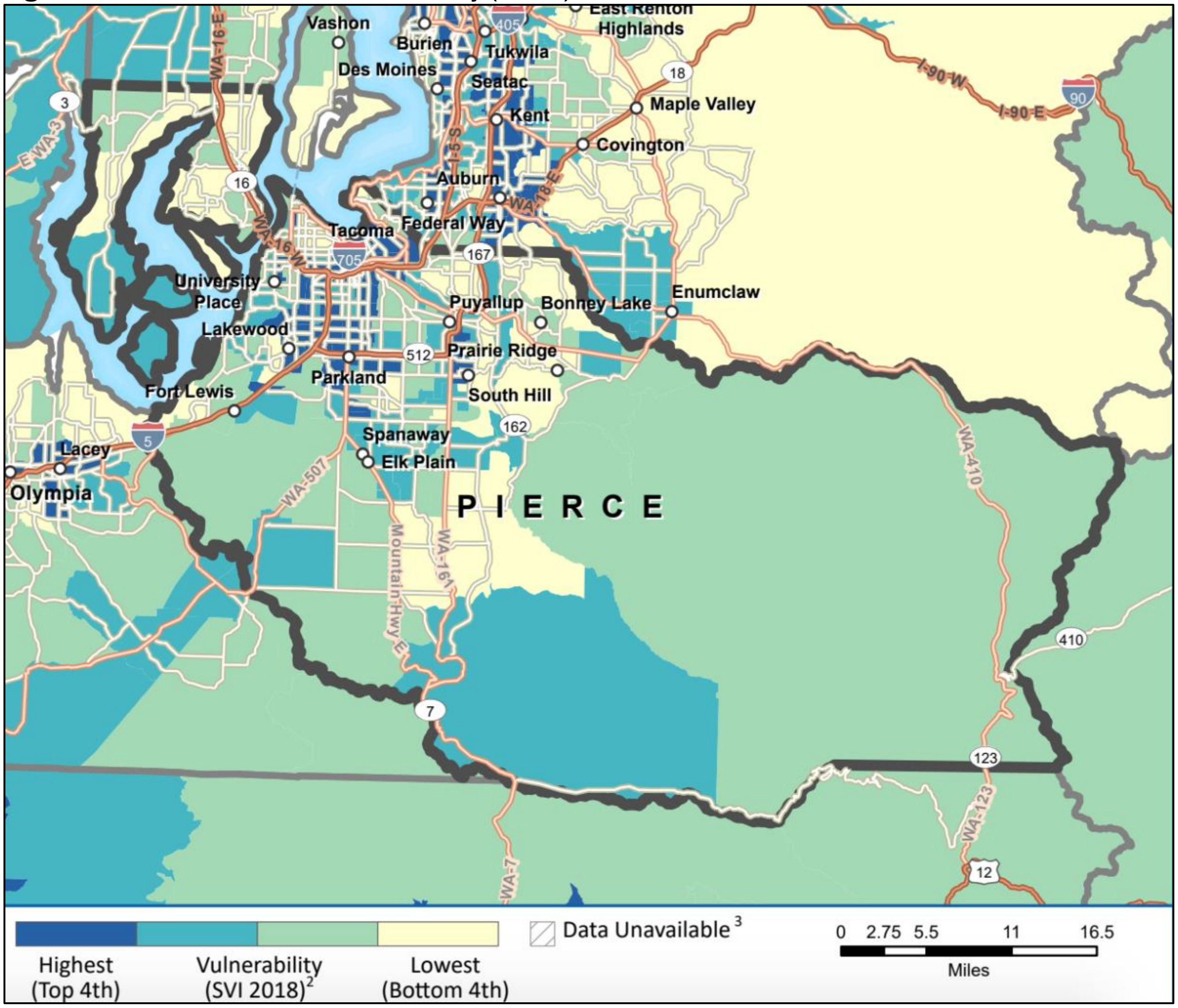
Overall Vulnerability	Socioeconomic Status	Below Poverty
		Unemployed
		Low Income
		No High School Diploma
	Household Composition and Disability	Aged 65 or Older
		Aged 17 or Younger
		Civilian with Disability
		Single-Parent Household
	Minority Status and Language	Racial/Ethnic Minority
		Speaks English "Less than Well"
	Housing and Transportation	Multi-Unit Structures
		Mobile Homes
		Crowding
		No Vehicles
		Group Quarters

Source: U.S. Center for Disease Control. (2016). CDC SVI 2016 Documentation. Retrieved from https://svi.cdc.gov/Documents/Data/2016_SVI_Data/SVI2016Documentation.pdf

Like the NRI, the SVI is also a national model. Pierce County's SVI score is 0.4873 on the 0 (lowest) to 1 (highest) scale, indicating a "low to moderate" level of vulnerability. The highest social vulnerability is in the areas near some of the major highways in the county (Figure 4-3).

[59] More information about the SVI is available at: https://www.atsdr.cdc.gov/placeandhealth/svi/index.html

Figure 4-3. SVI Results for Pierce County (2018)



Source: CDC Social Vulnerability Index 2018, Available at: https://svi.cdc.gov/prepared-county-maps.html

4.4.3 EPA's Environmental Justice Screening and Mapping Tool

Another tool for mapping community demographic factors is the Environmental Protection Agency's Environmental Justice Screening and Mapping Tool (EJSCREEN).[60] There are 11 "EJ Indexes" in EJSCREEN reflecting environmental indicators. The EJ indexes are combined with low-income and minority status with the environmental risk factors to create each EJ index. For example, the EJ index for Traffic Proximity and Volume is comprised of a traffic indicator with low-income and minority population levels. There is not an EJ index for flood risk.

[60] More information about EJSCREEN is available at: https://www.epa.gov/ejscreen

4.5 Socioeconomic and Demographic Results

The socioeconomic and demographic results in this section provide information about who is living in floodplains in Pierce County by floodplain type and by sub-planning area. As discussed in the beginning of this chapter, this information should be used as a first step towards understanding the potential ways in which certain areas and populations in Pierce County might be more or less vulnerable to flood risks and/or adverse outcomes from flooding. Socioeconomic and demographic factors do not make a community vulnerable, as it is the combination of risks and the specific circumstances of the household that influence vulnerability in terms of risk, response, and recovery from flooding.

Results are presented as population weighted averages. Using spatially weighted re-aggregation, block group populations are divided proportionally into component subarea and area within/out of the floodplain and then totaled by category to create demographic estimates for both the county and sub-planning area geographies.

Because spatial extents for the data are not available at the household level, the estimates for "in floodplain" are imprecise based upon the percent of the geography that overlaps the area. The true value for people living specifically in the floodplain, compared to just outside the floodplain but in the same census block group, may vary significantly from the numbers presented in the results section. This challenge highlights the importance of on-the-ground outreach to households who could be affected by a policy or project – since the data alone cannot provide a complete story about their circumstances.

4.5.1 Pierce County Results

Table 4-1 provides a summary of multiple socioeconomic and demographic variables at the county level, both inside and outside the floodplain extents (which include all flooding types: riverine, groundwater, coastal, and sea level rise). Overall, in Pierce County, areas in the floodplain have a higher median household income and per capita income, are less likely to be renters, are less likely to be people of color, and are more likely to be over the age of 65. The results for per capita income are consistent across type of flooding, with the exception of groundwater which indicates a lower average income in the floodplain compared to outside the floodplain (Table 4-2).

Maps showing the results for census tracts for all of Pierce County are available for three variables: median household income (Figure 4-4), communities of color (Figure 4-5), and renters (Figure 4-6).

Table 4-1. Socioeconomic and Demographic Variables by Floodplain (All types)

Variable	Pierce County Average	Population Weighted Average in Floodplain	Population Weighted Average outside of Floodplain	Difference in and out of floodplain
Median Household Income	$72,113	$81,638*	$74,631*	-$7,007
Per Capita Income	$34,618	$37,841	$22,676	-$15,165
Percent Renter	38%	34%	38%	-4%

Variable	Pierce County Average	Population Weighted Average in Floodplain	Population Weighted Average outside of Floodplain	Difference in and out of floodplain
Percent Non-Hispanic White	67%	69%	67%	3%
Percent People of Color	33%	31%	33%	-3%
Percent Below Federal Poverty Level	7%	6%	7%	-1%
Percent of Households Over Age 65	26%	27%	26%	1%
Percent Adults with High School Degree or Higher	92%	92%	92%	0%
Percent Adults with Bachelor's Degree or Higher	27%	27%	27%	0%
Percent English Limited Households	3%	3%	3%	0%

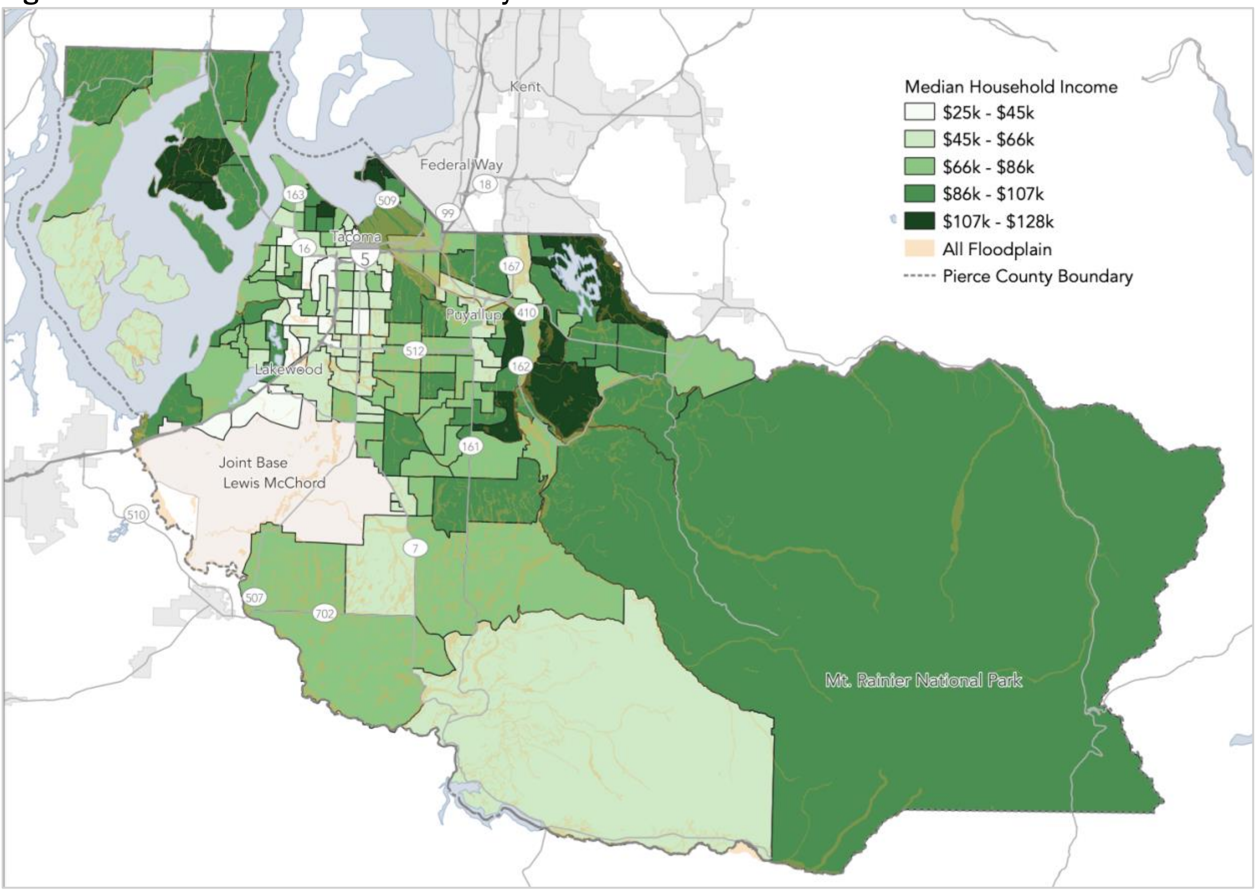
Source: U.S. Census, American Community Survey, 5-year averages, 2014-2019.
*Note: Represents a population weighted average of median household income

Table 4-2. Per Capita Income by Floodplain Type

Type of Flooding	Pierce County Average	Population Weighted Average in Floodplain	Population Weighted Average outside of Floodplain	Difference in and out of floodplain
Riverine	$34,618	$37,345	$22,745	-$14,600
Groundwater	$34,618	$31,085	$23,072	-$8,013
Coastal	$34,618	$50,438	$23,071	-$27,367
Sea Level Rise	$34,618	$42,984	$23,010	-$19,974

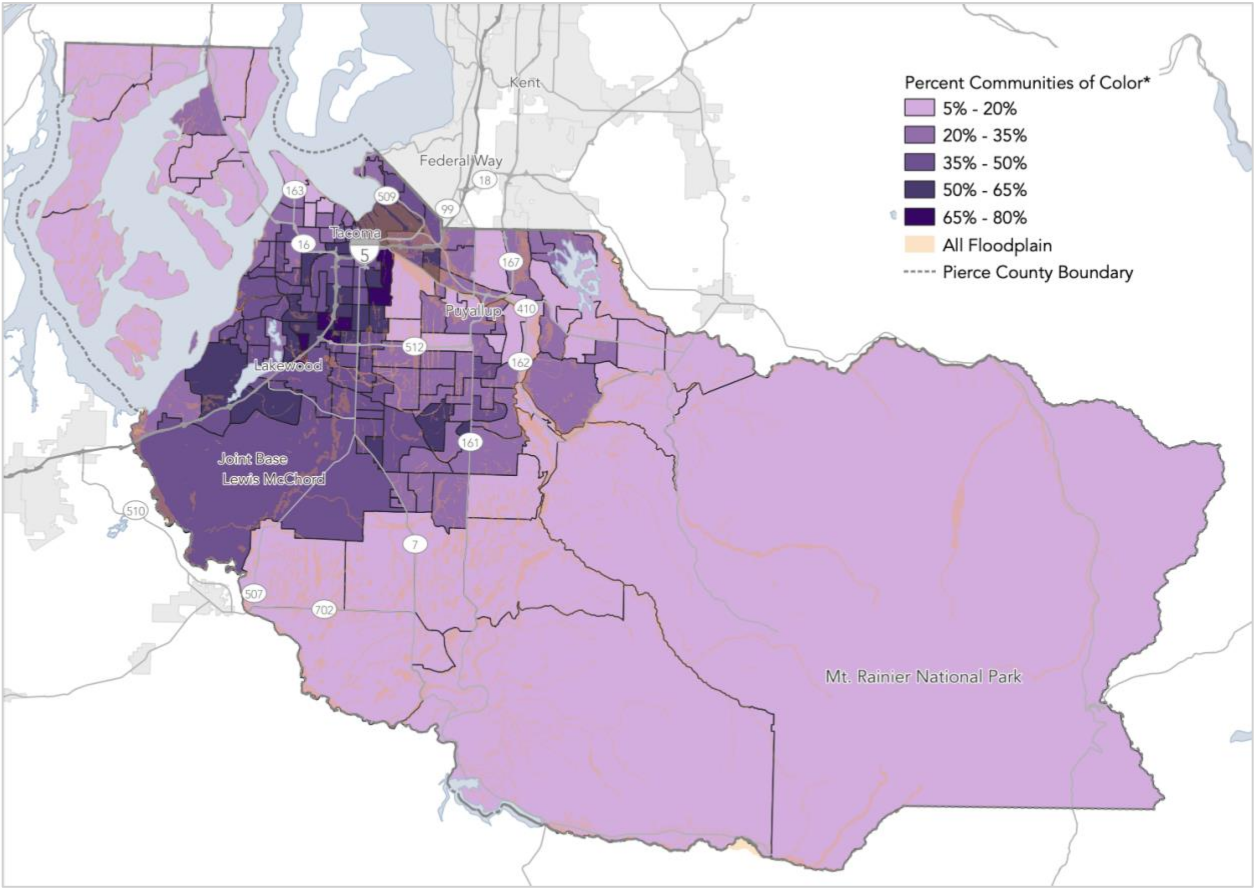
Source: U.S. Census, American Community Survey, 5-year averages, 2014-2019.
*Note: Represents a population weighted average of median household income

Figure 4-4. Median Household Income by Census Tract



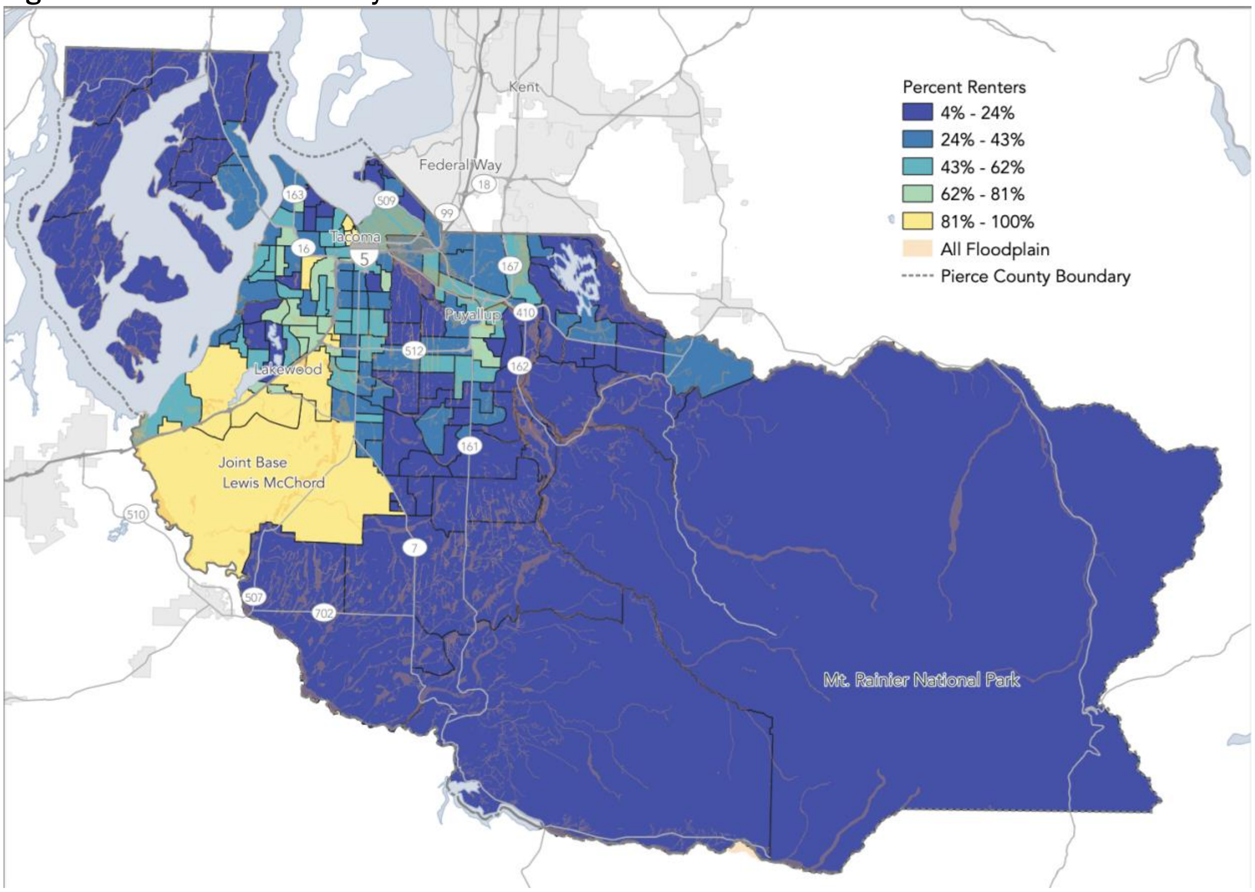
Source: Created by ECONorthwest using data from U.S. Census, American Community Survey, 5-year averages, 2014-2019.

Figure 4-5. Percent Communities of Color by Census Tract



Source: Created by ECONorthwest using data from U.S. Census, American Community Survey, 5-year averages, 2014-2019.

Figure 4-6. Percent Renters by Census Tract



Source: Created by ECONorthwest using data from U.S. Census, American Community Survey, 5-year averages, 2014-2019.

4.5.2 Sub-planning Area Results

The following tables present results for 10 variables for each sub-planning area (SPA) geography for areas within and outside of the floodplain. The variables are:

- Average Per Capita Income (Table 4-3)
- Average Median Household Income (Table 4-4)
- Percent of Households Below Federal Poverty Level (Table 4-5)
- Percent Black, Indigenous and People of Color (Table 4-6)
- Percent Non-Hispanic White Alone (Table 4-7)
- Percent Renters (Table 4-8)
- Percent of Households with at least one member over age 65 (Table 4-9)
- Percent of Adults over Age 25 with a Bachelor's Degree or Higher (Table 4-10)
- Percent of Adults over Age 25 with a High School Diploma or Higher (Table 4-11)
- Percent English Limited Households (Table 4-12)

The SPAs have different values for the average per capita income in the floodplain. The White River Basin has the highest per capita income in the floodplain with $60,060 and the Chambers

Bay/Clover Creek Basin has the lowest per capita income with $33,035 (although this value is still higher than the per capita income outside the floodplain of $30,922 for that SPA).

Table 4-3. Average Per Capita Income by Sub-planning Area

Sub-Planning Area (SPA)	SPA Average	Average in Floodplain	Average outside of Floodplain	Difference in and out of floodplain
Chambers Bay / Clover Creek Basin	$31,022	$33,035	$30,922	$2,113
Clear / Clarks Creek Basin	$34,600	$34,407	$34,618	-$211
Gig Harbor / Key Peninsula Basin	$46,692	$45,132	$46,832	-$1,701
Hylebos-Browns Point-Dash Point Basin	$39,754	$37,009	$40,114	-$3,105
Mid Puyallup Basin	$37,638	$35,960	$37,981	-$2,021
Muck Creek Basin	$33,013	$34,132	$32,881	$1,251
Nisqually Basin	$31,359	$36,793	$30,603	$6,190
Upper Puyallup Basin	$35,282	$34,686	$35,363	-$677
White River Basin	$46,562	$60,060	$43,994	$16,066

Source: U.S. Census, American Community Survey, 5-year averages, 2014-2019.

The results for median household income follow a similar pattern to the results for per capita income, with the exception of the Upper Puyallup Basin (Table 4-4). Per capita income is lower in the floodplain for that SPA, but median household income is higher.

Table 4-4. Average Median Household Income by Sub-planning Area

Sub-Planning Area (SPA)	SPA Average	Average in Floodplain	Average outside of Floodplain	Difference in and out of floodplain
Chambers Bay / Clover Creek Basin	$66,400	$69,372	$66,253	$3,119
Clear / Clarks Creek Basin	$72,564	$70,445	$72,756	-$2,311
Gig Harbor / Key Peninsula Basin	$92,738	$92,339	$92,774	-$435
Hylebos-Browns Point-Dash Point Basin	$90,855	$81,492	$91,995	-$10,503
Mid Puyallup Basin	$91,088	$85,298	$92,314	-$7,015
Muck Creek Basin	$78,202	$81,885	$77,757	$4,128
Nisqually Basin	$71,211	$81,434	$69,675	$11,759
Upper Puyallup Basin	$90,005	$93,721	$89,526	$4,195
White River Basin	$96,020	$113,657	$92,829	$20,828

Source: U.S. Census, American Community Survey, 5-year averages, 2014-2019.

The Chambers Bay/Clover Creek Basin has the highest percentage of households below the federal poverty level of all the SPAs (9 percent). None of the SPAs have a significant difference (more than 3 percent) between poverty levels for households within and outside of the floodplain.

Table 4-5. Percent of Households Below Federal Poverty Level by Sub-planning Area

Sub-Planning Area (SPA)	SPA Average	Average in Floodplain	Average outside of Floodplain	Difference in and out of floodplain
Chambers Bay / Clover Creek Basin	9%	9%	9%	0%
Clear / Clarks Creek Basin	6%	7%	6%	1%

Sub-Planning Area (SPA)	SPA Average	Average in Floodplain	Average outside of Floodplain	Difference in and out of floodplain
Gig Harbor / Key Peninsula Basin	3%	3%	3%	0%
Hylebos-Browns Point-Dash Point Basin	5%	6%	5%	1%
Mid Puyallup Basin	4%	5%	4%	1%
Muck Creek Basin	7%	6%	8%	-1%
Nisqually Basin	8%	5%	8%	-3%
Upper Puyallup Basin	4%	5%	4%	1%
White River Basin	3%	2%	3%	-1%

Source: U.S. Census, American Community Survey, 5-year averages, 2014-2019.

Chambers Bay/Clover Creek Basin has the highest percentage of people of color for any of the SPA (42 percent) and there is an even distribution for people inside and outside of the floodplain. Hylebos-Browns Point-Dash Point Basin and Mid Puyallup Basin have a higher percentage of people of color (more than 10 percent) inside the floodplain compared to outside the floodplain. The percentages for "Percent Non-Hispanic White Alone" follow a similar relationship as the "Percent Black, Indigenous and People of Color" for the SPAs.

Table 4-6. Percent Black, Indigenous and People of Color* by Sub-planning Area

Sub-Planning Area (SPA)	SPA Average	Average in Floodplain	Average outside of Floodplain	Difference in and out of floodplain
Chambers Bay / Clover Creek Basin	42%	42%	42%	0%
Clear / Clarks Creek Basin	27%	27%	27%	0%
Gig Harbor / Key Peninsula Basin	14%	14%	14%	0%
Hylebos-Browns Point-Dash Point Basin	33%	46%	32%	14%
Mid Puyallup Basin	23%	32%	21%	11%
Muck Creek Basin	19%	16%	19%	-3%
Nisqually Basin	26%	21%	27%	-6%
Upper Puyallup Basin	17%	19%	17%	2%
White River Basin	20%	12%	22%	-9%

Source: U.S. Census, American Community Survey, 5-year averages, 2014-2019.
*Note: Includes all races and ethnicities that are not non-Hispanic white alone

Table 4-7. Percent Non-Hispanic White Alone by Sub-planning Area

Sub-Planning Area (SPA)	SPA Average	Average in Floodplain	Average outside of Floodplain	Difference in and out of floodplain
Chambers Bay / Clover Creek Basin	58%	58%	58%	0%
Clear / Clarks Creek Basin	73%	73%	73%	0%
Gig Harbor / Key Peninsula Basin	86%	86%	86%	0%
Hylebos-Browns Point-Dash Point Basin	67%	54%	68%	-14%
Mid Puyallup Basin	77%	68%	79%	-11%
Muck Creek Basin	81%	84%	81%	3%
Nisqually Basin	74%	79%	73%	6%
Upper Puyallup Basin	83%	81%	83%	-2%
White River Basin	80%	88%	78%	9%

Source: U.S. Census, American Community Survey, 5-year averages, 2014-2019.

Hylebos-Browns Point-Dash Point Basin and Chambers Bay/Clover Creek Basin have the highest percentages of people who are renters out of the SPAs. Hylebos-Browns Point-Dash Point Basin and Mid Puyallup Basin have a higher percentage of people of people who are renters (more than 10 percent) inside the floodplain compared to outside the floodplain. These are also the two SPAs that have the highest percentages of people of color living in the floodplain compared to outside the floodplain.

Table 4-8. Percent Renters by Sub-planning Area

Sub-Planning Area (SPA)	SPA Average	Average in Floodplain	Average outside of Floodplain	Difference in and out of floodplain
Chambers Bay / Clover Creek Basin	46%	45%	46%	-1%
Clear / Clarks Creek Basin	37%	32%	38%	-5%
Gig Harbor / Key Peninsula Basin	20%	17%	20%	-3%
Hylebos-Browns Point-Dash Point Basin	35%	53%	33%	20%
Mid Puyallup Basin	25%	34%	24%	11%
Muck Creek Basin	16%	14%	16%	-2%
Nisqually Basin	40%	26%	42%	-16%
Upper Puyallup Basin	16%	18%	16%	3%
White River Basin	26%	16%	28%	-13%

Source: U.S. Census, American Community Survey, 5-year averages, 2014-2019.

Gig Harbor/Key Peninsula Basin is the SPA with the highest percent of households who have at least one member over age 65. There are not large differences in percentages for people living in or outside of the floodplain for this demographic variable.

Table 4-9. Percent of Households with at least one member over age 65 by Sub-planning Area

Sub-Planning Area (SPA)	SPA Average	Average in Floodplain	Average outside of Floodplain	Difference in and out of floodplain
Chambers Bay / Clover Creek Basin	24%	26%	24%	2%
Clear / Clarks Creek Basin	30%	31%	30%	1%
Gig Harbor / Key Peninsula Basin	40%	41%	40%	1%
Hylebos-Browns Point-Dash Point Basin	25%	22%	26%	-4%
Mid Puyallup Basin	23%	22%	24%	-2%
Muck Creek Basin	27%	29%	27%	2%
Nisqually Basin	23%	27%	22%	5%
Upper Puyallup Basin	24%	24%	24%	1%
White River Basin	24%	25%	24%	2%

Source: U.S. Census, American Community Survey, 5-year averages, 2014-2019.

Muck Creek basin has the lowest percent of people over age 25 with a bachelor's degree or higher education. As a continuation of the trend seen for the variables reflecting percent of people of color and renters, Hylebos-Browns Point-Dash Point Basin and Chambers Bay/Clover Creek Basin have the lowest percentage of people over age 25 with a bachelor's degree or higher education level living inside the floodplain compared to outside the floodplain. The results are similar for "Percent of Adults over Age 25 with a High School Diploma or Higher". However, Chambers Bay/Clover Creek Basin has the lowest average percent of people with that educational attainment level.

Table 4-10. Percent of Adults over Age 25 with a Bachelor's Degree or Higher by Sub-planning Area

Sub-Planning Area (SPA)	SPA Average	Average in Floodplain	Average outside of Floodplain	Difference in and out of floodplain
Chambers Bay / Clover Creek Basin	26%	25%	26%	-1%
Clear / Clarks Creek Basin	24%	24%	24%	0%
Gig Harbor / Key Peninsula Basin	39%	37%	40%	-2%
Hylebos-Browns Point-Dash Point Basin	31%	25%	31%	-7%
Mid Puyallup Basin	26%	26%	26%	0%
Muck Creek Basin	16%	18%	16%	2%
Nisqually Basin	25%	28%	24%	4%
Upper Puyallup Basin	22%	22%	22%	0%
White River Basin	35%	37%	34%	2%

Source: U.S. Census, American Community Survey, 5-year averages, 2014-2019.

Table 4-11. Percent of Adults over Age 25 with a High School Diploma or Higher by Sub-planning Area

Sub-Planning Area (SPA)	SPA Average	Average in Floodplain	Average outside of Floodplain	Difference in and out of floodplain
Chambers Bay / Clover Creek Basin	90%	90%	90%	0%
Clear / Clarks Creek Basin	91%	92%	91%	1%
Gig Harbor / Key Peninsula Basin	95%	95%	95%	0%
Hylebos-Browns Point-Dash Point Basin	93%	85%	94%	-9%
Mid Puyallup Basin	94%	92%	94%	-2%
Muck Creek Basin	91%	92%	91%	1%
Nisqually Basin	94%	93%	94%	-1%
Upper Puyallup Basin	91%	91%	91%	0%
White River Basin	95%	96%	95%	1%

Source: U.S. Census, American Community Survey, 5-year averages, 2014-2019.

Chambers Bay/Clover Creek Basin has the highest percentage of households that speak limited English of all the SPAs. None of the SPAs has a significant difference (more than 2 percent) in averages for households within and outside the floodplain for this variable.

Table 4-12. Percent English Limited Households by Sub-planning Area

Sub-Planning Area (SPA)	SPA Average	Average in Floodplain	Average outside of Floodplain	Difference in and out of floodplain
Chambers Bay / Clover Creek Basin	4%	5%	4%	1%
Clear / Clarks Creek Basin	1%	1%	1%	0%
Gig Harbor / Key Peninsula Basin	1%	0%	1%	0%
Hylebos-Browns Point-Dash Point Basin	2%	4%	2%	2%
Mid Puyallup Basin	1%	2%	1%	1%
Muck Creek Basin	1%	1%	1%	0%
Nisqually Basin	1%	1%	1%	0%
Upper Puyallup Basin	1%	1%	1%	0%
White River Basin	2%	0%	2%	-1%

Source: U.S. Census, American Community Survey, 5-year averages, 2014-2019.

4.6 Summary of Distributional Effects of Flooding

There is diversity throughout Pierce County in terms of socioeconomic and demographic variables for people living in and near floodplains. As noted previously, this information represents only the first step in promoting equitable floodplain management by understanding who is living in the floodplain. Additional and ongoing work should be done to avoid perpetuating historic inequities in floodplain management and reducing risks for vulnerable populations.

5 Flood Impacts to Properties

5.1 Introduction

Properties and infrastructure within the floodplain can be damaged by water inundation and debris. This chapter of the report describes property and improvements located within the floodplain and estimates the monetary costs of potential damage to those physical resources. This chapter is divided first into impacts to properties and buildings, and second into impacts to roads and bridges.

5.2 Potential Flood Impacts to Properties and Buildings

5.2.1 Methodology

5.2.1.1 Properties and Building in the Floodplain

The primary data used for the analysis of potential damage to properties is parcel data from Pierce County.[61] The parcel data includes the location, size, land use description, land value, improvement value, and total value for each tax parcel in Pierce County. The other dataset that is used for the analysis is geospatial data of building footprint locations, provided by Pierce County.[62]

Properties are identified as in the floodplain extent based on the total building footprint for the parcel. If 50 percent or more of the total building footprint for the parcel is within the floodplain extent, then the parcel is identified as in the floodplain and its values for land, improvement, and total value are included in the summary totals. The count of buildings in the floodplain are the number of buildings that intersect the floodplain. Buildings are included in the count even if less than 50 percent of the building is within the floodplain extent.

The majority of parcels located in the floodplain extent had buildings either completely in the floodplain or not (Figure 5-1). Some parcels have multiple building footprints. In these instances, the count of buildings in the floodplain is the number of buildings that intersect with the floodplain extent. The parcel is considered within the floodplain if 50 percent of all buildings are within the floodplain. For example, if there are two buildings on a parcel and one is completely in and the other is completely out of the floodplain the parcel would be considered in the floodplain because 50 percent of the buildings are within it. Parcels without buildings or with buildings that are not in the floodplain extent are not included in these estimates.[63]

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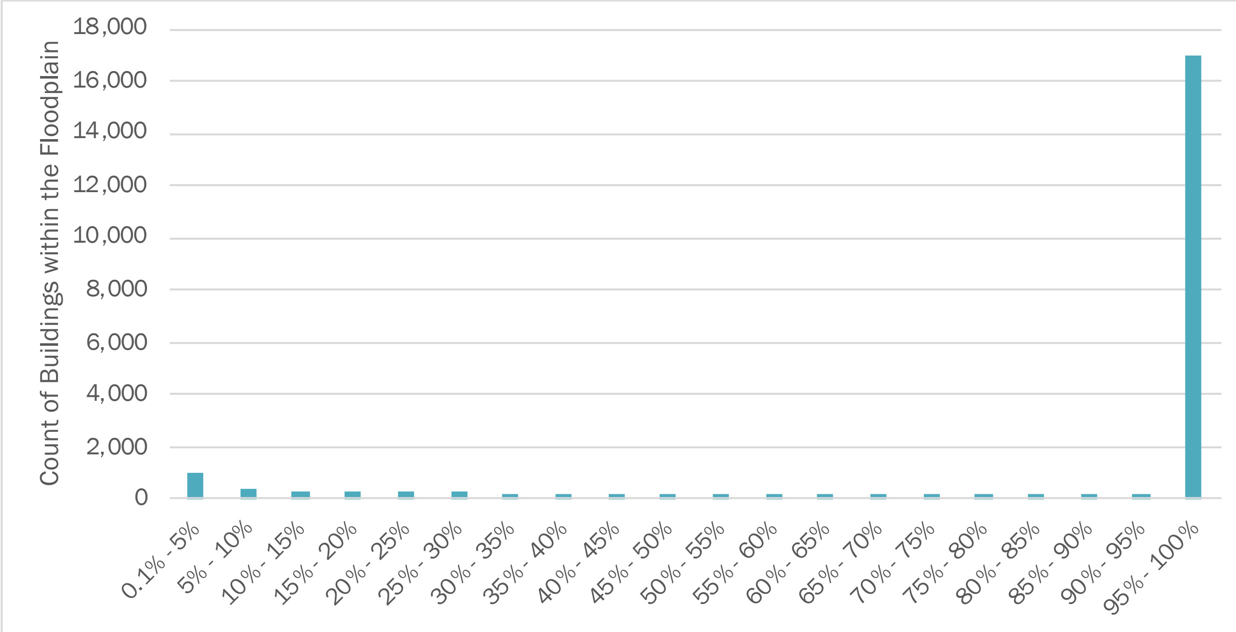
[61] Pierce County Open GeoSpatial Data Portal, *Tax Parcels* (2020), available at: https://gisdata-piercecowa.opendata.arcgis.com/datasets/roads?geometry=-122.225%2C47.025%2C-122.014%2C47.066

[62] Geodatabase provided directly by Pierce County and not available on the Open GeoSpatial Data Portal.

[63] Chapter 2 contains a summary of number of parcels and acres in each floodplain extent (regardless of buildings).

Figure 5-1. Count of Buildings within the 100 Year and Sea Level Rise Floodplain Extents, by percent of Building Footprint within the Floodplain



Source: Created by ECONorthwest

There are 180 individual land use categories within the parcel data. The land use categories were summarized into the following eight categories for the analysis and for reporting:

- Commercial/Industrial
- Public Lands and Facilities
- Recreation/Open Space
- Residential
- Vacant
- Other
- Resource Lands
- Tribal (some land that is owned by area tribal governments is included in the assessor data's land use category as public land)

5.2.1.2 Damage Estimates

This analysis relied upon damage curve estimates from the U.S. Army Corps of Engineers to estimate the damage associated with flooding for buildings that are located within the floodplain extents.[64] Flood damage to property varies by the depth of the inundation. Figure 5-2 displays the damage curves (i.e., the percent of the value of the property that is damaged by various flood depths) for residential, mobile home, warehouse, and vehicle property types.

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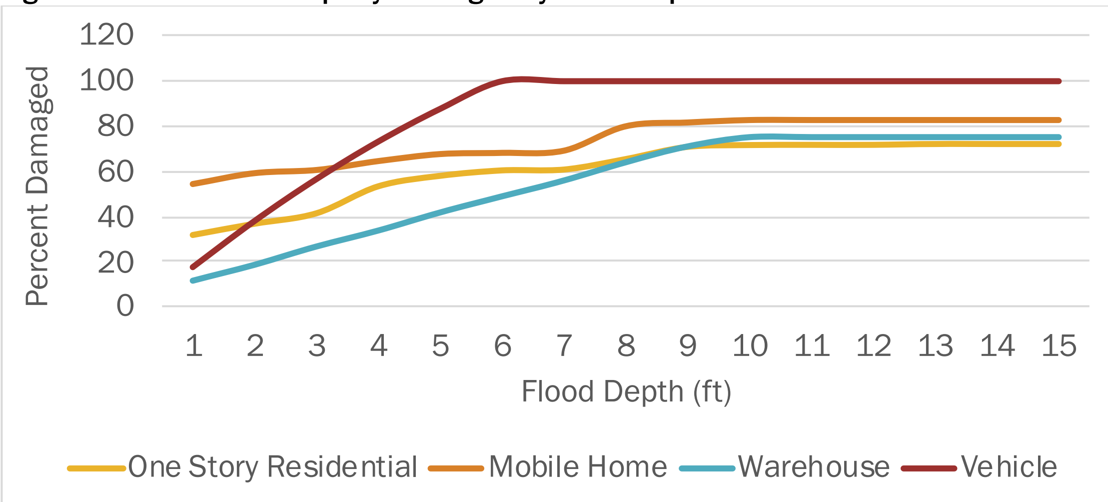
[64] U.S. Army Corps of Engineers New Orleans District. (2006). *Depth-Damage Relationships for Structures, Contents, and Vehicles and Content-to-Structure Value Ratios (CSVR) in Support of the Donaldsonville to the Gulf, Louisiana, Feasibility Study*. March. Available at: https://www.mvn.usace.army.mil/Portals/56/docs/PD/Donaldsv-Gulf.pdf

Because elevation data is not available throughout the county, this analysis assumes a 1-foot flood inundation extent for all properties.

Figure 5-2. Percent of Property Damaged by Flood Depth of the Inundation



Source: U.S. Army Corps of Engineers New Orleans District. (2006). Depth-Damage Relationships for Structures, Contents, and Vehicles and Content-to-Structure Value Ratios (CSVR) in Support of the Donaldsonville to the Gulf, Louisiana, Feasibility Study. March. Available at: https://www.mvn.usace.army.mil/Portals/56/docs/PD/Donaldsv-Gulf.pdf

The damages from flooding used for this analysis apply only to buildings located within the floodplain extents and their contents. It does not include vehicles, damage to land, or any other non-building or non-vehicle property. Table 5-1 displays the estimate of building and contents damage for a 1-foot inundation for multiple structure and property type.

Table 5-1. Building and Contents Damage Estimates for 1 Flood of Flood Inundation, Freshwater and Saltwater (2021 Dollars)

Building Damage	
Structure Type	**Damage Estimate**
One story on Slab	$50,460
Mobile Home	$24,313
Metal Frame	$125,873
Masonry	$38,073
Wood or Steel Frame	$199,572
Contents Damage Estimates	
Property Type	**Damage Estimate**
Mobile Home	$31,498
One-story	$28,235
Two-story	$35,771
Multi-family	$560,471
Professional Business	$39,859
Retail	$582,621
Warehouse	$254,669
Eating and Recreation	$114,385
Groceries and Gas Station	$398,413

Source: U.S. Army Corps of Engineers New Orleans District. (2006). Depth-Damage Relationships for Structures, Contents, and Vehicles and Content-to-Structure Value Ratios (CSVR) in Support of the Donaldsonville to the Gulf, Louisiana, Feasibility Study. March. Available at: https://www.mvn.usace.army.mil/Portals/56/docs/PD/Donaldsv-Gulf.pdf
Note: Dollar values inflated from 2008 to 2021 Dollars using a rate of 1.4316.

Each land use type was assigned a damage value based on the structure type and a contents value based on property type. All land types were assigned the damage value for one story on slab, with the exception of commercial/industrial land types that apply the metal frame value. The commercial/industrial land type is categorized under the warehouse contents value. Public lands and facilities, recreation/open space, vacant, and resource lands are categorized under the professional business category. Residential, other, and tribal are categorized under the one-story contents value. Table 5-2 summarizes the damage value and contents value for each land type. These assumptions are the basis for the damage estimates.

Table 5-2. Damage to Buildings and Contents Estimates by Land Type

Land Type	Building Damage Value	Contents Damage Value
Commercial/Industrial	$125,873	$254,669
Public Lands and Facilities	$50,460	$39,859
Recreation/Open Space	$50,460	$39,859
Residential	$50,460	$28,235
Vacant	$50,460	$39,859
Other	$50,460	$28,235
Resource Lands	$50,460	$39,859
Tribal	$50,460	$28,235

Source: Created by ECONorthwest

The estimates of damage to buildings and contents have multiple assumptions that may not necessarily reflect the replacement value of flood damaged property. Estimating replacement costs can require numerous assumptions and be impacted by market conditions and costs to rebuild. This analysis uses average values per building for structures and contents and does not account for site-specific conditions, such as size of the building or specialized equipment contents.

The estimates of damage to structures and their contents within the floodplain could range widely depending on the valuation method used. The purpose of the damage curve estimates is to estimate damage based on replacement costs. Another indicator of the potential damage to property is the land value, improvement value, and the total value of the parcel. Although not replacement costs, these values describe the magnitude of the current value of property that could be impacted by a flood.

5.3 Damage Estimates for Properties

This section details damage estimates to properties located within each of the floodplain extents. The section is divided into the 100-year floodplain and the sea level rise floodplain.

5.3.1 100-Year Floodplain

Table 5-3 provides a summary the land values, improvement values, taxable values, and damage estimates for parcels with buildings within the 100-year floodplain extent by SPA and flooding type. There are a total of 10,843 buildings that intersect the floodplain extent on 5,010 parcels of land. Mid Puyallup Basin has the largest total damage to buildings and contents estimate.

Table 5-3. 100-Year floodplain extents, by SPA and Flood Type (in Thousands of Dollars, 2021 Assessed Values)

SPA and flood type	Sum of Land Value	Sum of Improvement Value	Sum of Taxable Value	Sum of Building Damages	Sum of Contents Damages	Sum of Damage to Buildings and Contents
Chambers Bay / Clover Creek Basin	**$157,018**	**$175,003**	**$303,629**	**$69,050**	**$58,446**	**$127,496**
Coastal	$22,183	$10,309	$31,242	$2,949	$3,308	**$6,258**
Groundwater	$19,988	$20,837	$40,672	$9,375	$12,247	**$21,622**
Riverine	$114,847	$143,857	$231,716	$56,726	$42,890	**$99,616**
Clear / Clarks Creek Basin	**$131,350**	**$162,358**	**$272,564**	**$106,822**	**$79,938**	**$186,760**
Riverine	$131,350	$162,358	$272,564	$106,822	$79,938	**$186,760**
Gig Harbor / Key Peninsula Basin	**$206,504**	**$127,373**	**$322,060**	**$45,607**	**$31,663**	**$77,270**
Coastal	$160,400	$78,595	$234,677	$24,444	$16,674	**$41,117**
Riverine	$46,104	$48,778	$87,383	$21,164	$14,990	**$36,153**
Hylebos-Browns Point-Dash Point Basin	**$179,159**	**$115,895**	**$187,743**	**$28,940**	**$32,178**	**$61,118**
Coastal	$17,707	$7,624	$23,611	$3,478	$4,192	**$7,670**
Riverine	$161,452	$108,272	$164,131	$25,462	$27,985	**$53,447**
Mid Puyallup Basin	**$409,915**	**$604,728**	**$981,796**	**$188,033**	**$129,202**	**$317,234**
Riverine	$409,915	$604,728	$981,796	$188,033	$129,202	**$317,234**
Muck Creek Basin	**$14,157**	**$21,355**	**$34,046**	**$12,034**	**$7,197**	**$19,232**
Groundwater	$212	$278	$490	$353	$198	**$551**
Riverine	$13,945	$21,077	$33,556	$11,681	$7,000	**$18,681**
Nisqually Basin	**$21,641**	**$22,074**	**$39,044**	**$19,675**	**$14,147**	**$33,822**
Riverine	$21,641	$22,074	$39,044	$19,675	$14,147	**$33,822**
Upper Puyallup Basin	**$58,814**	**$80,141**	**$127,225**	**$50,231**	**$30,129**	**$80,360**
Riverine	$58,814	$80,141	$127,225	$50,231	$30,129	**$80,360**
White River Basin	**$222,141**	**$361,836**	**$561,484**	**$19,786**	**$24,179**	**$43,966**
Riverine	$222,141	$361,836	$561,484	$19,786	$24,179	**$43,966**
Total	**$1,400,698**	**$1,670,762**	**$2,829,590**	**$540,179**	**$407,079**	**$947,257**

Source: Created by ECONorthwest

Table 5-4 summarizes the land values, improvement values, taxable values, and damage estimates for parcels with buildings within the 100-year floodplain extent by land type. There are 8,591 residential buildings located in the floodplain extent on 4,300 properties – residential properties are the highest categories of both taxable value and total damage estimate value.

Table 5-4. 100-Year Floodplain Extents, by SPA and Flood Type (in Thousands of Dollars)

Land Type	Sum of Land Value	Sum of Improvement Value	Sum of Taxable Value	Sum of Building Damages	Sum of Contents Damages	Sum of Damage to Buildings and Contents
Commercial/ Industrial	$422,321	$544,982	$915,617	$65,202	$131,918	**$197,121**

Land Type	Sum of Land Value	Sum of Improvement Value	Sum of Taxable Value	Sum of Building Damages	Sum of Contents Damages	Sum of Damage to Buildings and Contents
Other	$3,594	$4,194	$3,317	$757	$424	**$1,180**
Public Lands and Facilities	$39,027	$39,849	$13,370	$4,945	$3,906	**$8,851**
Recreation/ Open Space	$30,372	$13,789	$14,592	$13,624	$10,762	**$24,386**
Residential	$812,266	$1,058,226	$1,828,361	$433,498	$242,571	**$676,069**
Resource Lands	$23,594	$8,229	$19,554	$17,863	$14,110	**$31,973**
Vacant	$69,524	$1,492	$34,779	$4,289	$3,388	**$7,677**
Total	**$1,400,698**	**$1,670,762**	**$2,829,590**	**$540,179**	**$407,079**	**$947,257**

Source: Created by ECONorthwest

5.3.2 Sea Level Rise

Table 5-5 provides a summary of the land values, improvement values, taxable values, and damage estimates for parcels with buildings within the sea level rise floodplain extent by SPA and flooding type. There are a total of 5,282 buildings that intersect the floodplain extent on 1,908 parcels of land. Only five of the nine SPAs have properties that are within the sea level rise floodplain extent. Hylebos-Browns Point-Dash Point Basin SPA has the highest total damage value.

Table 5-5. Sea Level Rise Floodplain Extents, by Land Use Type (in Thousands of Dollars)

SPA	Sum of Land Value	Sum of Improvement Value	Sum of Taxable Value	Sum of Building Damages	Sum of Contents Damages	Sum of Damage to Buildings and Contents
Chambers Bay / Clover Creek Basin	$429,972	$497,671	$731,225	$105,414	$177,953	**$283,367**
Clear / Clarks Creek Basin	$6,383	$5,013	$7,874	$8,121	$6,515	**$14,636**
Gig Harbor / Key Peninsula Basin	$439,717	$256,578	$671,118	$72,166	$52,643	**$124,808**
Hylebos-Browns Point-Dash Point Basin	$1,599,198	$859,165	$1,181,104	$242,788	$426,088	**$668,875**
Mid Puyallup Basin	$103,016	$81,233	$153,091	$14,350	$28,676	**$43,026**
Total	**$2,578,287**	**$1,699,660**	**$2,744,412**	**$442,839**	**$691,874**	**$1,134,712**

Source: Created by ECONorthwest
Note: Sum of taxable values may be less than the sum of land value and improvement values in instances where there are large portions of land that have tax exemptions (e.g., tribal land in Hylebos-Browns Point-Dash Point Basin SPA).

Table 5-6 summarizes the land values, improvement values, taxable values, and damage estimates for parcels with buildings within the sea level rise floodplain extent by land type. There are 275 residential buildings located in the floodplain extent on 69 properties. There are 2,362 commercial/industrial buildings located in the floodplain extent on 600 properties – commercial/industrial properties are the highest categories of both taxable value and total damage estimate value.

Table 5-6. Sea Level Rise Floodplain Extents, by Land Use Type (in Thousands of Dollars)

Land Type	Sum of Land Value	Sum of Improvement Value	Sum of Taxable Value	Sum of Building Damages	Sum of Contents Damages	Sum of Damage to Buildings and Contents
Commercial/Industrial	$1,349,920	$1,074,393	$1,875,952	$297,313	$601,528	**$898,841**
Other	$13,983	$12,520	$20,519	$807	$452	**$1,259**
Public Lands and Facilities	$533,977	$228,469	$20,997	$17,964	$14,190	**$32,153**
Recreation/Open Space	$43,062	$7,951	$11,191	$12,464	$9,845	**$22,309**
Residential	$522,155	$370,563	$788,274	$105,360	$58,956	**$164,315**
Resource Lands	$8,804	$5,050	$13,110	$1,817	$1,435	**$3,251**
Tribal	$2,880	$0	$0	$656	$367	**$1,023**
Vacant	$103,506	$714	$14,369	$6,459	$5,102	**$11,561**
Total	**$2,578,287**	**$1,699,660**	**$2,744,412**	**$442,839**	**$691,874**	**$1,134,712**

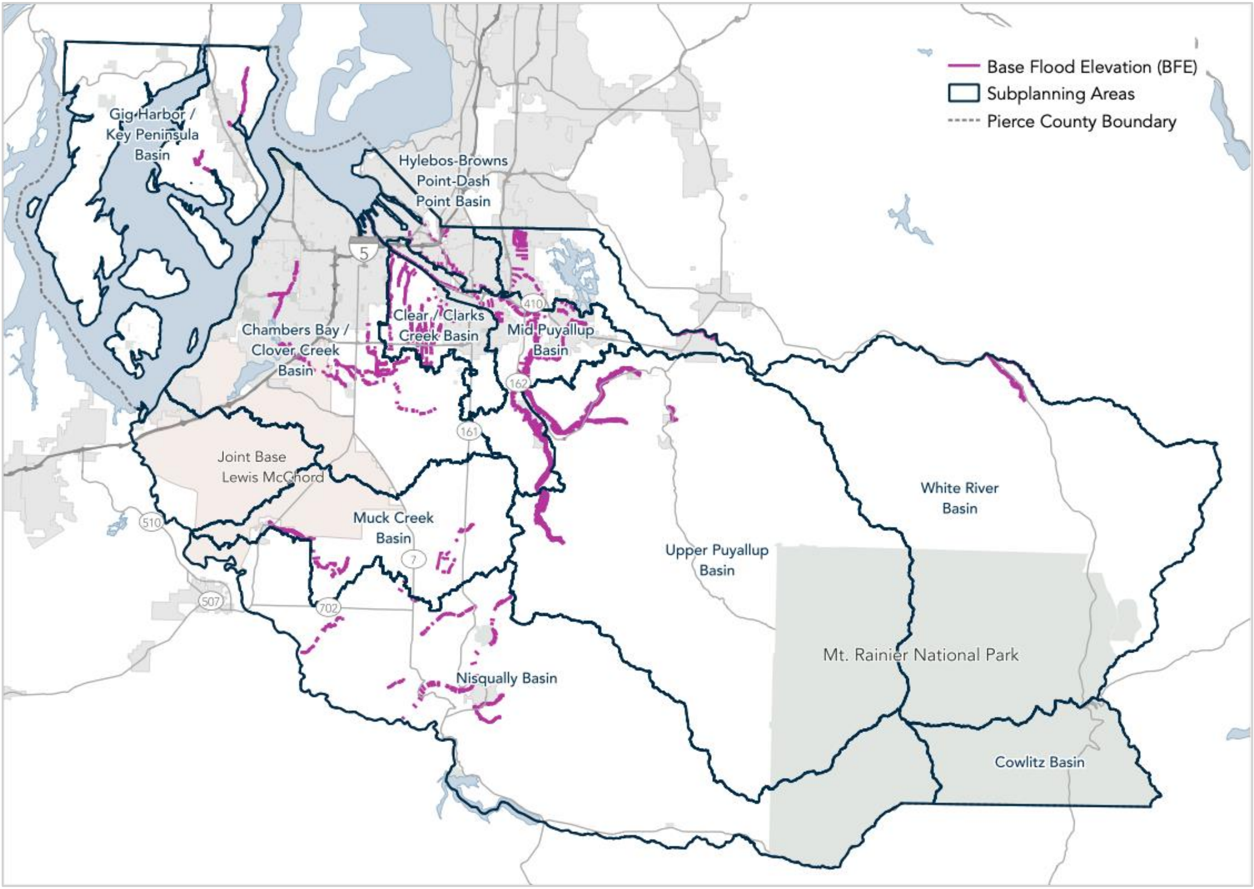
Source: Created by ECONorthwest

5.4 Potential Flood Impacts to Roads and Bridges

5.4.1 Methodology

This analysis assumes that damage to a bridge or road can occur if the floodwaters reach high enough elevations. The damage is likely to be due to the force of the lateral pressure from the water or from debris. To identify the height of the floodwaters requires knowing the elevation of the flood relative to the transportation infrastructure. Flood elevation data, also known as Base Flood Elevations (BFE), is not available for every SPA or river. Figure 5-3 displays the areas where there is base flood elevation data for the 100-year floodplain in Pierce County. Roads and bridges outside of the areas with BFE may also be affected by flooding – but there is not sufficient information to perform the same calculations (i.e., areas outside the BFE extent are excluded from the analysis).

Figure 5-3. Base Flood Elevation Extent



Source: Created by ECONorthwest with data from ESA

The inventory of bridges was obtained from Pierce County,[65] and from Washington State Department of Transportation (WSDOT).[66] The inventory of roads was obtained from Pierce County.[67] All estimates of impacted roadways and bridges are conducted only for the 100-year flood extent. Impacts from sea level rise are discussed in Chapter 9. The full methodology for the analysis of impacts to roads and bridges is available in Appendix A.

5.4.2 Flood Risk to Roads

Elevations for roads were estimated by LiDAR elevation values, which were added to the roads at 100-foot intervals using the DNR LiDAR surface[68] and averaged over the length of the road

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[65] Pierce County Open GeoSpatial Data Portal, *Bridges* (2020). Available at: https://gisdata-piercecowa.opendata.arcgis.com/datasets/bridges

[66] WSDOT. (2020). *WSDOT GIS Data Download: Bridge Data - Bridge On Locations.* Available at: https://www.wsdot.wa.gov/mapsdata/geodatacatalog/default.htm

[67] Pierce County Open GeoSpatial Data Portal, *Roads* (2020), available at: https://gisdata-piercecowa.opendata.arcgis.com/datasets/roads?geometry=-122.225%2C47.025%2C-122.014%2C47.066

[68] Washington Department of Natural Resources. (2011). *Lidar portal, Pierce County*. Available at: https://lidarportal.dnr.wa.gov/

segment to create an average road crest elevation for each road segment. Average road crest elevations were subtracted from average BFEs to estimate the depth of overtopping (or no overtopping) for each 100-foot road segment. This analysis estimates both potential for damage and potential for failure for roads. Damage to roads are evaluated based on two methods; the potential for overtopping and the potential for road failure. Road failure is defined as the roadway being inaccessible for transportation and requiring repairs.

Roads are assumed to be damaged if overtopping occurs (i.e., the BFE is higher than the elevation of the roadway). Roadway damage is based upon percent of embankment and pavement that is loss as a function of the flood overtopping depth. The monetary value of damage to roadways was estimated using replacement costs from Washington State Department of Transportation (WSDOT) estimates.[69] Section 4.3.2 of Appendix A has more information on the methodology for estimating roadway overtopping and associated damages.

Roads are assumed to fail based on velocity and flood depth combinations. Table 5-7 summarizes the velocities and flood depths that indicate the potential for road failure.

Table 5-7. Road Failure Flood Depth-Velocity Relationships

Flood Velocities	Flood Depths
Greater than 15 feet per second	2 to 4 feet and over
10 to 15 feet per second	2.5 to 4 feet and over
5 to 10 feet per second	Over 3 feet
2 to 5 feet per second	Over 4 feet

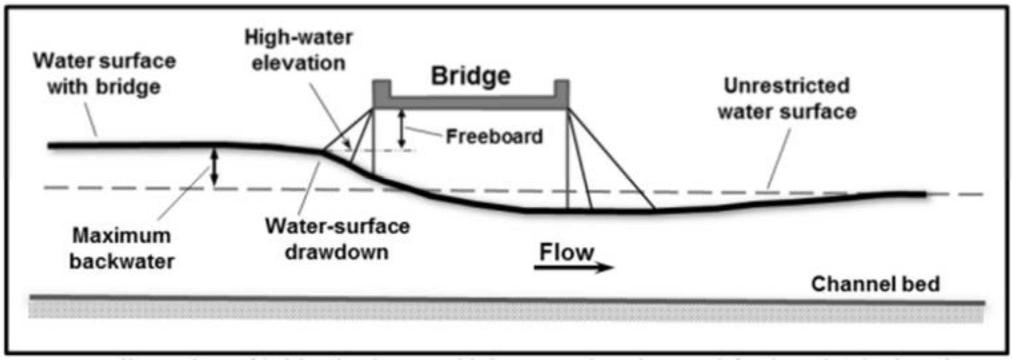
Source: U.S. Department of Agriculture. (1969). *TSC Technical Note – Watersheds UD-22, Economics – Floodwater Damages to Roads and Bridges.* June 30. Available at: https://www.nrcs.usda.gov/wps/PA_NRCSConsumption/download?cid=nrcseprd410822&ext=pdf

5.4.3 Flood Risk to Bridges

Flood risk to bridges in Pierce County was assessed in two ways. Bridges are assumed to be damaged if freeboard heights are violated, which assumes that flood flows and/or floating debris damages the bridge structure. Bridge freeboard is the vertical opening clearance height between the lowest elevation of a bridge superstructure (low chord) and the design water surface elevation (Figure 5-4). An appropriate amount of freeboard allows for the passage of flood flows and floating flood debris through the structure.

[69] Washington State Department of Transportation. (2012). Manual for Planning Level Cost Estimation (PLCE) Tool, Appendix B: Default Unit Prices, Exhibit B-1: Default Unit Costs for Central Puget Sound Region, December. https://www.wsdot.wa.gov/mapsdata/travel/pdf/PLCEManual_12-12-2012.pdf [last accessed October 17, 2021]

Figure 5-4. Bridge Freeboard Schematic



Source: South Carolina Department of Transportation. (2019). Hydraulic Design Bulletin No. 2019-4, Updated Hydraulic Bridge Design Criteria. Available at: https://www.scdot.org/business/technicalPDFS/hydraulic/HDB_2019-4.pdf

In addition to estimating flood risk to bridges from freeboard violations, the potential for bridge failure was also estimated. Bridge failure is defined as the bridge being inaccessible for transportation and requiring repairs. Table 5-8 summarizes the velocities and flood depths that indicate the potential for bridge failure.

Table 5-8. Bridge Failure Flood Depth-Velocity Relationships

Flood Velocities	Flood Depths
Greater than 15 feet per second	2 feet below bottom of bridge (low chord)
10 to 15 feet per second	1 foot below bottom of bridge (low chord)
5 to 10 feet per second	At bridge floor level
2 to 5 feet per second	2 feet over bridge floor

Source: U.S. Department of Agriculture. (1969). *TSC Technical Note – Watersheds UD-22, Economics – Floodwater Damages to Roads and Bridges.* June 30. Available at: https://www.nrcs.usda.gov/wps/PA_NRCSConsumption/download?cid=nrcseprd410822&ext=pdf

5.5 Damage Estimates for Roads and Bridges

5.5.1 Roads

As shown in Table 5-9, for road segments where BFEs "overtop" the estimated elevation of the road surfaces, an estimated $250 million in road embankment damages and $461 million in associated pavement damages are estimated to occur during 100-year flood conditions, with total roadway damages estimated to be $711 million in 2021 dollars.

Table 5-9. Summary of Embankment and Pavement Damages by Sub Planning Area (2021 Dollars)

Area	Embankment Damage	Pavement Damage	Combined Roadway Damage
Chambers Bay/ Clover Creek Basin	$23,990,000	$55,121,000	$79,070,000
Clear/Clarks Creek Basin	$34,068,000	$65,285,000	$99,324,000
Gig Harbor/Key Peninsula Basin	$315,000	$295,000	$610,000
Hylebos-Browns Point-Dash Basin	$4,465,000	$8,562,000	$13,022,000
Mid Puyallup Basin	$145,630,000	$239,947,000	$385,434,000
Muck Creek Basin	$1,950,000	$2,881,000	$4,829,000
Nisqually Basin	$562,000	$252,000	$808,000
Upper Puyallup Basin	$21,253,000	$54,916,000	$76,154,000

Area	Embankment Damage	Pavement Damage	Combined Roadway Damage
White River Basin	$17,613,000	$34,756,000	$52,361,000
Pierce County Total	**$249,943,000**	**$461,913,000**	**$711,607,000**

Source: Created by ESA

For road segments where the overtopping depth and velocity combinations exceed the roadway elevation, those road segments were assumed to fail. Table 5-10 provides a summary of estimated road failures by sub planning area. More detailed information about the height of roadway flood overtopping depths by SPA is available as Table 4-4 of Appendix A.

Table 5-10. Summary of Estimated Road Failures by Sub Planning Area

Area	Road Length (ft)	Number of Road Failures	Length of Road Failures (ft)	Percentage of Road Failures
Chambers Bay/ Clover Creek Basin	31,072	102	1,680	**5%**
Clear/Clarks Creek Basin	46,092	144	3,328	**7%**
Gig Harbor/Key Peninsula Basin	1,847	0	0	**0%**
Hylebos-Browns Point-Dash Basin	10,769	134	664	**6%**
Mid Puyallup Basin	106,017	505	12,890	**12%**
Muck Creek Basin	5,127	11	176	**3%**
Nisqually Basin	9,329	0	0	**0%**
Upper Puyallup Basin	35,697	47	1,196	**3%**
White River Basin	14,807	81	1,680	**11%**
Pierce County Total	**260,758**	**1,024**	**21,614**	**8%**

Source: Created by ESA

5.5.2 Bridges

There are 466 bridges in Pierce County and 255 of these bridges are over waterways. Pierce County is responsible for maintaining 94 bridges or 37 percent of the bridges over waterways in the County. A total of 44 bridges were identified from the hydraulic models and used in this analysis. All bridges are located over 100-year flood hazard areas that have BFEs established and therefore all resulting bridge clearances were compared to a required 6-foot freeboard to assess flood risk. Only 14 bridges have freeboard violations: five of these bridges are owned by WSDOT; two bridges are owned by railroads; two bridges are owned by the City of Sumner; and, five bridges are owned by Pierce County.

Based on the flood depth and velocity combinations, only two bridges are estimated to fail in Pierce County. These bridges also have the greatest freeboard violations of the 44 bridges described above. The bridges include the NE 8th/Stewart Road Bridge over the White River owned by the City of Sumner and the Foothills Trail Bridge over the Carbon River owned by

Pierce County. A project is planned to replace the existing NE 8th/Stewart Road Bridge. The project has an estimated completion date of 2025.[70]

Table 5-11 provides a summary of the values of bridge and roadway infrastructure at risk of flooding as a function of the chance of flood overtopping for the bridge deck approach. Pierce County bridges over waterways that have chance of overtopping are estimated to have a total potential damage value of $127.9 million. The greatest flood risk is associated with urban minor arterial bridges, with an estimated 77 percent of the total value of infrastructure exposed to flood risk for bridges.

Table 5-11. Summary of Bridge Costs by Flood Overtopping Frequency, Bridge Deck Approach

	Rural	Urban	Total
Chance of Overtopping Bridge Deck	$0	$0	$0
Frequent	$0	$0	$0
Occasional	$0	$0	$0
Slight	$8,558,000	$31,831,000	$40,389,000
Very Slight	$2,934,000	$84,601,000	$87,535,000
Remote	$0	$0	$0
Total	**$11,492,000**	**$116,432,000**	**$127,924,000**

Source: Created by ESA

5.6 Summary of Flood Impacts to Properties

This chapter summarized property and infrastructure that is located within the floodplain extents. There are hundreds of millions of dollars of buildings, contents, and transportation infrastructure located within the floodplain extents in Pierce County. The estimates provided in this chapter do not include other infrastructure located within the floodplain, such as trails, telecommunication equipment, electrical equipment, landscaping, or other property and resources that could be damaged in a flood event.

[70] City of Sumner Website, *Stewart Road/8th Street White River Bridge,* available at: https://connects.sumnerwa.gov/stewart-road-bridge

6 Transportation Impacts

6.1 Introduction

Transportation is important to the Pierce County economy because it allows for the movement of people and goods to locations within and outside of the County. A central hub for transportation-related economic activity is the Port of Tacoma and the roads and railroads that service the Port. Flooding in Pierce County could affect the transportation network through road and rail closures which would result in delays and additional costs of travel. This task focuses on the economic impacts to businesses, commuters, and intrastate and interstate commerce as a result of disruption to the major transportation corridors in the 100-year floodplain and other flood-prone areas in Pierce County.

6.2 Overview of Pierce County Transportation Network

Pierce County's transportation network includes roads, bridges, ferry terminals, railroads (including light rail), and airports. This section focuses on roadways, bridges, and railroads.

6.2.1 Roadway Transportation Volumes

For roadways, use data is defined in terms of Annual Average Daily Traffic (AADT) or Average Daily Traffic (ADT). AADT is an average for one year, while ADT is an average for another time period, such as one week or one month. There are two data sources that have AADT and ADT for Pierce County.

AADT counts for the state highway system are available for Washington State Department of Transportation (WSDOT).[71] Figure 6-1 displays the AADT by state highway in Pierce County. The highest AADTs are for Interstate 5, State Route 16, State Route 7, and State Route 410.

ADT counts for unincorporated county roads are available from Pierce County.[72] Figure 6-2 displays the ADT counts for each road segment by volume throughout Pierce County. In addition to Interstate 5 and the state highways, the highest ADTs are for Canyon Road East, South Tacoma Way, Steilacoom Blvd SW, Orting Kapowsin Hwy E, Steele St South, Bridgeport Way SW, Gravelly Lake Dr SW, and Spanaway Loop Road South.

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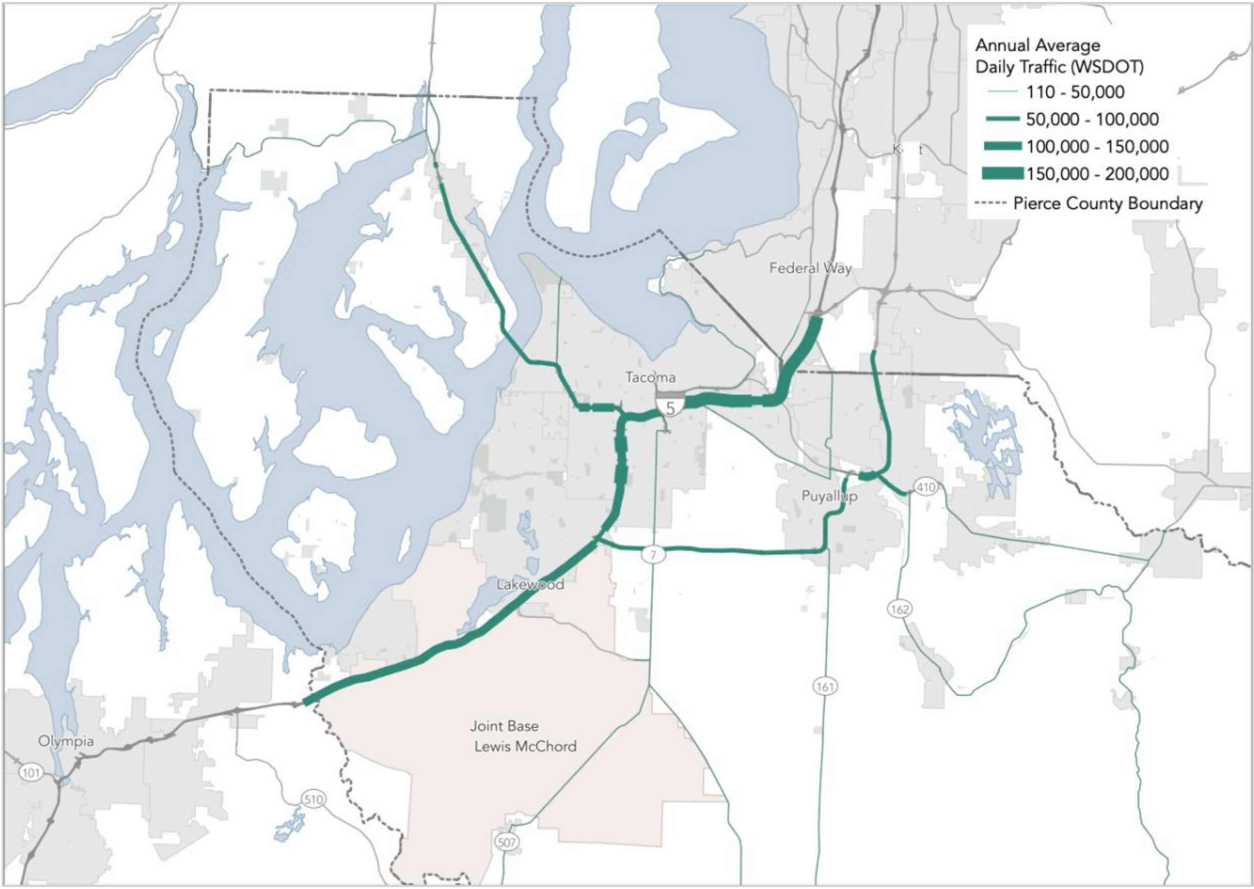
[71] Washington State Department of Transportation GIS Data, *WSDOT - Traffic Sections (AADT),* available at: https://gisdata-wsdot.opendata.arcgis.com/datasets/WSDOT::wsdot-traffic-sections-aadt-1/about

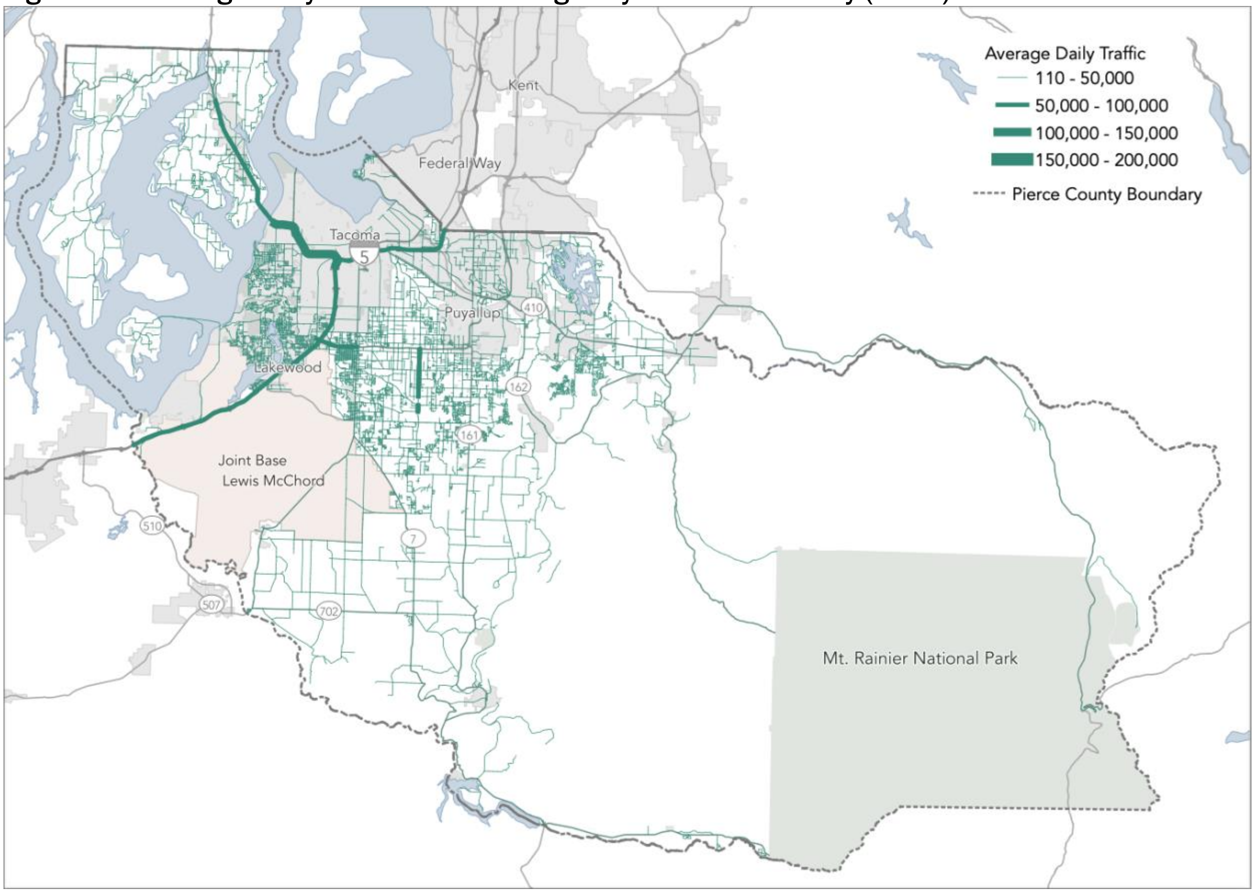
[72] Pierce County, Pierce County WA Open GeoSpatial Data Portal (v2.1), *Mobility Data*, available at: https://gisdata-piercecowa.opendata.arcgis.com/datasets/piercecowa::mobility-data/explore

Figure 6-1. Annual Average Daily Traffic for State Highways in Pierce County (2020)



Source: Washington State Department of Transportation GIS Data, WSDOT - Traffic Sections (AADT), available at: https://gisdata-wsdot.opendata.arcgis.com/datasets/WSDOT::wsdot-traffic-sections-aadt-1/about

Figure 6-2. Average Daily Traffic for State Highways in Pierce County (2021)



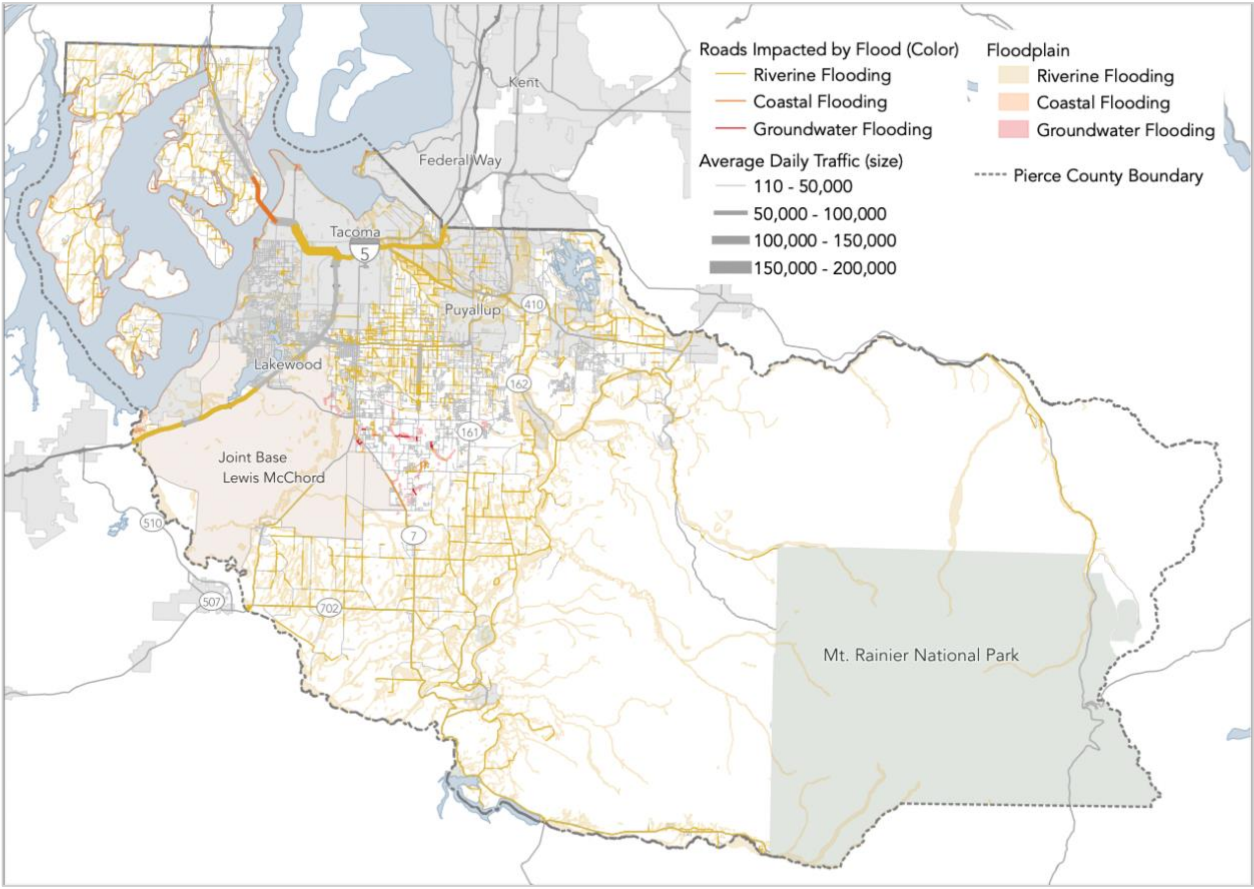
Source: Pierce County, Pierce County WA Open GeoSpatial Data Portal (v2.1), *Mobility Data*, available at: https://gisdata-piercecowa.opendata.arcgis.com/datasets/piercecowa::mobility-data/explore

6.3 Roads in the Floodplain

6.3.1 100-Year Floodplain

Figure 6-3 depicts the roads that intersect with the 100-year floodplain extent with the ADT volume thickness. This depiction and the subsequent analysis relies on the unincorporated road dataset from Pierce County (it does not include the WSDOT AADT estimates). There are many road segments that intersect with the floodplain extent. However, this does not necessarily mean that the road would be impacted by flooding as some roadways may be elevated beyond the floodplain extent, and thus not impacted. Chapter 6 provides further detail about roadways and bridges that could be impacted by flooding based on elevation of the infrastructure and the floodplain.

Figure 6-3. Roads that Intersect with the 100-Year Floodplain Extents by Volume



Source: Created by ECONorthwest using data from Pierce County, Pierce County WA Open GeoSpatial Data Portal (v2.1), *Mobility Data*, available at: https://gisdata-piercecowa.opendata.arcgis.com/datasets/piercecowa::mobility-data/explore

There are a total of 718 miles of road segments that intersect with the 100-year floodplain. Road segments are of varying length and the floodplain likely does not intersect with the full roadway extent. However, if flooding does impact access through the roadway the entire roadway segment extent could have access impacted. Table 6-1 summarizes the miles of roads in the 100-year floodplain extent by SPA and flooding type. Nisqually Basin SPA and Gig Harbor / Key Peninsula Basin SPA have the most miles road segments that intersect with the 100-year floodplain extent. Table 6-2 summarizes the ADT associated with the road segments that intersect with the floodplain. Chambers Bay/Clover Creek Basin SPA and Mid Puyallup Basin SPA have the highest ADT volumes for road segments in the floodplain, despite having fewer total road segments than other SPAs, indicating that the road segments that are impacted have higher total ADT volumes. Note that ADT volume totals do not represent the total amount of traffic because ADTs are double counted across road segments as people travel throughout the County.

Table 6-1. Road Lengths in the 100-Year Floodplain Extent by SPA and flood type

SPA	Riverine Flooding Miles	Coastal Flooding Miles	Groundwater Flooding Miles	Total Miles
Chambers Bay / Clover Creek Basin	88	2	8	98
Clear / Clarks Creek Basin	51	0	0	51
Gig Harbor / Key Peninsula Basin	115	12	0	127
Hylebos-Browns Point-Dash Point Basin	38	0	0	38
Mid Puyallup Basin	76	0	0	76
Muck Creek Basin	72	0	0	72
Nisqually Basin	146	0	0	146
Upper Puyallup Basin	65	0	0	65
White River Basin	45	0	0	45
Total in SPAs	**696**	**14**	**8**	**718**

Source: Created by ECONorthwest using data from Pierce County, Pierce County WA Open GeoSpatial Data Portal (v2.1), *Mobility Data*, available at: https://gisdata-piercecowa.opendata.arcgis.com/datasets/piercecowa::mobility-data/explore

Table 6-2. ADT Volumes in the 100-Year Floodplain Extent

SPA	Riverine Flooding Total ADT	Coastal Flooding Total ADT	Groundwater Flooding Total ADT	Total ADT
Chambers Bay / Clover Creek Basin	2,090,620	110,913	66,037	2,267,570
Clear / Clarks Creek Basin	988,955	0	0	988,955
Gig Harbor / Key Peninsula Basin	666,460	167,608	0	834,068
Hylebos-Browns Point-Dash Point Basin	686,954	2,655	0	689,609
Mid Puyallup Basin	1,189,868	0	0	1,189,868
Muck Creek Basin	429,991	0	3,475	433,466
Nisqually Basin	347,476	0	0	347,476
Upper Puyallup Basin	249,927	0	0	249,927
White River Basin	451,437	0	0	451,437
Total in SPAs	**7,101,688**	**281,176**	**69,512**	**7,452,376**

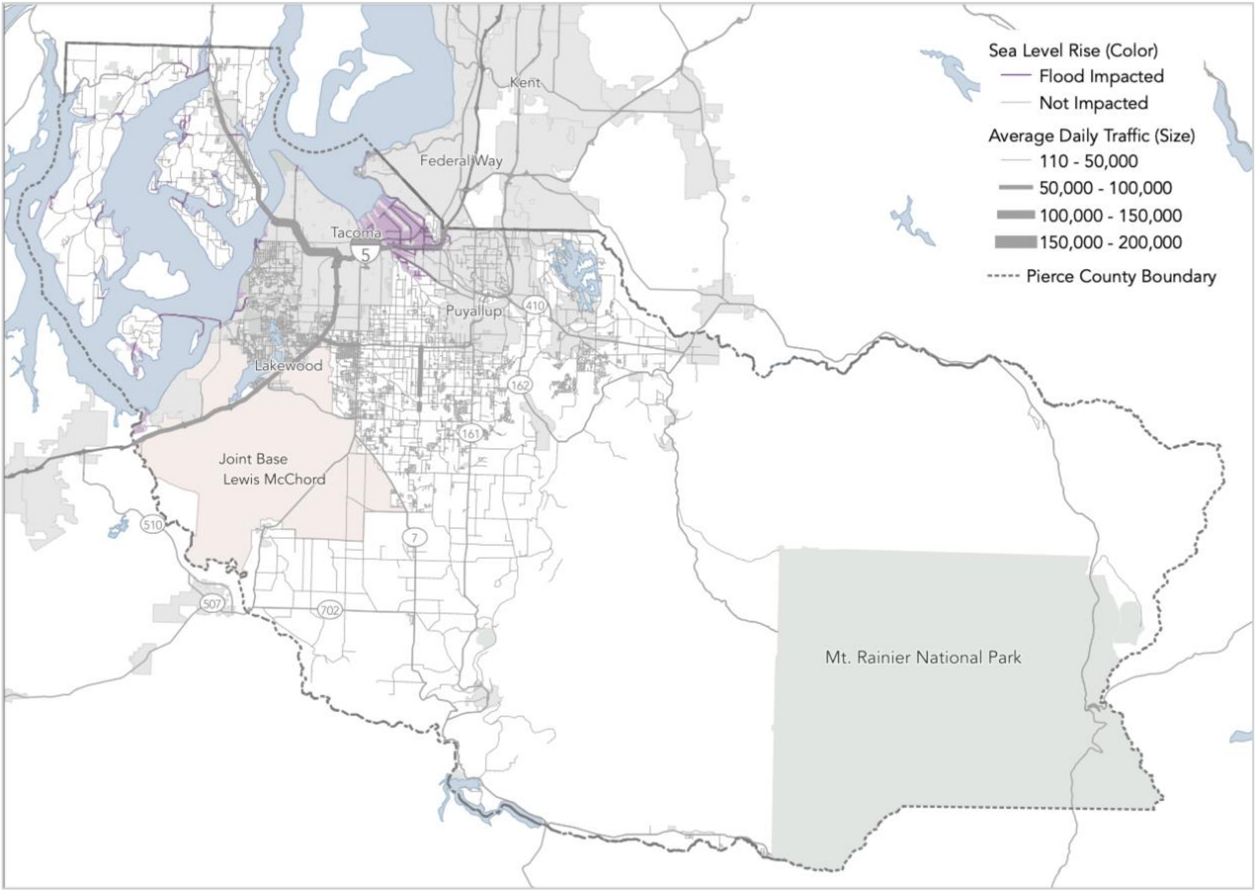
Source: Created by ECONorthwest using data from Pierce County, Pierce County WA Open GeoSpatial Data Portal (v2.1), *Mobility Data*, available at: https://gisdata-piercecowa.opendata.arcgis.com/datasets/piercecowa::mobility-data/explore

6.3.2 Sea Level Rise Floodplain

Figure 6-4 depicts the roads that intersect with the sea level rise floodplain extent with the ADT volume thickness. Roads that intersect with the sea level rise flood extent are lower volume than those that intersect the 100-year floodplain. Table 6-3 summarizes the roadway segment lengths and ADT volumes for road segments that intersect the sea level rise floodplain extent. A total of 134.3 miles of road segments intersect with the floodplain extent. Hylebos-Browns Point-Dash Point Basin SPA has the highest number of miles and ADT in the sea level rise floodplain.

Like the 100-year floodplain extent, roads that intersect with the sea level rise floodplain may not be impacted by flooding if the roadway elevation is higher than the floodwaters. Sea level rise flooding also is as of the year 2100 – by this time many of the roads that are in the floodplain may be updated or moved, reducing the flood risk.

Figure 6-4. Roads that Intersect with the Sea Level Rise Floodplain Extent by Volume



Source: Created by ECONorthwest using data from Pierce County, Pierce County WA Open GeoSpatial Data Portal (v2.1), *Mobility Data*, available at: https://gisdata-piercecowa.opendata.arcgis.com/datasets/piercecowa::mobility-data/explore

Table 6-3. Road Lengths and ADT Volumes in the Sea Level Rise Floodplain Extent by SPA and flood type

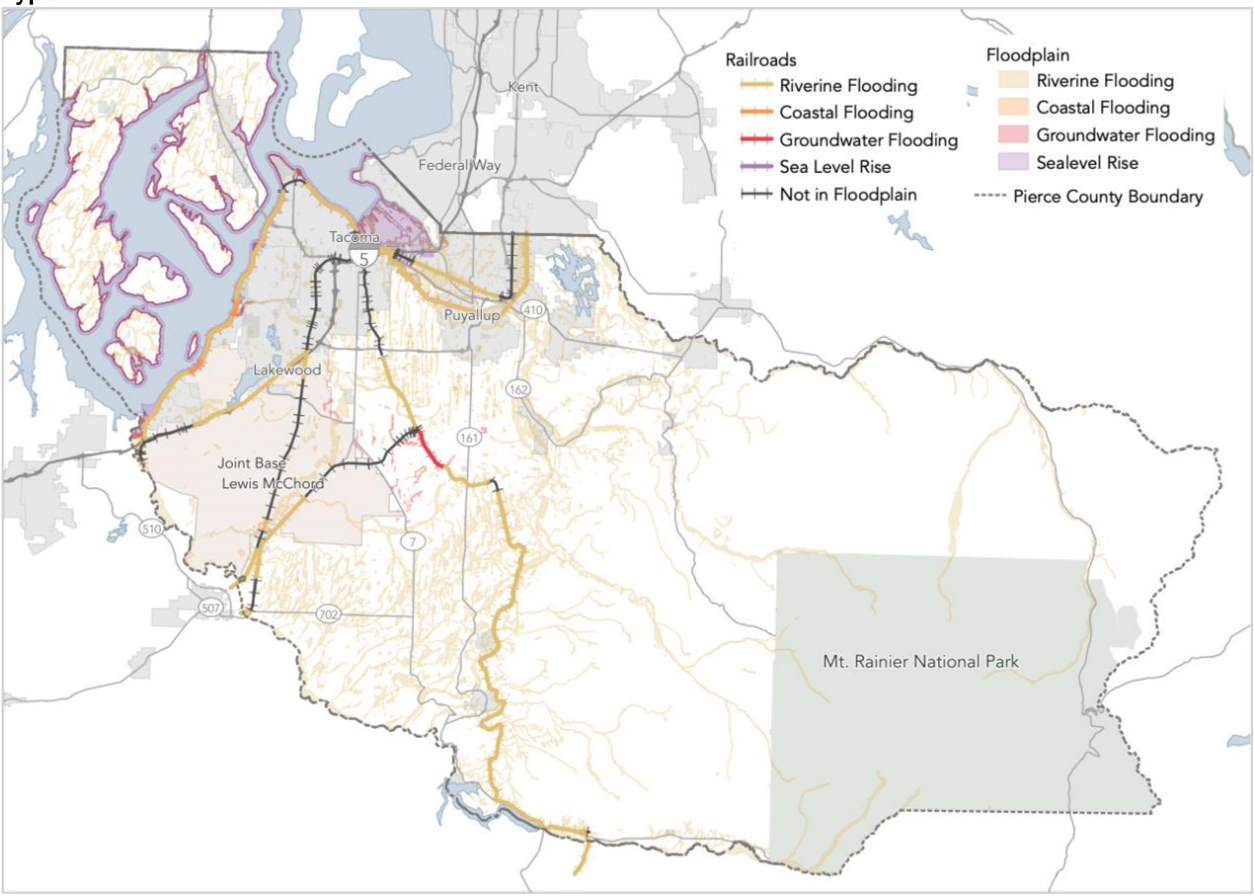
SPA	Sea Level Rise Total ADT	Sea Level Rise Miles
Chambers Bay / Clover Creek Basin	504,685	26.0
Clear / Clarks Creek Basin	5,429	2.1
Gig Harbor / Key Peninsula Basin	492,335	44.0
Hylebos-Browns Point-Dash Point Basin	805,657	45.0
Mid Puyallup Basin	313,992	17.0
Nisqually Basin	50	0.2
Total	**2,122,148**	**134.3**

Source: Created by ECONorthwest using data from Pierce County, Pierce County WA Open GeoSpatial Data Portal (v2.1), *Mobility Data*, available at: https://gisdata-piercecowa.opendata.arcgis.com/datasets/piercecowa::mobility-data/explore

6.4 Rail in the Floodplain

Figure 6-5 depicts railroads that intersect with both the 100-year and sea level rise floodplain extents. Multiple railroad segments intersect with riverine flooding. Chapter 9 contains more information about impacts to railroads from sea level rise flooding. There are 70 total segments comprising 224.8 miles that intersect with the railroad in the 100-year floodplain extent (Table 6-4).

Figure 6-5. Railroads that Intersect with 100-Year and Sea Level Rise Floodplain Extents by Flood Type



Source: Created by ECONorthwest with data from Pierce County, Pierce County WA Open GeoSpatial Data Portal (v2.1), *Railroads*, available at: https://gisdata-piercecowa.opendata.arcgis.com/datasets/railroads/explore.

Table 6-4. Railroads that Intersect with the 100-Year Floodplain and Sea Level Rise Flooding

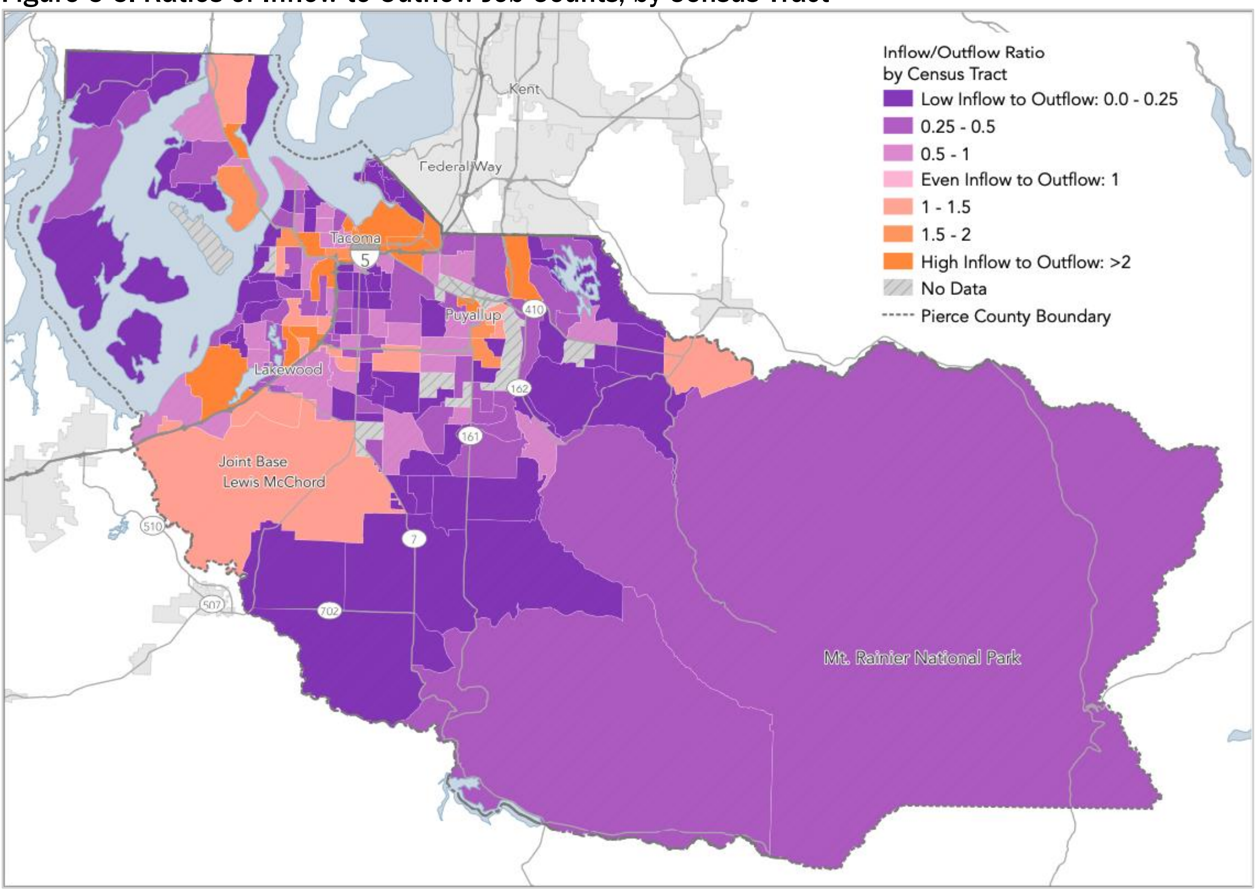
	Number of Rail Segments	Number of Miles of Rail Segment
Coastal Floodplain	7	15.9
Groundwater Floodplain	1	2.6
Riverine Floodplain	62	206.3
Total in 100-Year Floodplain	**70**	**224.8**
Sea Level Rise Floodplain	**70**	**125.9**

Source: Created by ECONorthwest with data from Pierce County, Pierce County WA Open GeoSpatial Data Portal (v2.1), *Railroads*, available at: https://gisdata-piercecowa.opendata.arcgis.com/datasets/railroads/explore.

6.5 Commuting

A portion of the ADT transportation volumes are people who use roads to commute. Another measure of commuting is data available from the U.S. Census.[73] Figure 6-6 displays the ratios of people who are employed in the census tract but live outside the tract (i.e., commute in for work) compared to those who live in the census tract but are employed outside the tract. (i.e., commute out for work). Areas with higher ratios have a higher portion of people who commute in compared to commute out. Generally, more urban areas have higher portions of people who commute in for work, while more suburban and rural areas have lower portions of people who commute in for work.

Figure 6-6. Ratios of Inflow to Outflow Job Counts, by Census Tract



Source: Created by ECONorthwest using U.S. Census Bureau, OnTheMap data, available at: https://onthemap.ces.census.gov/

[73] U.S. Census Bureau, OnTheMap data, available at: https://onthemap.ces.census.gov/

6.6 Transportation Impacts of Historical Flooding

Flooding has closed sections of the Interstate 5 corridor between Seattle and Portland for four days in 1996 and 2007, and for two days in 2009.[74] The closures occurred in a five-mile stretch encompassing the cities of Chehalis and Centralia. Washington State Department of Transportation estimates that the 2007 flood led to a $47 million loss in economic output (2008 dollars).[75]

Hallenbeck et al. (2014) estimated the general cost of flooding on Interstate 5 on regional transportation.[76] Their analysis suggests that a 100-year flood will lead to a 123-hour (five days and three hours) closure of Interstate 5 between mileposts 68 and 88 in Lewis County. Approximately 394,000 trips would be affected by a closure. The total cost of the 123-hour closure of Interstate 5 is $11.9 million. Of this, 70 percent ($8.5 million) is due to the cost of taking detours and 13 percent ($1.6) million is due to the cost of abandoned trips. The remaining 17 percent is attributed to changing the mode of travel, changing the destination, or postponing the trip. When broken down by mode of travel, the total closure cost is $4.5 million for cars and $7.4 million for trucks. The model is dependent on several key assumptions; that the flood will occur on a Monday in late autumn, and that the traffic patterns will be similar to those during the 2007 Interstate 5 closure.

Hallenbeck et al. (2014) also estimated the cost of flooding on US-12 and SR-6. They estimated that a 100-year flood would close US-12 for 152 hours (six days and eight hours). This would affect 41,200 trips and result in an additional travel cost of $340,000 over the period. A 100-year flood would close SR-6 for 51 hours (two days and three hours), affect 24,000 trips, and result in an additional travel cost of $114,000. Finally, a January 2008 flood closed I-90 for two days and led to a $28 million loss of economic output.[77]

6.7 Roadway Transportation Impacts Methodology

When roads are impacted by flooding, people and commerce is unable to pass through the roadway, requiring detours or in some instances making it so traffic is unable to access certain locations. Analyzing impacts to roadways and the transportation network requires identifying where flooding will result in road closures. The intersection of roads with the floodplain is not

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[74] Washington (State). Dept. of Transportation. (2014). Chehalis River Basin I-5 Flood Protection near Centralia and Chehalis.

[75] Ivanov, B., Xu, G., Buell, T., Moore, D., Austin, B., & Wang, Y. J. (2008). Storm related closures of I-5 and I-90: freight transportation economic impact assessment report, winter 2007-2008 (No. WA-RD 708.1). Washington State. Department. of Transportation.

[76] Hallenbeck, M. E., Goodchild, A., & Drescher, J. (2014). Travel costs associated with flood closures of state highways near Centralia/Chehalis, Washington (No. WA-RD 832.1). Washington (State). Dept. of Transportation. Research Office.

[77] Ivanov, B., Xu, G., Buell, T., Moore, D., Austin, B., & Wang, Y. J. (2008). Storm related closures of I-5 and I-90: freight transportation economic impact assessment report, winter 2007-2008 (No. WA-RD 708.1). Washington State. Department. of Transportation.

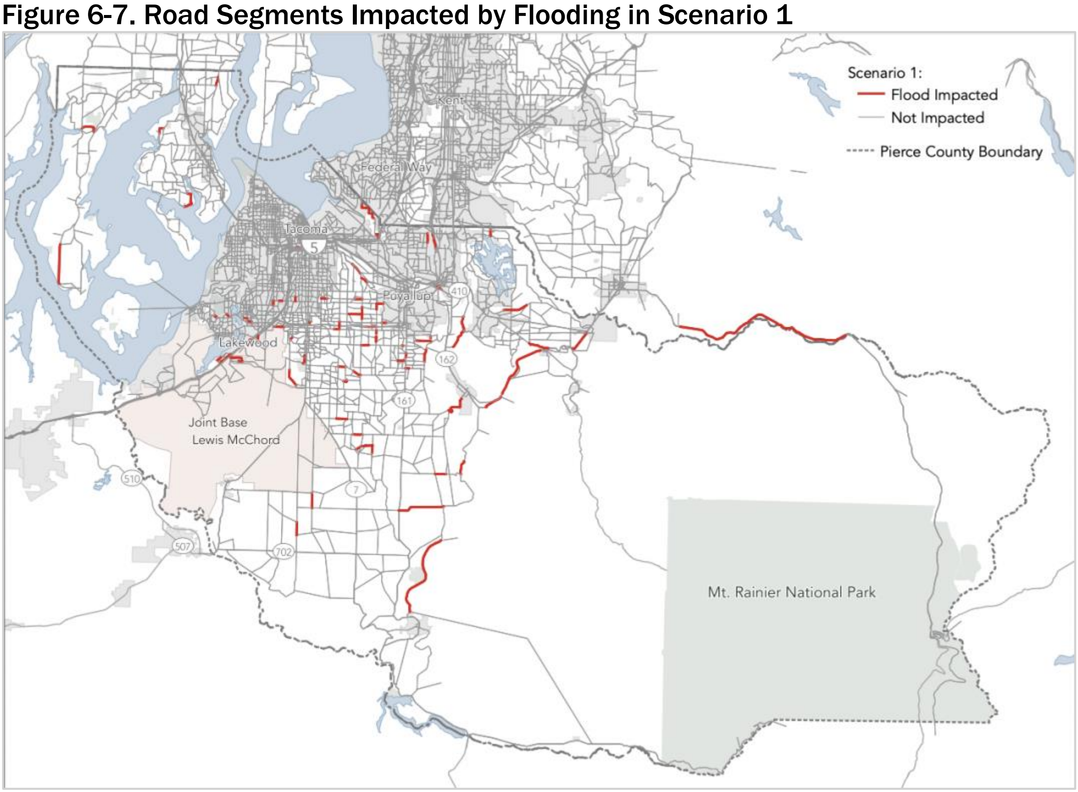
sufficient for this analysis because not all roads will be impacted at once and some roads may be higher than the floodplain elevation. Instead, this analysis relied upon historical and hypothetical road closure data provided by Pierce County to model road closure scenarios and calculate cost of road network disruption.

Four scenarios were used for the analysis, defined below:

- **Scenario 1:** This scenario used road closure data from flooding in February 1996, November 2006, and January 2009 from atmospheric river flood events. This scenario includes 169 road segments.
- **Scenario 2:** This scenario models a rain on snow type flood event using road closure data from flooding in 1997. This scenario includes 60 road segments.
- **Scenario 3:** This scenario models the catastrophic failure of North Levee Road along the Puyallup River. Flooding has not previously impacted North Levee Road, however, the 2009 flood threatened the roadway, as well as homes, businesses, and other infrastructure behind the levee. This scenario includes 647 road segments.
- **Scenario 4:** This scenario models road closures due to groundwater flooding. This scenario was not based on prior flood data, but rather identified through the intersection with groundwater flooding over roadways. Each roadway segment that intersected the groundwater flooding scenario was individually evaluated for inclusion in the scenario in coordination with Pierce County. This scenario includes 14 road segments.

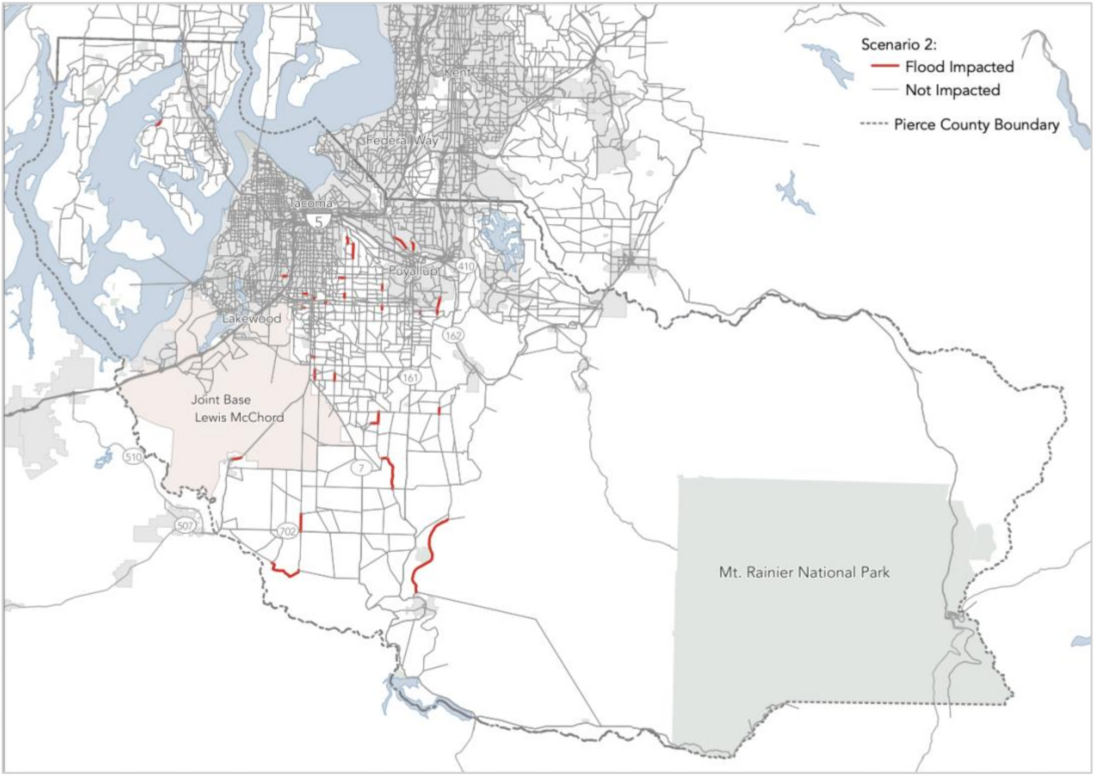
Figures 6-7 through 6-10 depict the spatial extents of the road segments that are assumed to be impacted by flooding under each Scenario.

Figure 6-7. Road Segments Impacted by Flooding in Scenario 1



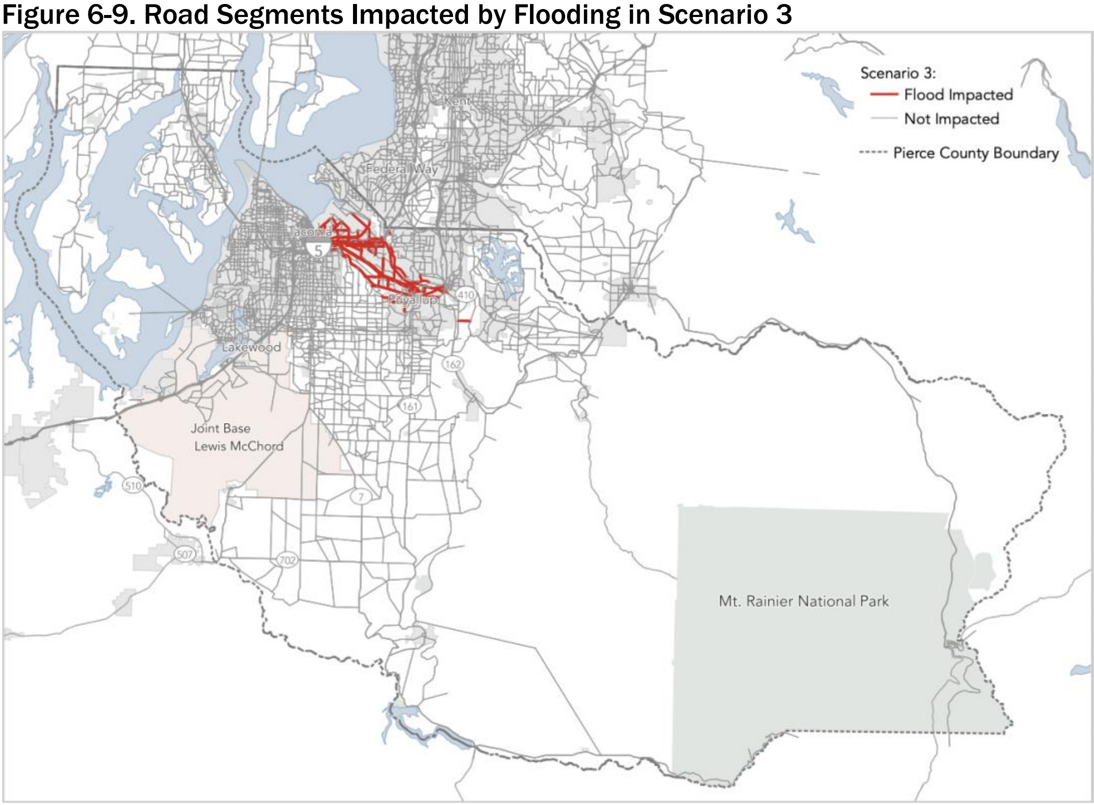
Source: Created by ECONorthwest

Figure 6-8. Road Segments Impacted by Flooding in Scenario 2



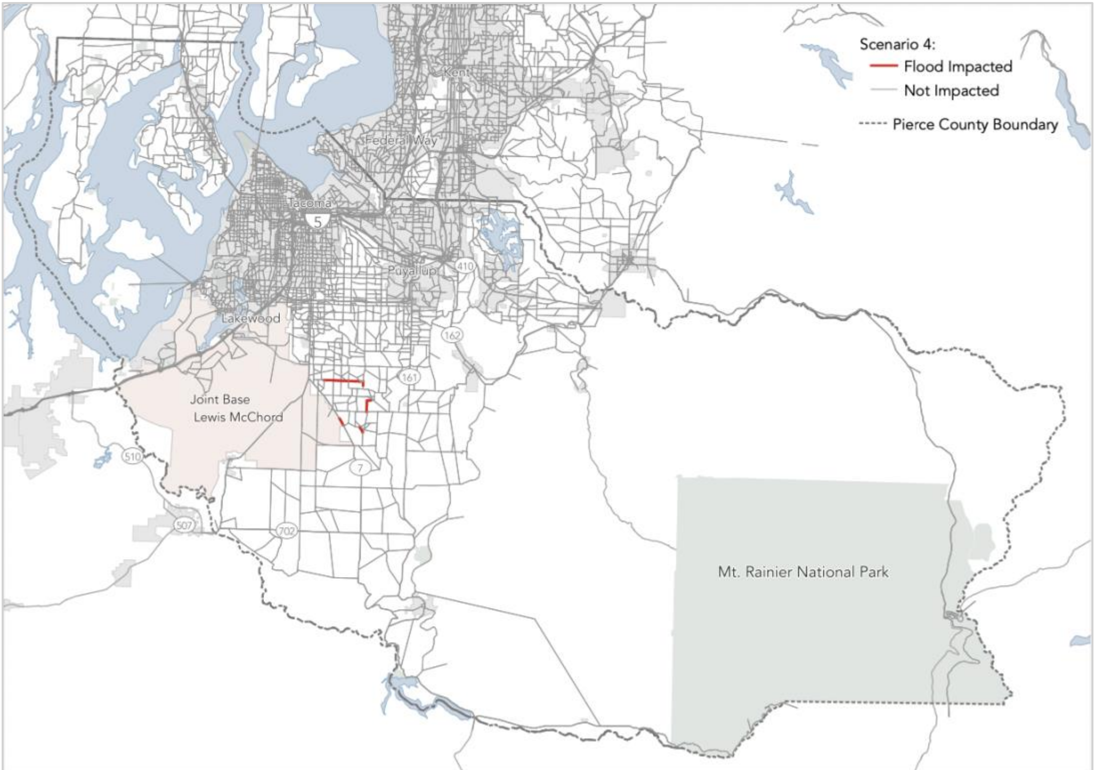
Source: Created by ECONorthwest

Figure 6-9. Road Segments Impacted by Flooding in Scenario 3



Source: Created by ECONorthwest

Figure 6-10. Road Segments Impacted by Flooding in Scenario 4



Source: Created by ECONorthwest

The estimation of traffic disruptions due to flooding events was undertaken with the aid of the Puget Sound Regional Council's (PSRC) travel demand model.[78] The analysis approach started with a definition of, and evaluation of flood events and the transportation infrastructure that would likely be disrupted during flooding. GIS was used to develop an inventory of road closures for a number of flood event scenarios. These roads were coded in the regional demand model road network to prevent vehicles from loading on those specific road network links. The traffic assignment phase of the demand model was run for each scenario that contained links that were closed to traffic due to flooding. The results of these assignments were compared to the results of a baseline version of the demand model where no road closures were implemented. These comparisons are the basis for estimation of the economic costs of disruption to the road network in the event of flooding.

By using only the traffic assignment phase of the demand models this analysis emulates the short-run disruption impacts. The regional model represents a typical weekday of travel. Vehicles that cannot use their normal routes (for both work and non-work related travel) divert to routes that are not disrupted due to road closures during the flood event. In some cases, these diversion routes are considerably longer than normal routing patterns. Since the closures are

[78] The theory, data, and methods of this model are described in detail on the PSRC webpage at https://www.psrc.org/trip-based-travel-model-4k.

due to sudden and unexpected flooding the analysis does not permit the quantity of trips, or their origins or destinations to change. Only routes are altered to avoid road closures.

Flood events are assumed to persist for two alternative durations, for 24 hours and for 48 hours. In the case of two-day closures it is realistic to imagine that some expected travel activities may be altered in a manner that avoids the anticipated disruption altogether. However, this change in planned activity represents its own form of economic scheduling cost and a simplified assumption that those costs can be approximated by holding trip counts constant is reasonable to a first approximation.

For each scenario total travel times for all vehicles in the road network were summed, for all hours of the day, and comparted with the Baseline scenario. The difference in travel time in vehicle minutes was then valued based on each vehicle type's value of time. The valuation includes factoring vehicle minutes based on expected vehicle occupancy and occupant's values of time as defined by the U.S Department of Transportation's February 2021 *Benefit-Cost Analysis Guidance for Discretionary Grant Programs*. The hourly value of time for personal vehicles is calculated using a value of $19.33 (2021 dollars) times an average occupancy of 1.52 per vehicle. The hourly value for commercial vehicles is $33.26 (2021 dollars) with an average occupancy of one person.

6.8 Roadway Transportation Results

6.8.1 Economic Impact of Traffic Disruptions

6.8.1.1 Roadway Traffic Disruptions

Table 6-5 describes the hours of delay for each transportation scenario. The hours of delay are a function of the number of trips that need to be rerouted and the added time for the detour route. Scenario 4 has the highest number of hours of delay of the four scenarios. In addition to these time delays, some people residing in the impacted area during the flood event may not be able to travel at all if floodwaters cut off their street from detour routes. This issue is particularly relevant for Scenario 3 which has a concentration of roads that could be impacted, compared to the other scenarios that have largely unconnected roadway segments impacted by flooding.

Table 6-5. Hours of Delay of Road Network Disruption from Flood Events

	One-Day Closure	Two-Day Closure
Scenario 1: Atmospheric River Flooding		
Personal Vehicles	99,857	199,714
Commercial Vehicles	3,908	7,816
All Vehicles	**103,765**	**207,531**
Scenario 2: Rain on Snow Event		
Personal Vehicles	17,725	35,449
Commercial Vehicles	995	1,989
All Vehicles	**18,719**	**37,439**
Scenario 3: Catastrophic Levee Failure		

Personal Vehicles	1,829,371	3,658,742
Commercial Vehicles	168,515	337,029
All Vehicles	**1,997,886**	**3,995,771**
Scenario 4: Groundwater Flooding		
Personal Vehicles	5,006	10,013
Commercial Vehicles	294	588
All Vehicles	**5,300**	**10,601**

Source: Created by ECONorthwest with data provided by PSRC

Table 6-6 demonstrates the magnitude of the economic costs of disruption from road closures due to a single flood event. The actual costs of disruption will depend upon flood event particulars, such as when the event occurs. Flooding that may occur in later years will disrupt more travel activities as the potential flood region accommodates additional urban growth and traffic. These larger costs, occurring later, are also subject to additional discounting if calculating a present value of disruption.

Table 6-6. Delay Costs of Road Network Disruption from Flood Events (2021 Dollars)

	One-Day Closure	Two-Day Closure
Scenario 1: Atmospheric River Flooding		
Personal Vehicles	$2,934,000	$5,869,000
Commercial Vehicles	$ 130,000	$260,000
All Vehicles	**$3,064,000**	**$6,129,000**
Scenario 2: Rain on Snow Event		
Personal Vehicles	$521,000	$1,042,000
Commercial Vehicles	$33,000	$66,000
All Vehicles	**$554,000**	**$1,108,000**
Scenario 3: Catastrophic Levee Failure		
Personal Vehicles	$53,755,000	$107,511,000
Commercial Vehicles	$5,605,000	$11,211,000
All Vehicles	**$59,361,000**	**$118,722,000**
Scenario 4: Groundwater Flooding		
Personal Vehicles	$147,000	$294,000
Commercial Vehicles	$10,000	$20,000
All Vehicles	**$157,000**	**$314,000**

Source: Created by ECONorthwest with data provided by PSRC

6.8.1.2 Additional Economic Impacts

The estimates of impacts from flooding discussed herein are based on travel costs through roadways for the four scenarios defined above. These estimates do not include costs from forgone trips that are not able to occur due to inaccessibility due to flooding. They also do not include costs from delays of freight or other shipments due to flooding. The estimates also do not include the costs of additional fuel consumption or additional wear and tear on the vehicles. These cost all represent additional costs of flooding of the transportation network.

6.9 Damage to Transportation Infrastructure

Flooding could damage roads and bridges in Pierce County due to washouts from water inundation, high velocity water, and debris that can cause damage to the infrastructure. The roadway sections identified in the Scenarios above are all roads that could have water and result in damage to the roads segments. Not all road segments will be damaged.

To estimate potential road damage more broadly, this analysis assumes that damage to a bridge or road can occur if the floodwaters reach high enough elevations cause inundation or damage infrastructure from debris. To identify the height of the floodwaters requires knowing the elevation of the flood relative to the transportation infrastructure. Flood elevation data, also known as Base Flood Elevations (BFE), is not available for every SPA or river. There is BFE for the Puyallup River and some tributaries (see Figure 5-3 for a map of the BFE extent). Roads and bridges outside of the areas with BFE may also be affected by flooding – but there is not sufficient information to perform the same calculations (i.e., areas outside the BFE extent are excluded from the analysis).

The inventory of bridges was obtained from Pierce County,[79] and from Washington State Department of Transportation (WSDOT).[80] The inventory of roads was obtained from Pierce County.[81] All estimates of impacted roadways and bridges are conducted only for the 100-year flood extent. Impacts from sea level rise are discussed in Chapter 9. The full methodology for the analysis of impacts to roads and bridges is available in Appendix A.

Table 6-7. Road Length (feet) and Number of Potential Road Failures for 100-Year Flood

Area	Road Length (ft)	Number of Road Failures
Chambers Bay/ Clover Creek Basin	31,072	102
Clear/Clarks Creek Basin	46,092	144
Gig Harbor/Key Peninsula Basin	1,847	0
Hylebos-Browns Point-Dash Basin	10,769	134
Mid Puyallup Basin	106,017	505
Muck Creek Basin	5,127	11
Nisqually Basin	9,329	0
Upper Puyallup Basin	35,697	47
White River Basin	14,807	81
Pierce County Total	**260,758**	**1,024**

Source: Created by ESA

There are 466 bridges in Pierce County and 255 of these bridges are over waterways. A total of 44 bridges are over waterways that have BFE data. Based on the flood depth and velocity combinations, only two bridges are estimated to fail in Pierce County (out of the 44 total with

[79] Pierce County Open GeoSpatial Data Portal, *Bridges* (2020). Available at: https://gisdata-piercecowa.opendata.arcgis.com/datasets/bridges

[80] WSDOT. (2020). *WSDOT GIS Data Download: Bridge Data - Bridge On Locations.* Available at: https://www.wsdot.wa.gov/mapsdata/geodatacatalog/default.htm

[81] Pierce County Open GeoSpatial Data Portal, *Roads* (2020), available at: https://gisdata-piercecowa.opendata.arcgis.com/datasets/roads?geometry=-122.225%2C47.025%2C-122.014%2C47.066

BFE data). These bridges also have the greatest freeboard violations of the 44 bridges with BFE data. Table 6-8 summarizes the bridges with freeboard violations and with the potential to fail by ownership.

Table 6-8. Bridges with Freeboard Violations from a 100-Year Flood Event

Bridge Ownership	Number of Bridges with Freeboard Violations	Bridges with the Potential to Fail
WSDOT	5	0
Railroads	2	0
City of Sumner	2	1
Pierce County	5	1
Total in Pierce County	**14**	**2**

Source: Created by ESA

Chapter 5 contains more information about damage to roads and bridges, including estimate of the cost of repairs. More information about impacts to roadways and railroads from sea level rise flooding is available in Chapter 9.

6.10 Commerce

Commerce is an important part of Pierce County's economy. Pierce County is home to both the Port of Tacoma as well as a portion of Interstate 5, both of which are critical transportation network resources in addition to the other roadways and railroads in Pierce County. For the entire state of Washington there were a total of $181.8 billion dollars of freight shipped into the state in 2017.[82] Intrastate commerce (freight shipped between areas of Washington) was valued at $243.3 billion in 2017. Exports of freight from Washington had a value of $174.1 billion statewide for 2017. As a centralized hub of commerce for Washington, Pierce County's transportation infrastructure is essential to facilitating these values of trade from, within, and outside of the region.

There are a total of 9,060.7 miles in the freight transportation network for the state of Washington, representing the essential routes in the state for commerce.[83] Pierce County includes 623.3 miles or 6.9 percent of the freight transportation network. Interstate 5 through Pierce County comprises approximately 24.6 miles or 0.3 percent of the network. The values of intrastate commerce are not available from the freight transportation network for small geographies. The estimate of the value of commerce through Pierce County and on Interstate 5 are estimated using the proportional values of the network. Given the concentration of businesses and transportation facilities, these estimates are likely an underestimate of the value of freight. Based on these estimates, as of 2017 approximately $4.45 million in commerce travels on Interstate 5 on a daily basis.

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[82] Bureau of Transportation Statistics, Freight Shipments by Value, available at: https://www.bts.gov/topics/freight-transportation/freight-shipments-value

[83] U.S. Department of Transportation, Freight Analysis Framework Network geospatial data, available at: https://data-usdot.opendata.arcgis.com/datasets/freight-analysis-framework-network/explore?filters=eyJGQUY0X1NUQVRFIjpbIldBIl19&location=47.174715%2C-122.479162%2C18.72

Table 6-9. Annual and Daily Values on Freight Estimates (2017)

	Annual - 2017 Values (in millions)			
Area	Interstate Inbound	Within	Interstate Outbound	Total
Interstate 5 in Pierce County	$493	$660	$472	$1,625
Pierce County	$12,508	$16,739	$11,977	$41,224
Washington State	$181,831	$243,324	$174,108	$599,263
	Daily - 2017 Values (in millions)			
Area	**Interstate Inbound**	**Within**	**Interstate Outbound**	**Total**
Interstate 5 in Pierce County	$1.351	$1.808	$1.294	$4.453
Pierce County	$34.270	$45.859	$32.814	$112.943
Washington State	$498.167	$666.641	$477.008	$1,641.816

Source: Created by ECONorthwest

The costs of delays to freight commerce span multiple cost categories. As discussed above, longer routes result in costs for the commercial vehicles in terms of labor, fuel, and time. Drivers who are paid by the hour and those who operate as private carriers (opposed to for-hire carriers) can personally incur higher costs from transport delays.[84] Estimates from the literature have shown an approximate per mile cost for drivers of $1.63 per mile (2012 dollars).[85]

Longer delays will result in larger costs, which are particularly pronounced for certain types of perishable products (e.g., agricultural products, chemicals, etc.) because delays depreciate the product's value. The logistics costs associated with deviations from expected travel times for freight are referred to as the value of reliability. The value of reliability impacts carriers, shippers, and the markets that receive the goods. Values of freight time reliability vary considerably by study and by region. Estimates from WSDOT provide values of $60 per hour for mining products, $176 per hour for agricultural products, and $223 per hour for certain types of manufactured products (2010 dollars).[86]

6.11 Transportation Impacts Summary

Pierce County's transportation network is critical for movement of people and goods to designations within and outside of the county. Flooding can result in economic costs due to time and operational costs associated with delays. The highest costs will be for routes with long delays, those without any alternative route, or flood impacts that impact a wide area of people. Freight transportation costs will be highest for longer delays and for perishable products. Interstate 5 and the state highways have the highest volumes of traffic and freight cargos. Prior

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[84] Miao, Q., Wang, B. X., & Adams, T. M. (2011). *Assessing the value of delay to truckers and carriers (No. CFIRE 03-15).* Texas A & M University.

[85] Fender, K.J. and Pierce, D.A. (2013). *An Analysis of the Operational Costs of Trucking: 2013 Update*. American Transportation Research Institute. September.

[86] Sage, J., Casavant, K., Goodchild, A., McCormack, E., Wang, Z., McMullen, B. S., & Holder, D. (2013). Development of a Freight Benefit/Cost Methodology for Project Planning (No. WA-RD 815.1). Washington State Department of Transportation.

flooding of Interstate 5 illustrates the large costs that can be incurred from impacts to these critical transportation resources.

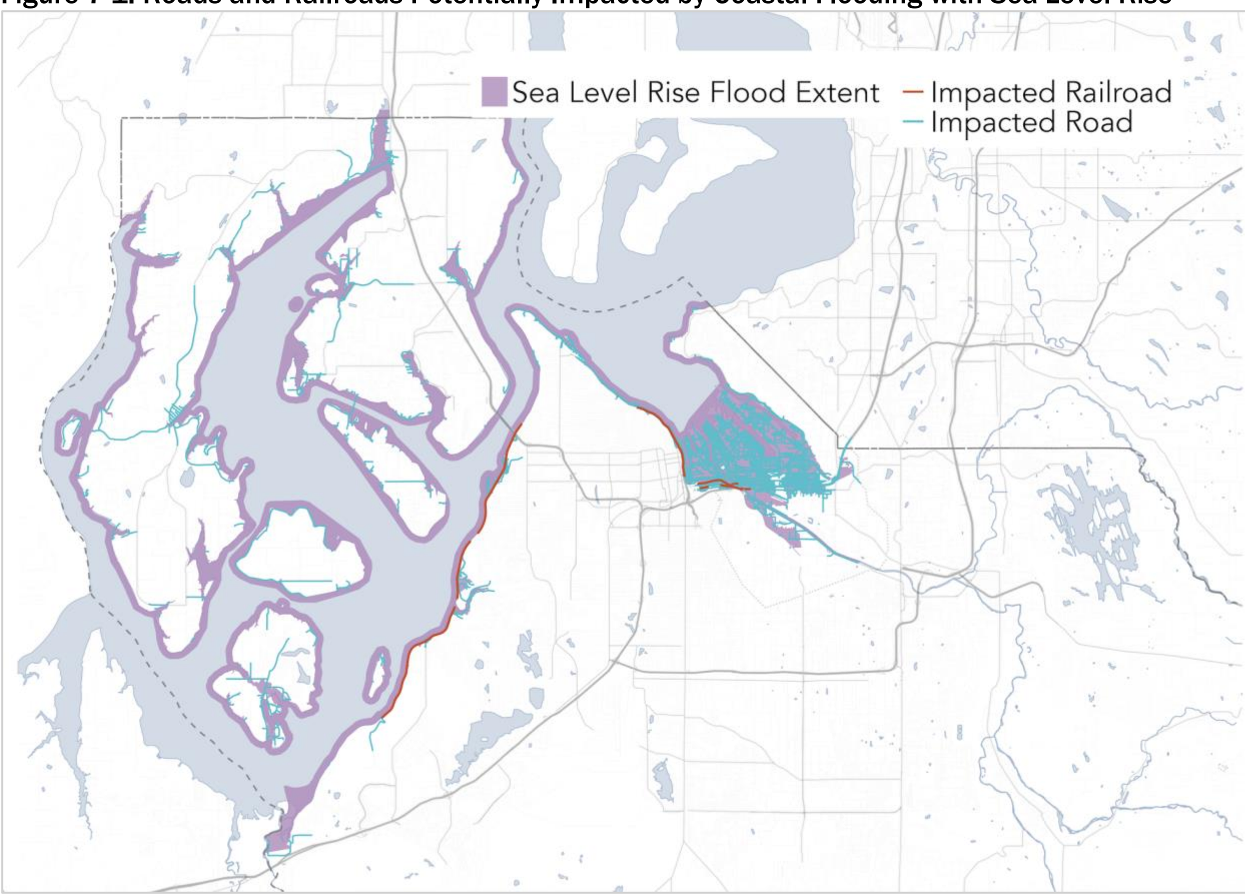
7 Sea Level Rise Transporation Impacts

7.1 Introduction

Pierce County has approximately 225 miles of coastline. Portions of this coastal area are subject to coastal flooding. Coastal flooding is expected to worsen due to sea level rise, further increasing the risks of flooding to transportation infrastructure for coastal communities. This type of flooding could impair access to the transportation network, including roads, railroads, and ferry landings. During a flood emergency, this may mean that people are unable to access or have longer routes to critical services, such as hospitals and fire stations.

The purpose of this analysis is to evaluate what segments of transportation resources are susceptible to coastal flooding, now and with sea level rise, and identify the extent to which flooding will impact a community's ability to access critical services. Figure 7-1 provides an overview of which roads and railroad segments are potentially impacted by coastal flooding (including future sea level rise).

Figure 7-1. Roads and Railroads Potentially Impacted by Coastal Flooding with Sea Level Rise



Source: Created by ECONorthwest with data from Pierce County

7.2 Data Sources

The sea level rise flood extent is from the *Projected Sea Level Rise for Washington State – A 2018 Assessment*.[87] The sea level scenario evaluated for potential coastal flooding is the 1 percent likelihood of occurring in 2100 flood event. This level of sea level rise flood risk represents the upper physical bound for the amount of sea level rise that Pierce County could experience in 2100, based on existing models, during a 100-year coastal flooding event. Roads and railroads that are potentially impacted by coastal flooding with sea level rise were provided by Pierce County.

Access to two types of critical infrastructure is evaluated in this analysis: hospitals and fire stations. Hospital location data was retrieved from Washington's geospatial data warehouse.[88] Fire station data was retrieved from the Homeland Infrastructure Foundation-Level Data warehouse.[89] Figure 7-2 displays the location of hospitals and fire stations that were used for the analysis. In some instances, the nearest facility is located in neighboring counties outside of Pierce County. Certain areas of Pierce County – the areas of the islands and Key Peninsula in particular – are the furthest from a hospital under current conditions (i.e., without flooding).

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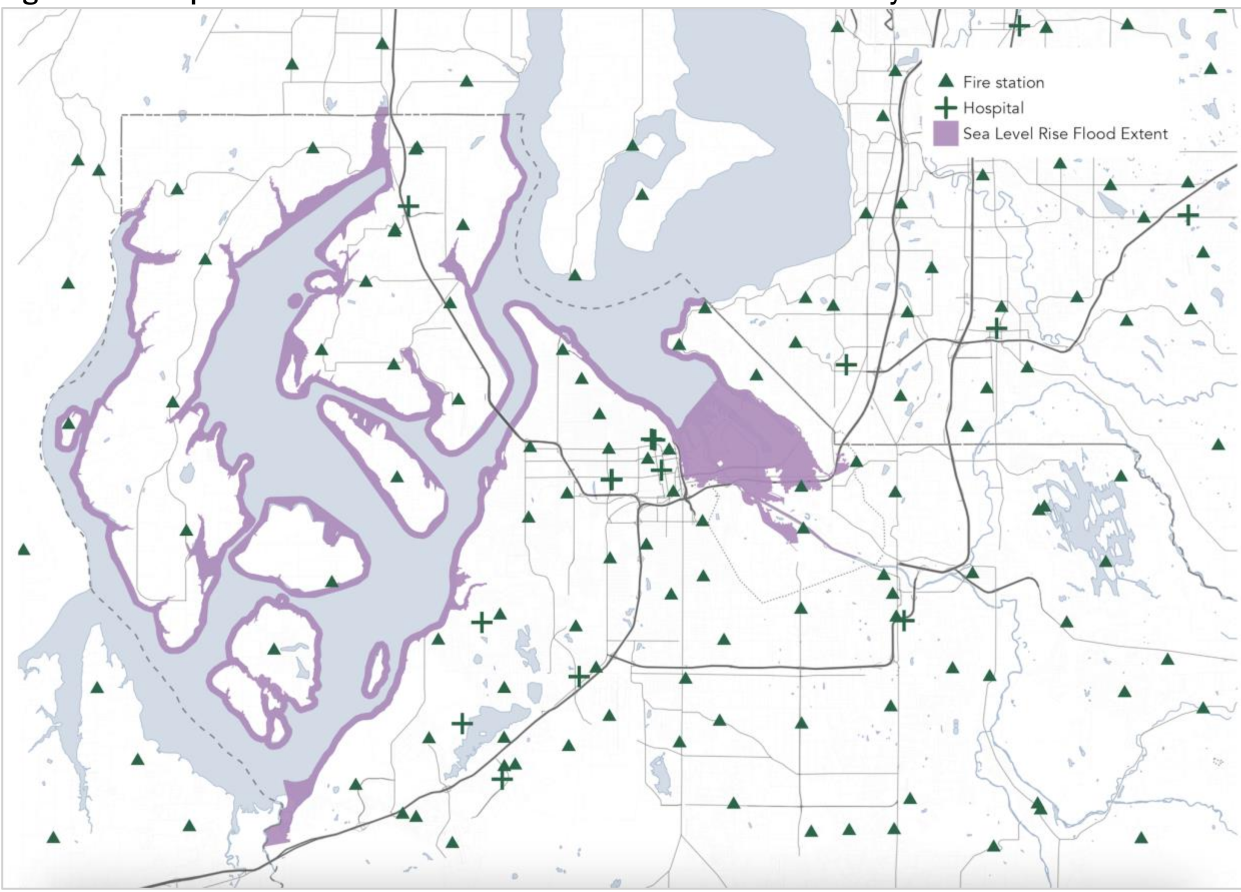
[87] Miller, I.M., Morgan, H., Mauger, G., Newton, T., Weldon, R., Schmidt, D., Welch, M., Grossman, E. (2018). *Projected Sea Level Rise for Washington State – A 2018 Assessment*. Prepared for the Washington Coastal Resilience Project. Available at: https://cig.uw.edu/resources/special-reports/sea-level-rise-in-washington-state-a-2018-assessment

[88] Washington Geospatial Open Data Portal, *Hospitals*, available at: https://geo.wa.gov/datasets/WADOH::hospitals/about

[89] U.S. Department of Homeland Security, Homeland Infrastructure Foundation-Level Data, *Fire Stations*, available at: https://hifld-geoplatform.opendata.arcgis.com/datasets/geoplatform::fire-stations/about

Figure 7-2. Hospitals and Fire Stations that are Nearest to Pierce County Residents



Source: Created by ECONorthwest

7.3 Coastal Flooding Impacts to Roadways

7.3.1 Roadway Impact Methods

To perform the analysis for roads, ECONorthwest modeled road closure scenarios using the inundation area spatial data provided by Pierce County and street network data retrieved from OpenStreetMap. Ferry crossings are also included as part of the wider transportation network. This analysis assumes that all road segments are impassable at the same time, and that any road segments intersecting the inundation area will be impassable. This road layer data within the OpenStreetMap network was cross-referenced against the impacted roadways data provided by Pierce County.

Using the R statistical software language and its suite of spatial and network analysis extensions, ECONorthwest evaluated the effects of road closures by modelling the transportation network under a *baseline* scenario and an *inundation* scenario with roadway segments removed or clipped. Hospital and fire stations were used as destination points in this analysis.

Trip *origins* were derived from the LandScan "nighttime population" dataset developed by Oak Ridge National Laboratory and provided via the Homeland Infrastructure Foundation-Level

Data warehouse.[90] LandScan data was clipped to our study region, and dissolved into a hexagonal grid, wherein each grid cell was approximately a quarter-mile across. Each of the grid cells contains an estimated "nighttime" population that is intended to represent the population distribution of an area in the evening when most, but not all, residents are at home instead of work or school.

ECONorthwest calculated travel distances between each grid cell centroid and its nearest essential service location (fire stations and hospitals) under the "baseline" and "inundation" scenarios using the OpenStreetMap travel network. For each grid cell, ECONorthwest calculated the difference in travel distances between the two scenarios, flagging parcels that would experience a difference of 5 or more miles under an inundation scenario.

ECONorthwest also analyzed the inundation scenario's impact on our study area's road network. As the inundation scenario will cause some residents to have to use alternate routes, or drive to an entirely different service location, some road segments could experience a significant increase in trips, or become pinch-points with no alternate routes to the nearest service location. To perform this analysis, ECONorthwest routed trips to the nearest service location from each grid cell that contains greater than zero population. Once this was done, we were left with a network of "overlapping" routes, to which we assigned a trip "weight" using the origin grid cell's population. These overlapping routes were then dissolved, and any overlapping weights added together to calculate the estimated total number of travelers on any given road segment. Like the grid-based analysis, this process was conducted under the *baseline* and *inundation* scenarios in order to calculate the difference in number of travelers between the two scenarios.

Our model makes assumptions, a key one being the assumption that trips originate from the centroid of our hexagonal grid cells. This center point of each cell is then "assigned" to its nearest node in the street network. Since the placement of the hex cells are semi-random, it is possible that some trip origins will begin on parts of the street network that might not reflect the likely starting points of all trips originating from within that grid cell (i.e., the nearest assigned node for a cell might be in a remote cul-de-sac with only a few houses nearby, whereas most houses within the cell might fall along a major arterial road). This semi-random assignment results in some erroneous edge-cases, but allows us to reduce the overall model complexity and technical requirements of computing several hundred thousand possible trips throughout network data.

7.3.2 Results of Coastal Flooding Impacts to Roadways

The vast majority of residents will likely have no impact to their ability to access the nearest hospital, but an estimated 43,000 residents will either have to drive further to the nearest hospital (which may be a different hospital) or will be cut off from the road network due to inundation. Large swaths of sparsely populated land in the county – areas of Key Peninsula and

[90] U.S. Department of Homeland Security, Homeland Infrastructure Foundation-Level Data, *Conus night*, available at: https://hifld-geoplatform.opendata.arcgis.com/datasets/conus-night-1/about.

Fox Island in particular – will be faced with significantly increased drive distances to service locations or be cut off completely if key bridges and intersections are closed or destroyed under the inundation scenario.

There are a larger number and more widespread geographic distribution of fire stations compared to hospitals. Most residents will likely have no impact to their ability to access or be accessed by the nearest fire station, but an estimated 20,000 residents will face longer routes or will be cut off from the road network due to inundation. Like for hospitals, Key Peninsula is still likely to see the worst effects of the inundation scenario. Likewise, the county's islands in the study area each contain one fire station, allowing residents of these islands to access these locations in the inundation scenario.

Impacts to the road network in our study area will also be felt throughout the larger roadway network, as residents reroute to alternate service locations or are cut off completely. Some road segments will likely experience net increases in the total number of trips compared to a baseline scenario, particularly around north Key Peninsula and in the area near the Port of Tacoma. Increased volumes on roadways are due to trips that must reroute because they no longer have access to their nearest hospital, or most choose a different route due to a road closure at some point along their baseline trip. Conversely, some road segments will experience net *decreases* in trips. Decreases in trips could be caused by reroutes (e.g., that segment is no longer part of the shortest route to a service location) or trip removals (our model assumes that trips cannot originate from within the inundation area). Localized flooding on smaller roadways – such as in front of someone's home or along a neighborhood street – will also impair access to critical services for the people who live in that area.

Figure 7-3. Impact Areas Under Inundation Scenario – Access to Hospitals
Source: Created by ECONorthwest

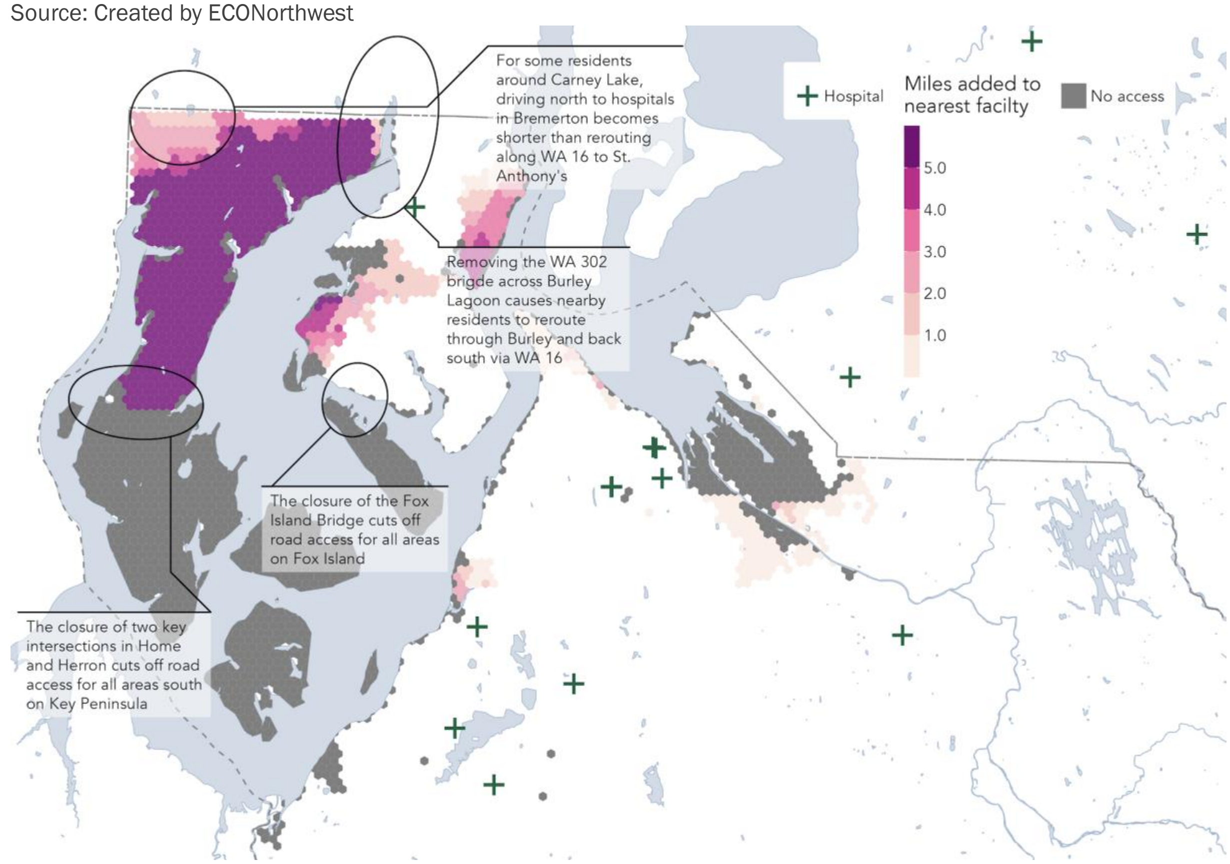


Figure 7-3 shows impacts to local areas caused by the inundation scenario, visualized in terms of the number of miles added to a car trip to the nearest hospital. Adverse inundation effects on Pierce County's transportation network will be most acute for residents on Key Peninsula, but some additional burden will be felt in parts of Kitsap Peninsula around Gig Harbor, and inundation-adjacent areas in Tacoma. Our model shows that the road network in the southern half of Key Peninsula (from Home-Herron southwards) may be completely cut off from hospital access under the inundation scenario, since two vital intersections close to sea-level are all that allow this area's residents to access to the rest of Kitsap Peninsula. With the removal of several bridges around the Sound, Fox, Anderson, and McNeil islands will be cut off from road access to the nearest hospital.

Figure 7-4. Impact Areas Under Inundation Scenario – Access to Fire Stations

Source: Created by ECONorthwest

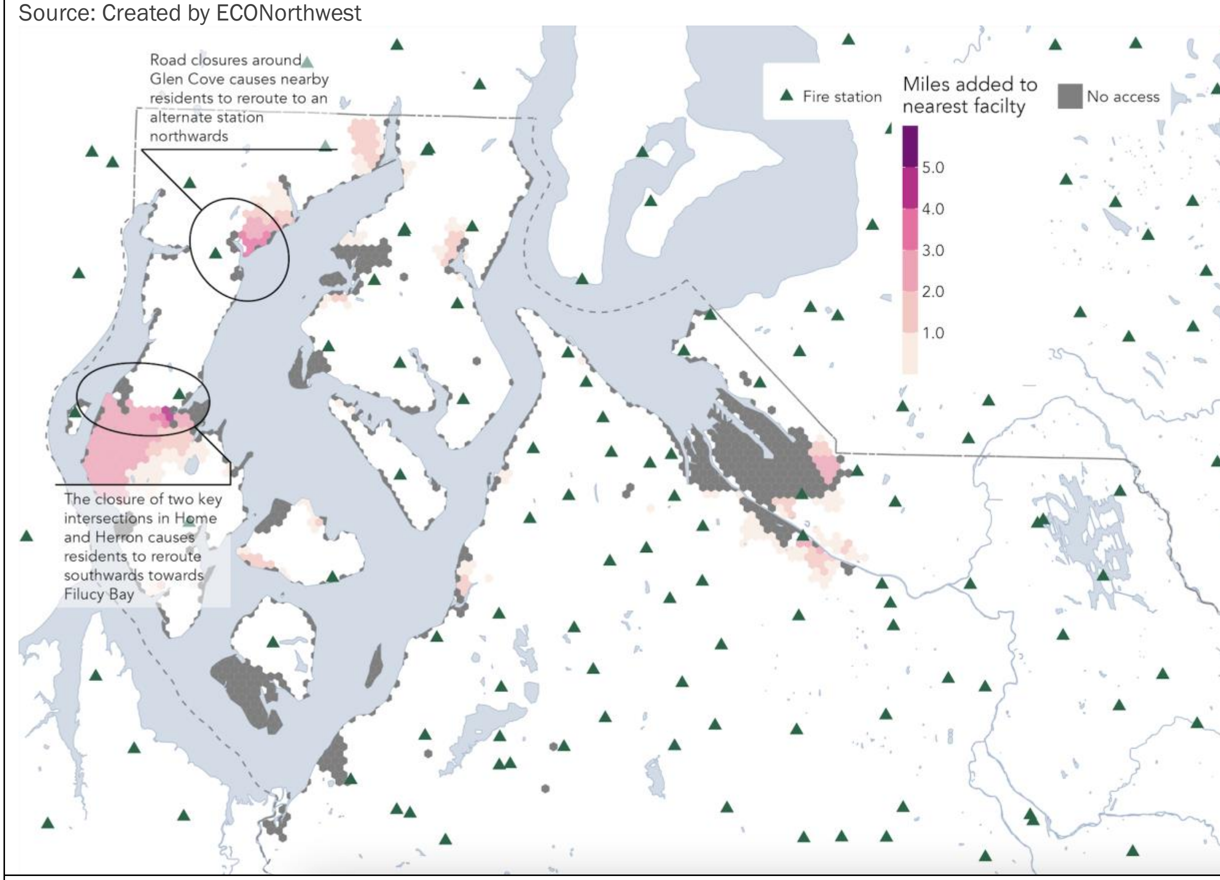


Figure 7-4 shows impacts to local areas caused by the inundation scenario, visualized in terms of the number of miles added to a car trip to the nearest fire station. Most areas in Pierce County will be unaffected in their ability to reach the nearest fire station under the inundation scenario. Like with hospitals, South Key Peninsula is the most impacted area, but increases in drive distances to the nearest fire station are typically less than 3 or 4 miles.

Figure 7-5. Impacted Road Segments Under Inundation Scenario – Access to Hospitals
Source: Created by ECONorthwest

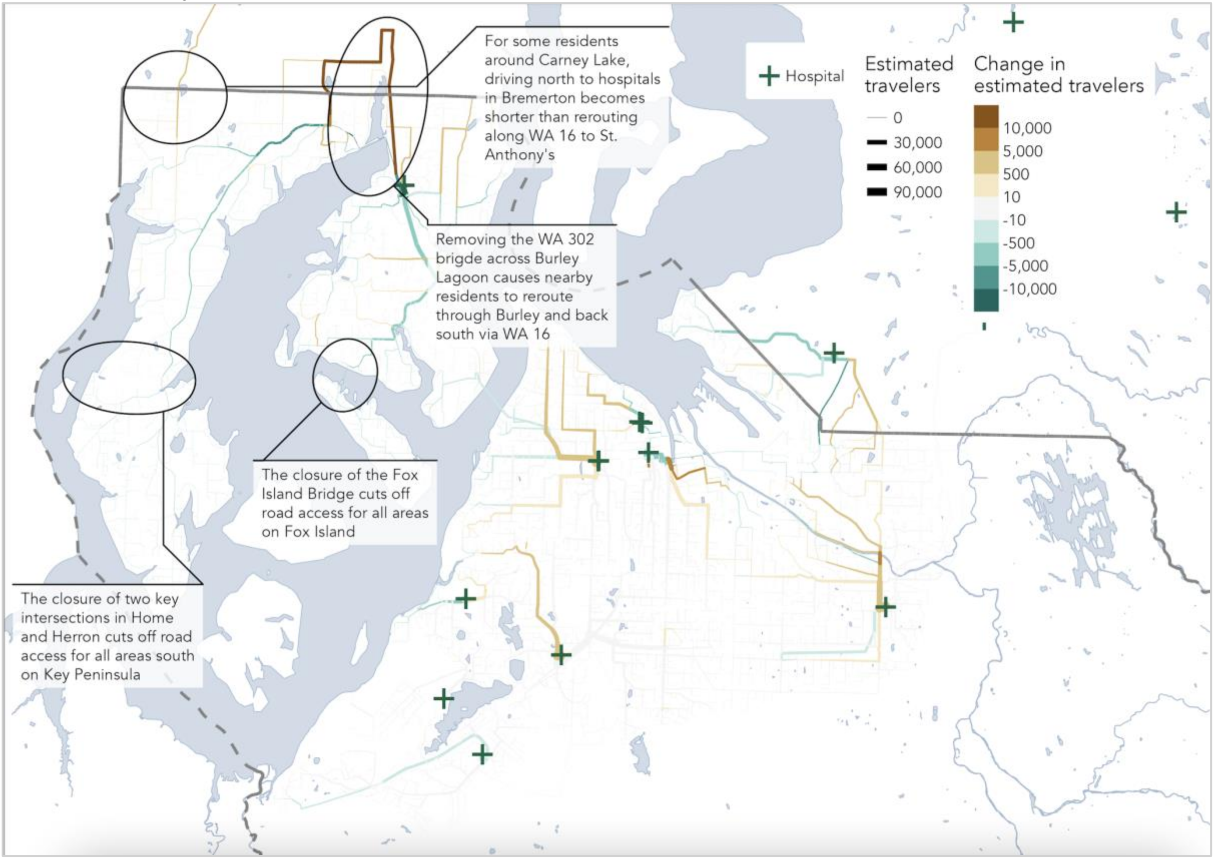


Figure 7-5 depicts our model results on the study area's road network in terms of trips added or removed from road segments. Impacts to the road network under the inundation scenario will be most pronounced in parts of Tacoma and in northern Pierce County around Burley Lagoon. Since the WA 302 bridge between Wauna and Purdy will be inoperable under the inundation scenario, residents in the surrounding area will have to re-route around the lagoon to access St. Anthony's Hospital in Gig Harbor. In Tacoma, many segments will likely see modest increases as the inundation affects the Port of Tacoma and coastal areas of the City. Some segments could experience a decrease in travelers as some trips are rerouted or removed altogether from the model either due to access being completely cut off in some areas (south Key Peninsula), or trip origins from inside the inundation area not being routed.

Figure 7-6. Impacted Road Segments Under Inundation Scenario – Access to Fire Stations
Source: Created by ECONorthwest

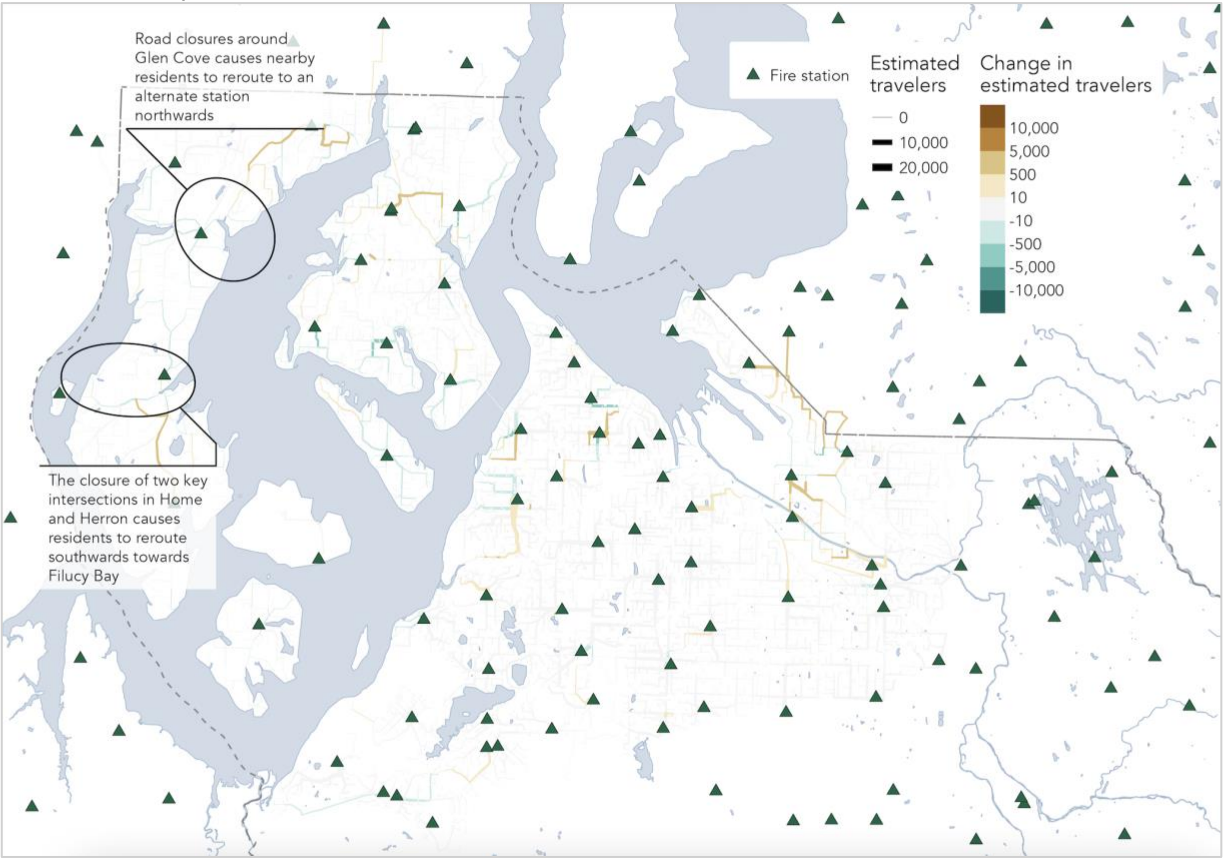


Figure 7-6 depicts our model results on the study area's road network in terms of trips added or removed from road segments. Impacts to the road network under the inundation scenario will be most pronounced in parts of Tacoma and around Key and Kitsap Peninsula. Given the density and dispersion of fire stations, most impacts to the road network will be light when compared to trips to the nearest hospital, as shown in Figure 7-5.

Figure 7-7. Impacts to Road Network Under Inundation Scenario - Access to Hospitals
Source: Created by ECONorthwest

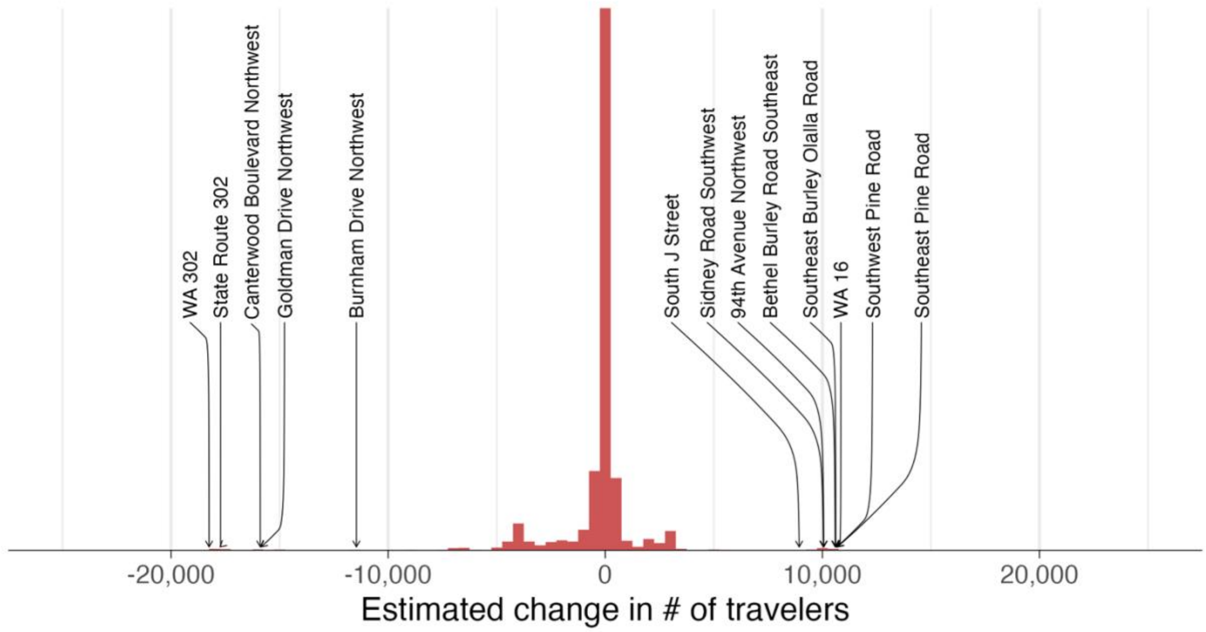


Figure 7-7 shows, in histogram form, the estimated impacts to the study area's road network under the inundation scenario, when modelling trips to the nearest hospital. Most of the study area's road network will likely experience little to no impact, though some segments, particularly those along Burley and Pine, will see significant increases in travelers due to rerouting. Other segments, particularly WA 302, will see a decrease in travelers caused by reroutes or from a net decrease in the total number of travelers as some areas of the county are cut off completely by inundation effects.

Figure 7-8. Impacts to Road Network Under Inundation Scenario - Access to Fire Stations
Source: Created by ECONorthwest

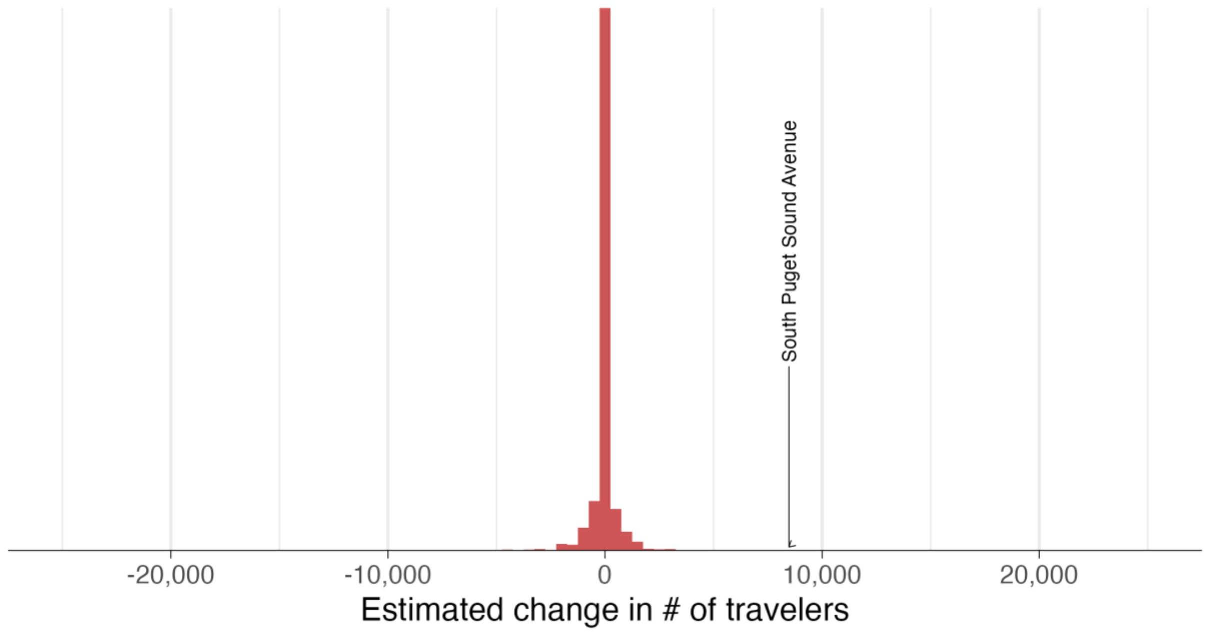


Figure 7-8 shows, in histogram form, the estimated impacts to the study area's road network under the inundation scenario. Because of the greater number of fire stations in the study area, it is less likely that any given trip to the nearest fire station will face a long reroute or be cut off completely, when compared to trips to the nearest hospital. A segment of South Puget Sound Avenue near Tacoma FD Station 9 will likely see an increase in trips, even though it is not near the inundation area – this is due to the number of reroutes for Station 9 causing a cumulative increase of travelers close to their destination.

7.3.2.1 Impacted Roadways that Impede Access to Hospitals

The following road segments and intersections have been identified through the model as impairing access to hospitals or fire stations for the highest number of people or having the most severe impacts by cutting off access.

- **Hospitals**
  - **Herron Road NW & Key Peninsula Highway:** Together with another segment of Herron Road, removing this segment from the network shuts off access to hospitals for all of south Key Peninsula.
  - **North Heron Road NW (btw. N Herron Road N & 205th Ave Ct):** Closure of this section would result in no access to critical services for the residents off North Heron Road NW.
  - **Purdy Spit Bridge (Burley Lagoon):** If access to this bridge is impaired it would require the population in and around Wauna to reroute more than 5 miles around Burley Lagoon.

- **Fox Island Bridge:** If access to this bridge is impaired it would shut off access for all of Fox Island.
- **Vernhardson Street (btw. Randall Drive NW & Jacobsen Lane):** Loss of access to this segment would causes short reroutes around Gig Harbor for residents.

- **Fire Stations**
  - **Herron Road NW & Key Peninsula Highway:** Together with another segment of Herron Road, removing this segment from the causes moderate reroutes for some areas of south Key Peninsula.
  - **North Heron Road NW (btw. N Herron Road N & 205th Ave Ct)**: Closure of this section would result in no access to critical services for the residents off North Heron Road NW.
  - **Cramer Road N & Glencove Road N:** Shutting this intersection down causes moderate-length (less than 5 miles) reroutes for the Glencove area.
  - **Purdy Spit Bridge (Burley Lagoon):** Shutting this bridge down causes short-length reroutes for the immediate surrounding areas.

7.4 Coastal Flooding with Sea Level Rise Impacts to Railroads

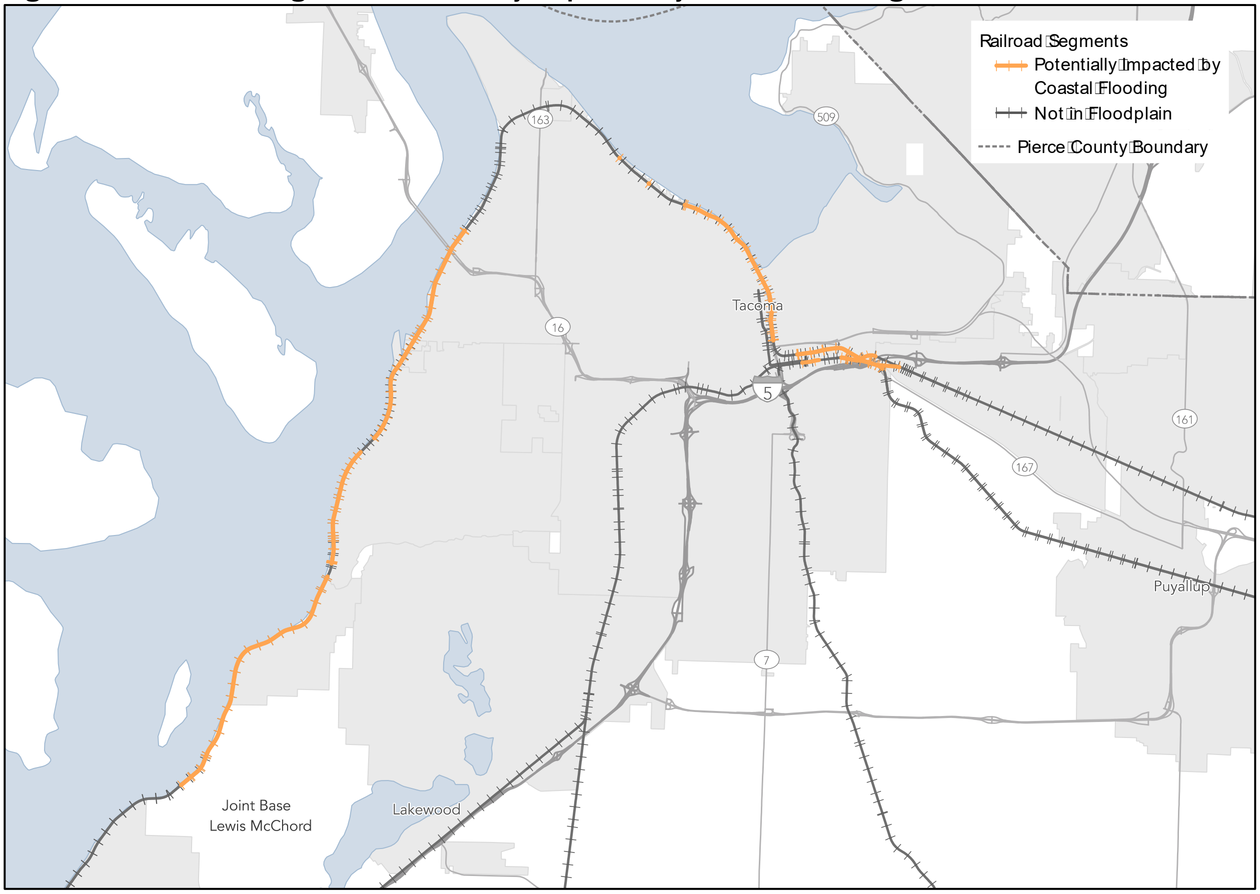
7.4.1 Railroad Impact Methods

There are 163 total sections of railroad of varying length in Pierce County. Of these, approximately 38 sections are within the flood extent for coastal flooding with sea level rise. Railroads in Pierce County are owned and operated by multiple entities, including:

- BNSF Railroad
- Union Pacific Railroad
- Tacoma Rail Mountain Division
- Sound Transit
- Tacoma Link

To understanding potential impacts from coastal flooding, ECONorthwest interviewed railroad service providers to confirm how they would adjust operations due to inundated railroads and the associated cost of those operational changes. Figure 7-9 displays the location of railroads that could be inundated due to a coastal flooding event with sea level rise.

Figure 7-9. Railroad Segments Potentially Impacted by Coastal Flooding



Source: Created by ECONorthwest

7.4.2 Results of Coastal Flooding Impacts to Railroads

Railroads are often able to continue operating even if there is some water inundation over the railroad tracks. If there is standing water on the tracks, but it is still passable, conductors will reduce the speed of the train. However, this continued operation cannot always occur if flooding is severe. In extreme instances, the line would be taken out of service until the water recedes. Erosion and washouts can result in more severe damage to the railway lines, which would cause the line to be out of service until the repairs can be completed. The most common types of repairs associated with flooding are replacing track ballast, which are the rock-like materials that are used below and between the rail tracks. Track ballast can washout due to flooding. Sea level rise flooding is particularly concerning if erosion does occur and the railroad needs to be moved inland, which may not always be possible.

If a reroute is needed, the train will reverse direction back to the nearest line switch. A train could become stranded due to floodwaters, but this would be very rare and only if the track was damaged in multiple locations or if floodwaters were so strong that it would be unsafe to run the train. Costs of delays are not something the train operators monetize. However, if a route is cancelled and diverted to another mode of transport, such as trucking, there would be a revenue loss from the lost freight.

The railroad operators interviewed are all aware of the future risk to their rail lines from coastal flooding with sea level rise. The operators are in the planning stages of addressing the issue, but do not yet have specific plans in place.

7.5 Summary of Impacts

Coastal flooding in Pierce County will worsen in the future with sea level rise. In these types of flood events, transportation infrastructure may be inaccessible, resulting in longer routes or complete loss of access to critical infrastructure needed for public safety. Both access to and from hospitals and fire stations to provide emergency services would be affected by coastal flooding. Some communities may be completed cut off from access if key roadways are inaccessible due to flooding. These areas include areas that are accessed via bridge as well as dead end roads – both of which are most common in the Key Peninsula area and on the islands. In addition to transportation routes that have large effects on the network, some localized flooding, such as inaccessibility through neighborhood roads, will result in loss of access or difficulty accessing critical services for residents.

8 Flood Impacts to the Recreation Sector

8.1 Introduction

Outdoor recreation is a defining feature of Pierce County, drawing users locally and from beyond the region to natural and developed parks, trails, rivers, and mountains. Economic contributions from outdoor recreation in Pierce County support a total of $3.8 billion in total economic activity and more than 25,000 jobs.[91] The recreation sector is growing in Washington's economy generally, with overall outdoor participation increasing by 30 percent in the last five years.[92]

Within Pierce County, the sites that draw the most visitation are Mount Rainier National Park and Crystal Mountain Ski Resort. Expenditures by visitors to these recreational amenities represent an important contribution to the local economy, especially for gateway communities that provide services for visitors. Aside from these attractions, Pierce County managed parks total 5,271 acres at 44 sites that served approximately 2.8 million park users in 2019 (not including other state or city parks).[93]

8.2 Methodology

This chapter evaluates the potential flood-related impacts to the recreation sector in Pierce County by focusing on four sites that represent large recreational offerings:

- Mount Rainier National Park
- Crystal Mountain Ski Resort
- Chambers Creek Regional Park
- Point Defiance Park

See Figure 8-1 for geographical reference of where these sites are relative to flood hazard areas within Pierce County.

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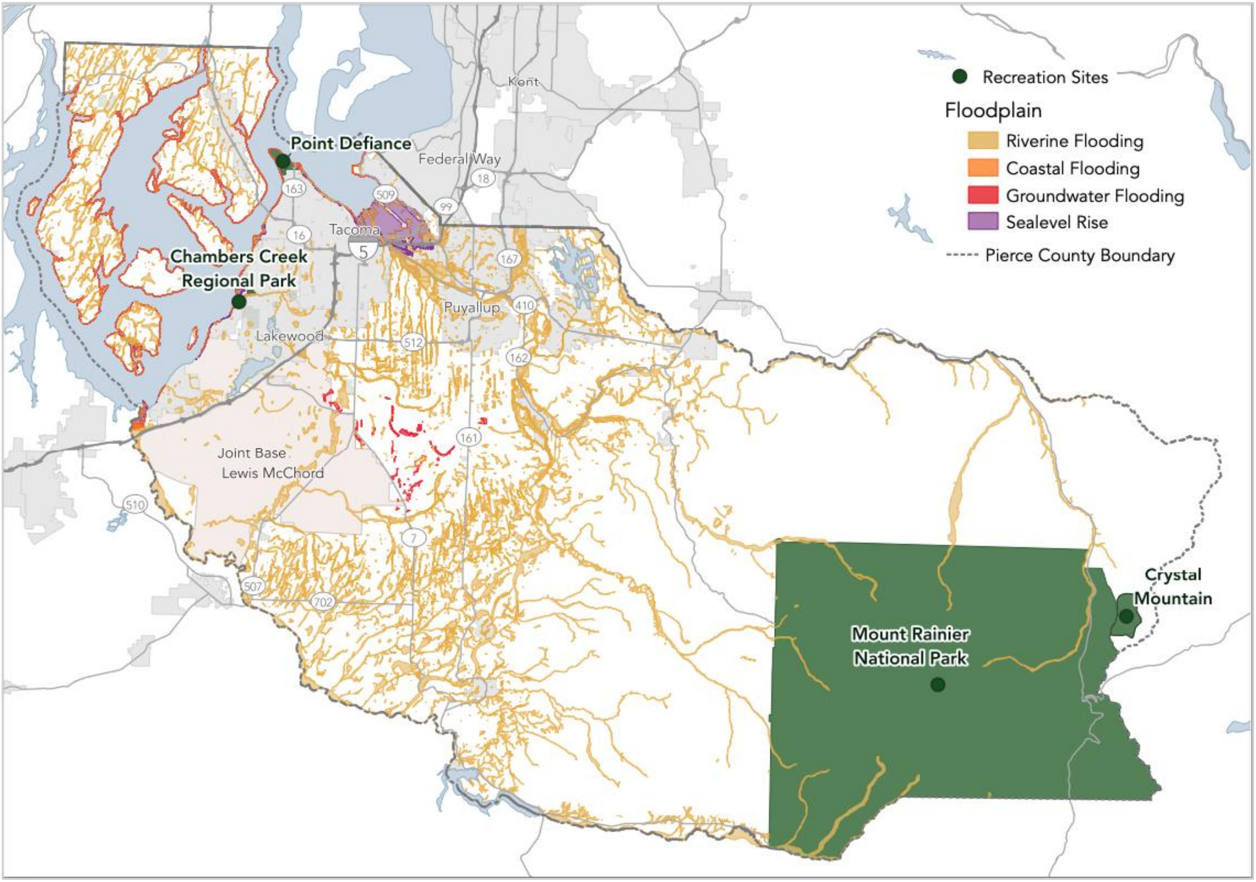
[91] Mojica, J. and Fletcher, A. (2020). *Economic Analysis of Outdoor Recreation in Washington State, 2020 Update.* Earth Economics. Tacoma, WA.

[92] Mojica, J. and Fletcher, A. (2020). *Economic Analysis of Outdoor Recreation in Washington State, 2020 Update.* Earth Economics. Tacoma, WA.

[93] Pierce County Parks and Recreation Department. (2019). *2019 Parks & Recreation Annual Report.* Available at: https://issuu.com/pierceco/docs/parks_annual_report2019

Figure 8-1. Location of the Four Recreation Sites



Source: Created by ECONorthwest

For each site, the analysis provides baseline visitation and spending information, as well as estimates of the number of jobs and level of economic activity supported by visitor spending. The secondary impacts of the spending represent the industries supported by the funds as they recirculate through the local economy. These economic contributions are calculated using IMPLAN.[94] This baseline information is then used to evaluate the direct and secondary impacts on the economy from potential losses in visitor spending due to flood-related closures of recreation sites.

8.2.1 Calculating Economic Contributions

Visitors and people who engage in recreation activities spend money in the local area on things like tickets, lodging, food, tours, souvenirs, transportation, and other goods and services that they need for the activity. This local economic activity resulting from spending represents the **direct effects**. From this spending there is additional economic activity as businesses purchase inputs from local suppliers – an element of economic contributions known as **indirect effects.** Businesses also pay their employees who further spend money on goods and services in the

[94] IMPLAN Group, LLC. *IMPLAN*. Huntersville, NC. IMPLAN.com.

local economy – this is the **induced effect**. Together, the direct, indirect, and induced effects represent the **total economic contribution** of the recreation and visitation spending.

The direct effect is measured by the direct spending levels of visitors to Pierce County that are attributable to the recreation or tourism visit. These estimates are obtained from visitor spending profiles and revenues to the recreation sites. The spending profiles and revenue impacts come from varying sources for each recreation site. Accordingly, they are described in the respective sections for each site.

To calculate the indirect and induced effects requires understanding the linkages between industries, business and employee spending patterns, and the extent to which that spending remains in the local economy. IMPLAN is an economic input-output modeling software that provides the information needed to calculate the indirect and induced effects at the county level using data derived from the U.S. Bureau of Economic Analysis. IMPLAN provides estimates for employment, labor income, and output – defined as follows:

- **Employment** is the measure of jobs which is expressed in terms of full-year-equivalents (FYE). One FYE job represents work over twelve months in an industry and can be either a part-time or full-time position. The FYE job measurement is the same definition used by the federal government's Bureau of Labor Statistics.
- **Labor Income** consists of employee compensation and proprietor income and is a subset of output. This includes workers' wages and salaries, as well as other benefits such as health, disability, and life insurance, retirement payments, and non-cash compensation.
- **Output** represents the total value of all goods and services resulting from the spending and is the broadest measure of economic activity. It does not include intermediate supply costs and can be thought of as the extent of the economic footprint of the total spending.

8.2.2 Methodological Considerations

The focus of this report is on economic contributions resulting from visitor spending on trips to recreation sites. This economic activity can be thought of as the value of the trip to the local economy. In addition, visitors themselves experience economic value associated with being able to take the recreation trips and visit specific sites. If a visitor cannot take a trip due to flooding-induced closures they will either not engage in the recreation at all or visit an alternative site. By not being able to engage in their first choice trip there is a reduction in economic value for the visitor. This report does not explicitly measure the reduced economic value (i.e., consumer surplus) for visitors due to flood impacts for each scenario. However, any missed or disrupted trips due to flooding will result in a loss of economic value for the people impacted.

This analysis does not consider any fiscal impacts (e.g., reduced sales tax revenues) resulting from recreational area closures due to flooding. Washington State has a 6.5 percent sales tax and Pierce County has a 1.5 percent sales tax. Additional local sales taxes as well as lodging and other taxes are applicable in some locations. Reductions in taxable visitor spending would result in proportional reductions in sales tax revenues.

An important consideration in this analysis is that it only evaluates the potential loss of economic activity due to closures of recreation facilities that are caused by flooding events. This analysis does not consider any increases in economic activity resulting from the spending required to clean up and repair any sites or infrastructure damaged by flooding. This analysis is not a net effects impact analysis, but rather an evaluation of the potential loss in economic contributions associated with visitor spending at each of the sites.

This analysis does not directly evaluate any substitution effects that could retain economic activity within Pierce County if visitors are able to substitute to other sites. Substitution is most applicable for recreation sites that are less unique and there is a nearby alternative where visitors can engage in the same activity. For example, substitution is more difficult at locations such as Mount Rainier National Park, Crystal Mountain Resort, and Point Defiance Zoo and Aquarium that have unique offerings and no close substitutes available. For this reason, most trips that cannot occur due to flood-related closures at these sites are likely to result in full losses of spending within Pierce County and not substituted to other sites. In contrast, if flooding causes closures at sites with more common offerings, like parks and trails, visitors could substitute to alternative sites within Pierce County to engage in the activity, which would not result in a loss of associated economic activity.

If the visitation is local or non-local (i.e., from within Pierce County or not) is also a consideration that affects if visitors will substitute their trip, and their spending, to other locations within Pierce County. Non-local visitors will usually spend more than local visitors because they have to travel further and have additional costs associated with the additional time and distance. For example, if a non-local visitor is unable to go to Point Defiance Zoo and Aquarium they may choose to instead visit the Seattle Aquarium in King County. As a result, there would be a complete loss of spending and the associated economic activity for Pierce County. Where possible, we discuss any available information about the proportion of local compared to non-local visitors.

8.3 Mount Rainier National Park

8.3.1 Park Overview

At 14,410 feet high, Mount Rainier (called Tahoma by many local indigenous people) is the tallest peak in the Cascade Range. Mount Rainier National Park is the traditional land of the Cowlitz, Muckleshoot, Nisqually, Puyallup, Squaxin Island, and Yakama tribes. Indigenous traditional customs continue to be practiced today and are closely tied to the land.

Mount Rainier National Park was established in 1899 – it is the fifth oldest national park in the country. As a National Park, it is a popular tourist destination that draws both local visitors and non-local visitors, including international tourists. Approximately 1.5 million recreation visits were made to Mount Rainier National Park in 2019 (Table 8-1).[95] The months of May to

[95] Note that although 2020 data is available it is not used for this analysis due to the large variation in visitation that occurred from due to COVID-19 associated closures and public health warnings.

September were busiest with 83.5 percent of total visits made within that period. The 10-year averages calculated using data collected between 2010 and 2019 also mimic this trend.

Table 8-1 Visitation to Mt. Rainier National Park by Month

	2019		10-Year Average	
Month	Recreation Visits	Percent of Total	Recreation Visits	Percent of Total
January	12,933	0.9%	23,401	1.8%
February	11,743	0.8%	18,961	1.5%
March	32,101	2.1%	24,578	1.9%
April	29,632	2.0%	30,812	2.4%
May	106,136	7.1%	73,916	5.8%
June	219,641	14.6%	170,204	13.4%
July	365,200	24.3%	292,305	23.0%
August	378,305	25.2%	304,280	23.9%
September	184,166	12.3%	181,768	14.3%
October	74,355	5.0%	73,091	5.7%
November	48,248	3.2%	55,717	4.4%
December	39,161	2.6%	23,176	1.8%
Total	**1,501,621**	**100%**	**1,272,210**	**100%**

Source: U.S. National Park Service Visitor Use Statistics. (2020). *Recreation Visits by Month, Mount Rainier NP*. Available at: https://irma.nps.gov/Stats/SSRSReports/Park%20Specific%20Reports/Visitation%20by%20Month

Recreation activities available at Mount Rainier National Park include biking, mountaineering, hiking, snowplay, and camping.[96] Approximately 10,000 people per year attempt to climb Mount Rainier. The park features two inns, three car campgrounds, and several wilderness camping sites.[97] Visitors have the option of two restaurants, two snack bars, a café, and a general store for food and beverage purchases.[98] There are also popular interpretive visitors centers at Paradise, Longmire and Sunrise.

Tourism to the park is an important contributor to the economies of the gateway communities near the park entrances. As visitors travel through these communities they spend money on food, transportation, and other goods and services. There are three general routes into the park, from the southwest, the northwest, and the east. The southwest route is the most popular because it is located near population centers in the western part of the state, it is open year-round, and it provides access to a large area of the park. The southwest route via SR-161, SR-7, and SR-706 takes tourists through the communities of Ashford, Elbe, and Eatonville. The

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[96] U.S. National Park Service website, "Things To Do - Mount Rainier National Park". Available at: https://www.nps.gov/mora/planyourvisit/things2do.htm.

[97] U.S. National Park Service website, "Lodging - Mount Rainier National Park". Available at: https://www.nps.gov/mora/planyourvisit/lodging.htm.

[98] U.S. National Park Service website, "Restaurants - Mount Rainier National Park". Available at: https://www.nps.gov/mora/planyourvisit/restaurants.htm.

northwest route via SR-165 is through Wilkeson and Carbonado. The eastern route through SR-410 is through the town of Greenwater.

Table 8-2 provides a demographic overview of these communities. Although the gateway communities have small populations, they offer groceries, gasoline, resturants, and some retail to visiting tourists. Accordingly, visitation to the park drives a portion of their economies.

Table 8-2. Demography of Mount Rainier Gateway Communities, 2020

	Southwest			Northwest		East
	Ashford	**Elbe**	**Eatonville**	**Wilkeson**	**Carbonado**	**Greenwater**
Population	240	35	3,063	505	727	83
Households	100	15	1,154	190	250	34
Median Household Income	$53,332	$49,999	$63,078	$83,522	$87,499	$59,999
Non-White %	11.7%	11.4%	13.5%	7.33%	13.4%	6.0%
Total Dwellings	135	20	1,310	245	260	66
Total Dwellings Occupied	100	15	1,154	190	250	35
Owner Occupied %	75.0%	73.3%	74.56%	82.54%	90.16%	77.14%
Renter Occupied %	25.0%	26.6%	25.44%	17.46%	9.84%	0.23%
Labor Force	111	17	1,410	252	409	42
Unemployment rate	8.1%	11.8%	9.4%	7.5%	12.7%	0.0%

Source: GIS Planning website, *Washington Zoom Prospector*. Demographics Report for Ashford, Elbe, Greenwater, Eatonville, Carbonado, Enumclaw, and Wilkeson. Available at: http://washington.zoomprospector.com/

Mount Rainier National Park employs approximately 125 permanent employees (both full-time and part-time positions).[99] In addition to the permanent employees, the park also adds 175 temporary employees during the peak visitation season between May and September. Assuming these temporary employees are hired at wage grades ranging from WG-4 to WG-10, each temporary employee may earn between $22 to $35 per hour or an average of $28.50 per hour.[100] A previous National Park Service study reported that payroll at Mount Rainier National Park was $10.3 million in salaries and $2.3 million in benefits in fiscal year 2009 when employment was 243 (measured as full-year equivalent positions).[101] Applying these values to the employment estimate of 212 full-year equivalent positions (adjusting for temporary workers) suggests that the 2021 payroll and benefits level is approximately $13.6 million (2021 dollars).

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[99] U.S. National Park Service website, "Work With Us - Mount Rainier National Park". Available at: https://www.nps.gov/mora/getinvolved/workwithus.htm.

[100] Defense Civilian Personnel Advisory Service (DCPAS) website, "Benefits, Wage, NAF". Available at: https://www.dcpas.osd.mil/BWN/AFWageSchedules/.

[101] Stynes, D.J. (2011). *Economic Benefits to Local Communities from National Park Visitation and Payroll, 2009*. U.S. National Park Service. Natural Resource Report NPS/NRPC/SSD/NRR—2011/281.

8.3.2 Economic Contributions of Mount Rainier National Park

The National Park Service collects data on park visitation, visitor spending patterns and trip characteristics through visitor surveys. This data is used to estimate visitor spending at and in the surrounding gateway communities for National Parks. The estimated spending includes expenditures by local visitors who live in the gateway communities as well as non-local visitors who travel to the national parks from outside the communities. Visitor spending includes expenditures on amenities like lodging, camping fees, restaurants, groceries, gas, local transportation, recreation industries like equipment rental, and retail purchases like souvenirs.

8.3.2.1 Visitor Spending

Table 8-3 presents the National Park Service estimates for total spending by visitors to Mount Rainier National Park in 2019 for individual expenditure categories.[102] The expenditure values were updated from 2019 to 2021 dollar values using the Consumer Price Index (CPI) Inflation Calculator.[103] These spending estimates are for spending in communities within 60 miles of the National Park.

Table 8-3. Total Spending in 2019 by Park Visitors by Sector (2021 Dollars)

Sector	Direct Visitor Spending (Millions)	Percent of Total
Camping	$2.2	3.8%
Gas	$9.6	16.5%
Groceries	$4.7	8.1%
Lodging	$14.0	24.2%
Recreation Industries	$4.5	7.7%
Restaurants	$13.3	23.0%
Retail	$5.5	9.5%
Transportation	$4.2	7.2%
Total	**$57.9**	**100.0%**

Source: Thomas, C.C. and Koontz, L. (2020). *2019 National Park Visitor Spending Effects: Economic Contributions to Local Communities, States, and the Nation.* U.S. Department of Interior, National Park Service. Natural Resource Report NPS/NRSS/EQD/NRR—2020/2110.

In 2019, visitors to Mount Rainier National Park spent approximately $57.9 million in the surrounding communities of Yakima, Pierce, and Lewis counties, the majority of which was spent on lodging, restaurants and gas. Of this, 96.3 percent of visitor spending occurred from non-local visitors travelling from outside the local area surrounding the park.[104] Certain expenditures such as lodging and camping fees would be confined to Pierce County due to proximity to the park. For the remaining categories, this analysis estimates the portion of the

[102] Thomas, C.C. and Koontz, L. (2020). *2019 National Park Visitor Spending Effects: Economic Contributions to Local Communities, States, and the Nation.* U.S. Department of Interior, National Park Service. Natural Resource Report NPS/NRSS/EQD/NRR—2020/2110. Available at: https://pubs.er.usgs.gov/publication/70211321.

[103] U.S. Bureau of Labor Statistics website, "CPI Inflation Calculator". Available at: https://www.bls.gov/data/inflation_calculator.htm.

[104] Thomas, C.C. and Koontz, L. (2020). *2019 National Park Visitor Spending Effects: Economic Contributions to Local Communities, States, and the Nation.* U.S. Department of Interior, National Park Service. Natural Resource Report NPS/NRSS/EQD/NRR—2020/2110.

spending that likely took place in Pierce County. According to a Dean Runyan Associates analysis, approximately 64 percent of travel spending within the three counties occurs in Pierce County.[105] This percentage was applied to the categories of purchases that may have taken place across the three counties: gas, groceries, recreation industries, retail, and transportation. The total estimated spending in 2019 by visitors to Mount Rainier National Park in Pierce County was $42.9 million.

Table 8-4. Spending in Pierce County by Mount Rainier Park Visitors by Sector (2021 Dollars)

Sector	Visitor Spending (Millions)
Camping	$2.2
Gas	$6.1
Groceries	$3.0
Lodging	$14.0
Recreation Industries	$2.9
Restaurants	$8.5
Retail	$3.5
Transportation	$2.7
Total	**$42.9**

Source: Calculated by ECONorthwest using information from Thomas, C.C. and Koontz, L. (2020). *2019 National Park Visitor Spending Effects: Economic Contributions to Local Communities, States, and the Nation*. U.S. Department of Interior, National Park Service. Natural Resource Report NPS/NRSS/EQD/NRR—2020/2110.

Lodging, restaurants and gas make up the largest expenditures. The 10 year average of monthly shares of total recreation visits to the national park in Table 8-1 was used to add seasonality to the expenditure data. The recreational visitor spending by month and by sector is presented in Table 8-5.

Table 8-5. Estimated Monthly Spending in Pierce County by Mount Rainier Park Visitors (2021 Dollars)

Month	Total Spending
January	$790,000
February	$640,000
March	$830,000
April	$1,040,000
May	$2,495,000
June	$5,744,000
July	$9,865,000
August	$10,270,000
September	$6,135,000
October	$2,467,000
November	$1,880,000
December	$782,000
Total	**$42,938,000**

[105] Dean Runyan Associates. (2015). *Washington State County Travel Impacts & Visitor Volume 1991-2014p*. Prepared for Washington Tourism Alliance. Available at: http://www.lakechelan.com/wp-content/uploads/2018/01/WACoImp14pRev.pdf.

Source: Calculated by ECONorthwest

Average visitor spending varies depending on the type of visitor and the type of lodging the visitor seeks out. Average spending information is available at the national level from the National Park Service (Table 8-6). These spending levels include the spending categories of camping (if applicable), gas, groceries, lodging (if applicable), recreation industries, restaurants, retail, and transportation. Visitors who stay at a lodge within a National Park have the highest spending levels, while local visitors who visit for the day have the lowest spending levels.

Table 8-6. Average Visitor Spending at All National Parks

Visitor Segment	Average Spending per Party per Day/Night (2021 Dollars)
Local Day Trip	$39.49
Non-Local Day Trip	$92.30
NPS Lodge	$464.36
Lodge Outside Park	$343.79
NPS Camp	$127.67
Camp Outside Park	$140.51
Other	$46.36
Total	**$165.01**

Source: Thomas, C.C. and Koontz, L. (2020). *2019 National Park Visitor Spending Effects: Economic Contributions to Local Communities, States, and the Nation.* U.S. Department of Interior, National Park Service. Natural Resource Report NPS/NRSS/EQD/NRR—2020/2110. Table 1.

More detailed information about visitor spending is available from a 2012 survey of visitors to Mount Rainier National Park.[106, 107] On average, visitors to Mount Rainier National Park in 2012 spent $306 per trip (2021 dollars) both inside and outside the park for their group. The majority of this spending ($274 out of $306) was outside the park. On average, 28 percent of visitors spent money on lodging outside the park, including at a lodge, hotel, motel, cabins, bed and breakfast, vacation rental, etc. Due to Pierce County's proximity to the park it is likely that the majority of lodging expenditures were in Pierce County – particularly for the 81 percent of non-local visitors whose primary reason for being in the area is to visit Mount Rainier National Park (suggesting that they are not travelling elsewhere where they would seek lodging). Of the visitors who lodged outside of the park, 58 percent stayed one or two nights, while 42 percent of visitor groups stayed three or more nights.

8.3.2.2 Total Economic Contributions

The total economic contributions from visitation to Mount Rainier National Park have been calculated by the National Park Service.[108] However, these values are for all gateway

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[106] Manni, M. F., Le, Y., Hollenhorst, S.J. (2013). *Mount Rainier National Park Visitor Study: Summer 2012*. Prepared for U.S. Department of the Interior, National Park Service. Natural Resource Report NPS/NRSS/EQD/NRR—2013/376.

[107] Cook, P.S. (2013). *Impacts of Visitor Spending on the Local Economy: Mount Rainier National Park, 2012*. Prepared for U.S. Department of the Interior, National Park Service. Natural Resource Report NPS/NRSS/EQD/NRR—2013/721

[108] Thomas, C.C. and Koontz, L. (2020). *2019 National Park Visitor Spending Effects: Economic Contributions to Local Communities, States, and the Nation.* U.S. Department of Interior, National Park Service. Natural Resource Report NPS/NRSS/EQD/NRR—2020/2110.

communities, including some in Lewis County and Yakima County, and not defined for Pierce County alone. To disaggregate the economic contributions for only Pierce County we assume that all lodging is local and 64 percent of travel spending occurs in Pierce County.[109] This results in approximately 71 percent of the total economic contributions flowing to Pierce County.

Based on these calculations, the total spending in Pierce County as of 2019 was $42.9 million (2021 dollars). This direct spending supports a total of 450 direct and secondary jobs, $19.8 million in annual labor income, and $54.1 million in total economic output in Pierce County (Table 8-7).

Table 8-7. Local Annual Economic Contributions from Mount Rainier National Park (2021 Dollars)

	Total within All Gateway Communities	Pierce County Alone
Direct Spending	$57,883,000	$42,938,000
Jobs	608	450
Labor Income	$26,662,000	$19,778,000
Output	$72,938,000	$54,106,000

Source: Calculated by ECONorthwest using information from Thomas, C.C. and Koontz, L. (2020). *2019 National Park Visitor Spending Effects: Economic Contributions to Local Communities, States, and the Nation.* U.S. Department of Interior, National Park Service. Natural Resource Report NPS/NRSS/EQD/NRR—2020/2110.
Note: Local gateway region definitions are defined by the National Park Service by working directly with staff at each park to identify the nearby towns and cities (and counties) where visitors typically stop and make purchases or spend the night while visiting the park

8.3.3 Economic Impacts Associated with Park Closure

Heavy rain and flooding have closed Mount Rainier National Park in the past and future flooding presents a risk of future closures. When the park is closed there is missed economic activity due to the absence of visitors and their associated spending – both in the park itself as well as in the gateway communities that provide goods and services to park visitors. A park closure during the peak season from May to September when 80 percent of the visitation occurs would have larger economic impacts than in the non-peak season, but both would result in lower levels of economic activity as a result of the closure.

This analysis presents the results of four scenarios: one week and one month closures during both the peak and non-peak season. For purposes of this analysis we consider only the lost economic contributions resulting from the loss of visitation to the park during these time periods.[110] An assumption within this analysis is that all visitation to the park is lost due to the closure and visitors do not spend funds within Pierce County at substitute sites.

8.3.3.1 Prior Flooding History

Mount Rainier National Park has experienced closures due to flooding in the past. Heavy rains and flooding can washout roads and result in landslides, making the park inaccessible. In February 2020 the park experienced a closure due to flooding and mudslides that affected SR-

[109] Dean Runyan Associates. (2015). *Washington State County Travel Impacts & Visitor Volume 1991-2014p*. Prepared for Washington Tourism Alliance. Available at: http://www.lakechelan.com/wp-content/uploads/2018/01/WACoImp14pRev.pdf.

[110] This analysis does not consider the economic contributions associated with any spending for road repairs or other activities resulting from flood damage.

706 and SR-410.[111] It took 16 days before the SR-706 entrance to the park reopened.[112] The largest flood event in Mount Rainier National Park's history was on November 5, 2006 when the park was closed for 6 months following a massive flooding event. Heavy rains washed away portions of roads, trails, bridges, and other infrastructure while landslides also damaged roadways. The National Park Service estimates that damage to roads, trails, campgrounds, and buildings exceeded $36 million.[113]

8.3.3.2 Methodology

To understand the potential costs of future flooding, this analysis estimates the direct economic impact of one week and one month closures during the peak and non-peak season. The peak season is May through September and the non-peak season is October through April. These various time periods inform the relative impact depending on the time of year of the closure. These results can also be scaled to inform relative magnitudes of multi-week and multi-month closure periods. Flooding is more likely in the non-peak season which corresponds to the rainy season in the Pacific Northwest.

The economic impact of park closure is based upon the proportional decline in economic contributions in Pierce County gateway communities, presented in Table 8-7, for the one week and one month scenarios in the peak and non-peak seasons. Visitation during each season and timeframe is calculated based on the average of 2019 visitation (Table 8-1) for the peak and non-peak months. Average weekly visitation is calculated by dividing the monthly visitation by the number of days in the month and multiplying by seven, then averaging the weekly visitation for the peak (May-September) and non-peak (October-April) months.

8.3.3.3 Scenario Results

The potential loss in economic contributions for each of the four scenarios is presented in Table 8-8. A closure of one month in the peak season would result in a loss of direct visitor spending for Pierce County of approximately $7.2 million dollars and total lost output of $9.0 million.

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[111] U.S. Department of the Interior, National Park Service. (2020). *Mudslides and Flooding Block Entrances to Mount Rainier National Park*. February 8. Available at: https://www.nps.gov/mora/learn/news/mudslides-and-flooding-block-entrances-to-mount-rainier-national-park.htm

[112] U.S. Department of the Interior, National Park Service. (2020). *Mount Rainier National Park Reopens After February Mudslides Blocked Access*. February 24. Available at: https://www.nps.gov/mora/learn/news/mount-rainier-national-park-reopens-after-february-mudslides-blocked-access.htm

[113] U.S. Department of the Interior, National Park Service. (2019). *November 2006 Flood*. July 11. Available at: https://www.nps.gov/mora/learn/news/november-2006-flooding.htm

Table 8-8. Potential Lost Economic Contributions Associated with One Week and One Month Park Closure Scenarios in Peak and Non-Peak Seasons (2021 Dollars)

			Potential Economic Contribution Losses		
	Average Visitation	Loss of Visitor Spending	Jobs Supported	Labor Income Supported	Output Supported
Peak Season Impacts					
Peak Month	250,690	$7,168,000	75	$3,292,000	$9,006,000
Peak Week	57,215	$1,636,000	17	$751,000	$2,055,000
Non-Peak Season Impacts					
Non-Peak Month	35,453	$1,014,000	11	$466,000	$1,274,000
Non-Peak Week	8,130	$232,000	2	$107,000	$292,000

Source: Calculated by ECONorthwest using information from NPS (2019) and Dean Runyan Associates (2015)

The industries affected by this loss of revenue are those associated with tourism, including restaurants, lodging, grocery, retail, etc. (see Table 8-4. Spending in Pierce County by Mount Rainier Park Visitors by Sector (2021 Dollars) for all associated tourism industries). Without this visitor spending, these industries will make fewer sales, resulting in lower demand for their suppliers. The industries will also have less revenue to use to pay their employees and use as income for the owners and the business.

Key differences between the scenarios are the potential impacts on workers. A closure of one week to one month likely would not result in loss of permanent or temporary employees. However, a longer closure like the one in 2006 could result in the loss of permanent and/or seasonal jobs, particularly if the closure occurs during the peak season, which is when the majority of temporary workers are hired but the least likely time for flooding to occur.

8.4 Crystal Mountain

8.4.1 Resort Overview

Crystal Mountain Ski Resort is the largest ski resort in Washington, spanning 2,600 acres. It is located on the eastern edge of Pierce County and is accessed via SR-410. Since its opening in 1962, the resort has expanded to include over 80 ski runs and 11 ski lifts that can carry 19,888 passengers per hour. The resort enjoys 480 inches of snowfall annually on average. It hosts several restaurants for dining, an equipment rental shop, a demo shop, and a retail shop for apparel and accessories. One ski lift is an enclosed gondola, popular with tourists, which provides access to one of the resort's restaurants and to stunning views of Mt. Rainier and the Cascade range. Crystal Mountain Resort offers a wide range of activities from skiing, snowboarding, and snowshoeing in the winter season to scenic gondola rides, hiking, mountain biking, and horseback riding in the summer.

Only two hours from Seattle, Crystal Mountain Resort serves an average of 430,000 per year.[114] The highest visitation to the resort is in the winter season between November and April which has an average of 350,000 visitors. Approximately 98 percent of visitors during the winter season are from the Puget Sound region. Approximately 80,000 visits are made to the resort during the summer months of May to October. Of these, approximately 60 percent of visits are from people within the Puget Sound region. The resort is open seven days a week during the winter and in the summer between June and Labor Day weekend but is open only on the weekend from May to June and the month of September.

Crystal Mountain Ski Resort employs approximately 77 permanent employees.[115] During each season the resort employs temporary employees for jobs including ski patrol, ticket sales, ski lift personnel, parking attendants, and food service workers. During the winter season the resort employs an additional 525 temporary workers. During the summer season the resort employs approximately 70 temporary workers. The average hourly wage for the temporary employees is between $14.50 and $16.00 during the summer and winter seasons, respectively, as of 2020. Assuming employees work 8 hours a day, in total Crystal Mountain Ski Resort would disburse $8,120 a day and $67,200 a day on temporary employee wages in the summer and winter, respectively.

8.4.2 Economic Contributions of Crystal Mountain

8.4.2.1 Visitor Spending

The monthly average number of recreation visits made to the resort is 58,333 in the winter season and 13,333 in the summer season for a total of 430,000 visits per year. Historically, the highest volume days for visitation are the days before and after Christmas and through the New Year, as well as the weekends of Martin Luther King Jr. Day and Presidents Day.

Crystal Mountain has not completed their own visitor survey to develop specific spending patterns, habits, or demographics for their visitors. In lieu of this site-specific information, the U.S. Forest Service's National Visitor Use Monitoring (NVUM) Program has data on visitor and trip characteristics, including visitor spending for skiing and snowboarding.[116]

The NVUM program estimates that spending on downhill skiing and snowboarding varies from a low of $69 per party per day for local residents on day trips to $232 per party per day for non-local overnight visits staying in a motel (2021 dollars). On average, visitors spend a total of $181 per visit per party (Table 8-9). A large component of the trip is the entry fee (i.e., lift tickets), as well as lodging for overnight visitors. The average party size ranges from a low of

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[114] Personal communication with Crystal Mountain Resort in June 2021.

[115] Personal communication with Crystal Mountain Resort in June 2021.

[116] White, E. M. (2017). *Spending patterns of outdoor recreation visitors to national forests*. Gen. Tech. Rep. PNW-GTR-961. Portland, OR: US Department of Agriculture, Forest Service, Pacific Northwest Research Station. Available at: https://doi.org/10.2737/PNW-GTR-961.

2.1 persons for local day trips to 3.0 persons for non-local overnight trips.[117] Average number of days per visit is 2.7; with a range from a low of 1.0 days for day trips (local and non-local) to a high of 4.7 for overnight visitors that stay in a private home.

Table 8-9. Per Party per Day Spending Profile for Downhill Skiers and Snowboarders (2021 Dollars)

Sector	Per Party Per Day Spending (2021 Dollars)	Percent of Total
Lodging	$49.56	27%
Camping	$0.19	0%
Restaurant	$35.86	20%
Groceries	$16.11	9%
Gas and Oil	$17.39	10%
Other transportation	$0.57	0%
Entry fees	$25.66	14%
Recreation and entertainment	$24.84	14%
Sporting goods	$6.09	3%
Souvenirs and other expenses	$5.32	3%
Total	**$181.58**	**100%**

Source: White, E. M. (2017). *Spending patterns of outdoor recreation visitors to national forests*. Gen. Tech. Rep. PNW-GTR-961. Portland, OR: US Department of Agriculture, Forest Service, Pacific Northwest Research Station.

Combining the information on visitor spending from the NVUM with visitation estimates suggests that the total average visitor spending per month is $11.2 million in the winter season, suggesting average daily visitor spending of $367,000 (Table 8-10). Note that daily visitation can fluctuate heavily for weekend versus weekday visits depending on snow conditions.

Table 8-10. Average Visitor Spending for Downhill Skiing and Snowboarding in National Forests (2021 dollars)

	Number of Visitors	Number of Parties	Total Spending
Annual Winter Visits	350,000	137,255	$67,290,000
Monthly Winter Visits	58,333	22,876	$11,215,000
Weekly Winter Visits	13,425	5,265	$2,581,000
Daily Winter Visits	1,918	752	$367,000

Source: Calculated by ECONorthwest using information from White (2017) and Crystal Mountain Ski Resort (2021)

8.4.2.2 Total Economic Contributions

The winter season is the focus of this analysis because flooding is most likely to occur and affect visitation in the winter season and there are large differences in visitation and spending between summer and winter activities. The activities available in the summer also have substitutes available within Pierce County, with the exception of gondola rides, suggesting that

[117] Local visitors are those who have traveled 60 miles or less from home to reach a recreation site. Day visitors are those who did not report a night spent in a local (within 50 miles) forest area.

forgone visits to Crystal Mountain in the summer would be able to be substituted by other locations in Pierce County.

The spending by visitors to Crystal Mountain Ski Resort represents the direct impact from visitors. In addition, there are secondary impacts associated with that spending as it recirculates through the local economy and supports additional jobs, labor income, and economic activity. The average monthly economic contributions are calculated using IMPLAN for the spending categories from White (2017). Because flooding is most likely to affect visitation in the winter season, the results are presented for only the winter season visitation and visitor spending.

Jobs are calculated using the direct jobs information provided by Crystal Mountain, normalized from position estimates to FYE jobs by dividing the temporary jobs by two. Additional direct jobs and secondary jobs are calculated using IMPLAN without the industries corresponding to "entry fees" and "Recreation and entertainment" – assuming that these expenditures support jobs at the resort and are thus covered by direct employment.

The annual economic contributions associated with Crystal Mountain Resort are displayed in Table 8-11. Spending by visitors to Crystal Mountain supports approximately 557 jobs, $13.5 million in labor income, and $36.2 million in total economic output. The majority of the jobs are at Crystal Mountain Resort, but spending also supports other jobs, particularly in the hospitality industry. As local employees then spend their paychecks in Pierce County that money further recirculates to support additional jobs and economic activity.

Table 8-11. Economic Contributions of Crystal Mountain Resort in the Winter Season (2021 Dollars)

	Total Spending	Total Jobs Supported (FYE)	Total Labor Income Supported	Total Output Supported
Total Winter Season	$24,922,000	557	$13,537,000	$36,188,000

Source: Created by ECONorthwest using IMPLAN, Pierce County, WA Model (2019)

8.4.3 Economic Impacts Associated with Resort Closure

8.4.3.1 Prior Flooding History

Crystal Mountain Resort has closed in the past due to mudslides that result in road closures, impeding access to the resort. Crystal Mountain Resort is accessed via SR-410 in the winter, and this road has been closed in the past which impacts resort operations. In February 2020 a mudslide on SR-410 caused Crystal Mountain Resort to close for four days, including Saturday and Sunday of what is typically a busy weekend. The flooding in 2006 that resulted in the closure of Mount Rainier National Park did not have similar impacts at Crystal Mountain Resort because it occurred before the resort opened for the winter season. However, flooding over SR-410 in this event could have closed the resort, had it occurred when the resort was operational. SR-410 runs along the White River, which contains high amount of sediment from runoff of Mount Rainier. With more sediment deposited into the riverbed, the height of the White River increases, resulting in higher flood risk over time.

8.4.3.2 Methodology

The analysis considers only visitation during the winter season since those activities overlap with when flooding is most likely to occur. There are three scenarios associated with resort closures of various time periods: one day, one week, and one month. Based on past closures due to flooding and mudslides, unless roads are significantly damaged the most likely closure scenario is less than one week. However, significant road damage could result in longer periods of closure, so the one week and one month scenarios are also included for reference.

The economic impacts of these closures is a proportion of the annual economic contributions provided in Table 8-11. Accordingly, the results are based on average visitation levels and do not take into consideration differences in visitation if the day is a weekday or weekend or if the closure occurred in the early season, mid-season, or late season. For purposes of this analysis we assume that all visitor spending and all jobs at Crystal Mountain Resort occur in Pierce County.

8.4.3.3 Scenario Results

The potential loss in economic contributions for each of the three closure scenarios at Crystal Mountain Resort is presented in Table 8-12. A closure of one day would result in lost visitor spending of approximately $369,000, which would mean that the spending is not available to businesses to support 5 jobs, $200,000 in labor income, and $535,000 in total economic output. Longer closures of one week and one month would have more severe impacts to economic activity. In the shorter closure scenarios the most likely impact is that businesses would restrict employee hours, resulting in reduced wages. Longer closures could result in layoffs or reductions in hiring.

Table 8-12. Economic Contributions of Crystal Mountain Resort in the Winter Season (2021 Dollars)

	Total Spending	Total Jobs Supported (FYE)	Total Labor Income Supported	Total Output Supported
One Month	$11,215,000	154	$6,091,000	$16,284,000
One Week	$2,581,000	36	$1,402,000	$3,748,000
One Day	$369,000	5	$200,000	$535,000

Source: Created by ECONorthwest using IMPLAN, Pierce County, WA Model (2019)

8.5 Chambers Creek Regional Park

8.5.1 Park Overview

Chambers Creek Regional Park is located along the shore of south Puget Sound, southeast of Tacoma. The park is managed by the Pierce County Parks and Recreation Department. Initially settled by the Steilacoom Indian Tribe, the region underwent industrial development after European settlers arrived.[118] Since the 1850s, the land was used for various commercial activities like paper mills and lumber companies, as well as a railroad center. It eventually became the

[118] Pierce County website, "History". Available at: https://www.co.pierce.wa.us/3454/History.

largest producer of sand and gravel in the country.[119] Mining continued until 2003 after which the land was converted for use as a recreational park and as the site for the Chambers Creek Regional Wastewater Treatment Plant.

Chambers Creek Regional Park covers 930-acres and includes the Chambers Bay Golf Course, Chambers Bay Clubhouse and Grill, and Chambers Creek Canyon Park. There are trails and recreation opportunities through shoreline access, urban creek and canyon access, walking trails, two soccer fields, a dog park, a playground, and two open space meadows. The meadows may be rented as event space; each rental generates $1,701 in revenue and the average number of rentals is approximately 11 times in a year.[120,121] The park is set to generate more recreational opportunities in the future as it develops the Chambers Bay Resort and finalizing the Chambers Creek Canyon trail.[122, 123]

8.5.2 Economic Contributions of Park Visitation

The economic contributions of visitation to Chambers Creek Regional Park represent the spending that visitors make in Pierce County when they visit. The largest source of spending at Chambers Creek Regional Park is the golf course, since that has admissions fees and visitors stay for multiple hours at a time. Although there is no admission fee for other daily park use (excluding events), visitors could still spend money in the local economy on things like gasoline, restaurants, grocery, retail, and other items due to their trip to a local trail. Visitors coming from further distances will generally spend more than local visitors. However, the majority of visits to the park for things like walking, seeking open space, dog park visits, and other similar visit types likely have no associated spending.

8.5.2.1 Trail Use

The Chambers Creek Regional Park has two primary trails – Grandview trail (1.25 miles) and Soundview trail (2 miles).[124] A third major trail, Chambers Creek Canyon Trail, is under development. Pierce County Parks and Recreation Department uses a trail counter to track the use of trails at its parks. They recorded 559,855 counts and 524,569 counts of trail use for Grandview and Soundview trails, respectively, during 2019 (Table 13). The trail usage was

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[119] Chambers Bay Golf website, "The History of Chambers Bay". Available at: https://www.chambersbaygolf.com/history/.

[120] Pierce County Parks and Recreation. (2017). *Pierce County Parks and Recreation Annual Report 2017.* Available at: https://www.piercecountywa.gov/DocumentCenter/View/73961/Final_ParksReport_Digital.

[121] Personal Communication with NeSha Thomas-Schadt, Pierce County Parks, on February 10, 2021.

[122] Pierce County website, "Chambers Bay Resort". Available at: https://www.co.pierce.wa.us/4858/Chambers-Bay-Resort.

[123] Pierce County website, "Chambers Creek Canyon Trail". Available at: https://www.piercecountywa.gov/6673/Chambers-Creek-Canyon-Trail

[124] Pierce County website, "Chambers Creek Regional Park Trails". Available at: https://www.piercecountywa.gov/2417/Trails.

highest between the months of May and August. On average, approximately 1,400 to 1,600 counts were recorded on each trail per day.

Table 8-13. Trail Use Counts for Chambers Creek Regional Park (2019)

Month	Grandview Trail	Soundview Trail
January	19,504	16,399
February	30,279	29,007
March	47,895	43,731
April	50,245	31,544
May	67,381	57,878
June	64,233	60,978
July	66,838	67,151
August	63,721	62,793
September	40,806	37,837
October	40,622	51,343
November	32,604	34,797
December	35,727	31,111
Total	**559,855**	**524,569**

Source: Burgess, B. (2020). *Pierce County Parks Department.* Trail Counter data for January to December 2019. October 20.

Although there may be some spending in Pierce County by visitors who use the trails, the majority of local trips do not have associated spending. Absent information on local and non-local trail visitors, for the purpose of this analysis we assume that there is no economic contribution in the form of visitor spending associated with trail use at Chambers Creek Regional Park.

8.5.2.2 Chambers Bay Golf Course

The Chambers Bay Golf Course is an 18-hole championship golf course and driving range where locals and non-locals can enjoy golfing activities. The golf course also has a restaurant and an academy for golf lessons.[125] On average, the number of rounds played per year is approximately 31,186. The most popular golfing months are the summer months of June to September when both the number of rounds and the revenue generated per round is highest (due to dynamic pricing for rates). On average, the total annual revenue generated by golf rounds is $6.0 million. The resort also generates additional revenue from merchandise, food, and beverage sales. Chambers Bay employs a total of 145 employees, 55 of whom are full-time, and 90 who are part-time. Of those, 137 are permanent employees and 88 are seasonal during the busy season from May through September.

Table 8-14. Average number of rounds, revenue per round and total revenue generated at Chambers Bay Golf Resort by Month (2010-2020)

Month	Rounds	Total Revenue (Nominal Dollars)
January	1,175	$133,331
February	1,462	$169,088

[125] "The History of Chambers Bay," Chambers Bay, accessed February 11, 2021, https://www.chambersbaygolf.com/history/.

Month	Rounds	Total Revenue (Nominal Dollars)
March	1,937	$262,093
April	2,740	$427,112
May	3,282	$614,520
June	3,541	$893,106
July	4,600	$1,015,920
August	4,431	$1,011,219
September	3,643	$764,458
October	2,667	$416,678
November	1,401	$180,920
December	1,283	$195,042
Total	**32,162**	**$6,083,488**

Source: Based on monthly data on rounds and revenue per round for 2010-2020 provided by Chamber Bay Golf Course. Total revenue is a product of rounds and revenue per round.

The economic contributions associated with golfing at Chambers Bay Golf Course are driven by the spending by golf visitors which funds the golf course and allows the facility to spend on employee wages, maintenance and operations, and other supply purchases. Beyond the revenue to the golf course, economic contributions will also flow from any spending that visitors make associated with their golf trip, such as transportation and food costs outside of the resort. The largest economic impacts will be from non-local golfers who spend additional funds beyond the average on transportation, lodging, and food.

The economic contributions associated with the revenues to Chambers Bay Golf Course alone support a total of $9.8 million in economic activity in Pierce County. These economic impacts only consider spending at Chambers Bay Golf Course based on gross revenues and the secondary economic impacts associated with supply-chain and employee spending. For purposes of this analysis we assume that all expenditures attributable to the golf course occur at the resort, and there are not additional expenditures outside of the resort on lodging, transportation, food and beverage, etc. To the extent that visitors also purchase goods and services outside of the resort on a trip to Chambers Bay Golf Course then there will be additional economic activity in Pierce County.

Table 8-15. Economic Contributions of Revenues to Chambers Bay Golf Course (2021 Dollars)

	Employment	Labor Income	Output
Direct	137	$2,321,000	$6,083,000
Secondary	20	$1,017,000	$3,669,000
Total	**157**	**$3,338,000**	**$9,753,000**

Source: Calculated by ECONorthwest using IMPLAN, Pierce County, WA Model (2019)

8.5.3 Economic Impacts Associated with Park Closure

While certain weather events like extreme snow, wind, or ice can lead to temporary closures of outdoor facilities like the golf courses, the County Parks and Recreation Department did not report any history of park closures due to flooding. Heavy rain events that would lead to a 100-year flood would require any rentals of outdoor spaces at the park to be moved indoors or postponed. The Chambers Bay Golf Resort reported that it has not experienced a closure of the entire facility due to rain. While the number of visitors decreases during rain events, the sand and gravel make-up of the site reduces the impact of surface water and allows the facility to operate. Given the limited history of flooding at this site, future flood closures would likely be limited to short periods of time.

Economic impacts to recreation resources are most likely to occur during the rainy season which corresponds to lower levels of use at Chambers Bay Golf Course compared to the busy summer season. The economic impacts associated with a one week closure at Chambers Bay Golf Course stem from the potential loss of approximately 418 rounds of golf that would not be played (Table 8-16). The revenue from the rounds and associated spending on other revenue to the golf course would be a loss that represents two employment positions, $43,000 in total labor income, and $127,000 in total economic activity (including both direct and secondary impacts). A closure in the busier season from May through September would have larger economic impacts.

Table 8-16. Economic Contributions Associated with Chambers Bay Golf Course Closures in Low Season and High Season (2021 Dollars)

	Rounds	Total Employment	Total Labor Income	Total Output
High Season - Per Week (May-Sept)	891	4	$93,000	$270,000
Low Season - Per Week (Oct-April)	418	2	$43,000	$127,000

Source: Calculated by ECONorthwest using IMPLAN, Pierce County, WA Model (2019)

8.6 Point Defiance Park

8.6.1 Park Overview

Previously an undeveloped federal military reservation, Point Defiance was converted into a park in 1888.[126] The 700-acre park, located along Puget Sound in the city of Tacoma, features a large number of attractions and activities that make it a popular destination for local recreation. Point Defiance Park is managed by Metro Parks Tacoma.

The park is home to the Point Defiance Zoo and Aquarium and the Fort Nisqually Living History Museum that averages over 1,000 visitors per day. Visitation is especially high during the summer months. Visitors can enjoy waterfront activities like boating, fishing and picnicking at Owen Beach, the Point Defiance Marina, and at the Dune Peninsula. The park features multiple walking trails, gardens, an off-leash dog park, and a five-mile loop that allows visitors to enjoy the park forests. With various public venues like picnic shelters, plazas and pavilions, the park is also used to host events.

This analysis focuses on flooding impacts to Point Defiance Zoo and Aquarium and Fort Nisqually Living History Museum. Visitation outside of these two facilities is not considered in

[126] "Point Defiance Park History," Metro Parks Tacoma (blog), accessed June 15, 2021, https://www.metroparkstacoma.org/point-defiance-park-history/.

this analysis since several of the recreational activities like trail use and picnicking enjoyed at the park can be easily substituted by other sites or activities in Pierce County. These sites also have visitation and revenue informational available. Although other sites within Point Defiance Park, particularly Owen Beach and 5 Mile Drive, are also unique offerings within the Tacoma metro area, these sites do not have visitation information. As a result, the conclusions that can be drawn about flooding impacts are discussed qualitatively.

8.6.2 Economic Contributions of Point Defiance Park

8.6.2.1 Visitation to Point Defiance Zoo and Aquarium

The Point Defiance Zoo and Aquarium (PDZA) spans 29 acres and was established in 1905.[127] It is the only combined zoo and aquarium in the Pacific Northwest. Admission to the park is free. There is a fee to visit the zoo and aquarium of $14 to $20 depending on age (excluding free days and discounts). During the holiday season, from late November to early January, PDZA also sells tickets to the Zoolights event, a festive lightshow using 700,000 LED lights. The park features three food and beverage stations and two gift shops.

Located 40 miles from Seattle and 30 miles from Olympia, the PDZA is a popular local tourist destination. In 2019, PDZA received 827,470 visitors with 724,364 general day visitors and 103,106 visitors for Zoolights. On average from 2015 to 2019, 641,491 people visit PDZA for general attendance and 110,807 people visit PDZA for the Zoolights event annually (Table 8-17). In 2019, PDZA reported earned revenue amounting to $13.1 million, of which approximately 85 percent came from ticket sales for admissions and membership.

Table 8-17. Paid and Unpaid Recreation Visits to Point Defiance Zoo and Aquarium (2015 to 2019)

Year	General Attendance	Zoolights Attendance	Total Attendance
2015	628,636	103,572	732,208
2016	585,901	110,755	696,656
2017	570,486	122,443	692,929
2018	698,070	114,159	812,229
2019	724,364	103,106	827,470
Average	**641,491**	**110,807**	**752,298**

Source: Personal Communication with Donna Powell, "Information Request: Flood Closures and Visitation Data," January 25, 2021.

While Zoolights is a popular attraction at PDZA during the winter months, recreational visitation to the Zoo and Aquarium, in general, is highest during the summer months between May and August. In 2019, PDZA received over 720,000 visitors through General Attendance with over 50 percent visiting the Zoo during the summer months (Table 8-18). This seasonality in recreational visitation was applied to the annual revenue earned by PDZA in admissions and memberships in 2019. As a result, $12.9 million, to estimate the seasonal revenue earned by PDZA in 2019.

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[127] Point Defiance Zoo & Aquarium website, "About Us at Point Defiance Zoo & Aquarium: Team, Mission, Vision, History". Available at: https://www.pdza.org/connect/about/.

Table 8-18. Number of General Attendance Recreation Visits and Revenue to PDZA in 2019 by Month

Month	Number of Visitors	Revenue (2019 Dollars)	Percent of Total
January	42,313	$657,698	5.9%
February	20,811	$323,479	2.9%
March	70,419	$1,094,567	9.7%
April	63,590	$988,420	8.8%
May	80,559	$1,252,180	11.1%
June	93,549	$1,454,091	12.9%
July	111,447	$1,732,291	15.4%
August	110,089	$1,711,183	15.2%
September	48,652	$756,229	6.7%
October	32,623	$507,080	4.5%
November	27,839	$432,719	3.9%
December	20,747	$322,484	2.9%
Total	**722,638**	**$11,232,421**	**100%**

Source: Calculated by ECONorthwest using daily attendance data provided by PDZA

8.6.2.2 Visitation to Fort Nisqually History Museum

At the Fort Nisqually Living History Museum, visitors can engage with history and information about Fort Nisqually, the first globally connected European settlement on the Puget Sound. Fort Nisqually was established in 1833 when the British Hudson's Bay Company used it as a fur trading outpost. While the original settlement was located in DuPont, Washington, it was reconstructed at its current location in Tacoma in the 1930s. The Museum offers tours and hosts several informational events through the year. There is a fee of $8.58 for youth, $10.82 for military/seniors, and $11.94 for adults. During fiscal year 2015, the museum received 14,163 paid admissions in total.[128] This averages to 1,180 admissions per month. Visitation is generally higher in the summer months and lower in the winter months, matching the higher visitation patterns in the larger Point Defiance Park area.

8.6.2.3 Economic Contributions

This analysis calculates the economic contributions associated with visitation to Point Defiance Park for only PDZA and Fort Nisqually Living History Museum. Visitation at these facilities supports employee wages, maintenance and operations, supply purchase, etc. at the sites. Beyond the revenue to the facilities, economic contributions will also flow from any spending that visitors make associated with their trip, such as transportation and food costs on their way to or from the site. The largest economic impacts will be from non-local visitors who spend additional funds beyond the average on transportation, lodging, and food.

[128] Metropolitan Park District of Tacoma. (2016). *Mission-Led Comprehensive Program Plan Final Report 2016-2022.* Available at: https://www.metroparkstacoma.org/about/agency-plans-partnerships/mission-led-comprehensive-plan/.

Spending outside Point Defiance Park would only be an economic contribution of the park if the primary reason that visitors are making the trip to the area is to visit sites at Point Defiance Park. It is unclear how much non-local visitors spend outside of the park and how many come to the area for the primary reason of visiting a site like PDZA or Fort Nisqually Living History Museum. Accordingly, we do not offer estimates of additional visitor spending to augment the economic contributions, but do know there is some additional economic activity supported in Pierce County from these sites.

8.6.3 Economic Impacts Associated with Park Closure

Facilities within Point Defiance Park occasionally experience closures due to extreme snow, wind or ice weather events but they do not report any flooding or closures due to heavy rain. There are three routes that can be used to access Point Defiance Park, so road closures due to flooding are unlikely to affect all three routes and result in park closures. Given that PDZA attendance is highest during the summer and the peak flooding season in the region occurs in the winter, the attraction does not anticipate significant impacts on its operations and revenue. If PDZA and/or Fort Nisqually Living History Museum was to be closed because of a flooding event the impact on revenue would be proportional to the monthly revenues reported above.

Flooding within the Point Defiance Park could impact specific trails and other recreation features, resulting in partial closures. Because there is limited visitor spending associated with these closures there would not be financial impacts to the Pierce County economy, but visitors would need to substitute to other sites to engage in similar recreation experiences.

8.7 Recreation Impacts Summary

Flood-related impacts to recreation in Pierce County will vary by the site affected, the length of the closure, and the season. In particular, time of year will influence the magnitude of the effect. For example, impacts in the winter ski season on popular weekends will have much larger economic impacts compared to flooding in the shoulder season for winter recreation activities. In addition to the flood risks at the four sites evaluated in this analysis, there may be other locations not considered in this analysis that are more prone to the effects of flooding but because they draw smaller attendance will have relatively less economic impact. Flooding on fields during the fall and spring sports seasons will impact field sports and the people who play them, particularly youth sports.

The likelihood of recreation site closures due to flooding is dependent on accessibility in the event of road closures as well as any damage to the recreation site itself. Crystal Mountain Resort and Mount Rainier National Park are most at risk because they are located in rural areas with limited access roads, particularly in the winter season. As such, a road closure due to a mudslide or other flooding damage can impede access and close the site for long periods of time. Examples of these flood-related closures include the four-day closure in 2020 at Crystal Mountain Ski Resort and the six month closure in 2006/2007 at Mount Rainier National Park.

The economic impact to Pierce County of recreation closures due to flooding will depend on visitors ability to substitute to other sites. Activities that are offered more broadly at multiple sites, like parks and trails, will be easier to substitute than at sites with unique offerings like Mount Rainier National Park, Crystal Mountain Resort, and Point Defiance Zoo and Aquarium. Visitors to these sites spend significant time travelling to and from the locations and on the way contribute to the economies of local communities as they spend money on food, lodging, and transportation. As unique sites these locations also draw visitors from outside of Pierce County which brings in economic activity that would not otherwise be in the county.

9 Flood Impacts to Wastewater Treatment Plants and Overflows

9.1 Introduction

Wastewater treatment plants (WWTPs) provide a critical community service by treating wastewater before releasing it back into local waterways. Flooding could affect wastewater treatment plant operations and harm the community by disrupting wastewater treatment processes and potentially causing a discharge of untreated sewage. Such events could result in environmental contamination, costs to clean up spilled sewage, potential fines, and potentially economic costs to service area customers.

9.2 Overview of Pierce County WWTPs

There are 20 WWTPs that treat and discharge wastewater in Pierce County.[129] To estimate the environmental impact of a 100-year flood event in Pierce County, this analysis focused on the four WWTPs located near or within the 100-year floodplain:

- **Tacoma Central Wastewater Treatment Plant (CTP)** has a service area of 77,398 customers that includes the City of Tacoma and about 20,000 customers in Fife, Fircrest, and unincorporated Pierce County.[130] It has a maximum daily flow capacity of 150 million gallons per day (mgd).[131] The WWTP was originally constructed in 1952. Tacoma CTP discharges into Commencement Bay and is located within the Port of Tacoma in the Chambers Bay/Clover Creek sub-planning area. Tacoma CTP was flood proofed through floodwalls by a project partially funded by Pierce County Flood Control Zone District.
- **Puyallup Water Pollution Control Plant (WPCP)**, provides services to the City of Puyallup as well as to unincorporated sections of Pierce County to the south of the city. The WWTP was originally constructed in 1984. The service area covers 18.6 square miles and includes 11,410 customers, made up of residential units (single and multi-family)

[129] Pierce County website, Pierce County Open Data ArcGIS, "Waste Water Treatment Plants". Available at https://gisdata-piercecowa.opendata.arcgis.com/datasets/piercecowa::waste-water-treatment-plants/about.

[130] City of Tacoma website, "Central Wastewater Treatment Plant". Available at: https://www.cityoftacoma.org/government/city_departments/environmentalservices/wastewater/wastewater_system/ctp

[131] Direct Communication with Lance Bunch, Tacoma Central Wastewater Treatment Plant, on December 8, 2020.

and a core commercial area.[132, 133] It has a maximum daily flow capacity of 13.9 mgd.[134] Puyallup WWTP is located in the Mid-Puyallup sub-planning area and discharges into the Puyallup River. Puyallup WPCP was flood proofed through floodwalls by a project in 2016 partially funded by Pierce County Flood Control Zone District.

- **Sumner WWTP** serves 28,700 customers in the city of Sumner, Bonney Lake, and portions of unincorporated Pierce County. The service area covers over 15 square miles. The WWTP processes 860 million gallons of wastewater every year.[135] It has a maximum daily flow capacity of 11.66 mgd.[136] Sumner WWTP discharges into the White River at a location very near to the confluence with the Puyallup River. Sumner WWTP spans both the Mid-Puyallup and White River sub-planning area. This treatment plant was flood proofed in 2011 by raising the facility's floodwall.
- **Orting WWTP** has a service area that includes 3,940 customers and that includes all properties within the City of Orting, including the High Cedars Golf Club Development and the Soldier's Home.[137] It has a maximum daily flow capacity of 1.8 mgd. The facility has been operational on this site since the early 1940s.[138] Orting WWTP discharges into the Carbon River, a tributary to the Puyallup River. Orting WWTP is located in the Upper Puyallup sub-planning area. The Orting WWTP is located behind a 500-year flood levee and faces flood risk only from pooling water or if the levee is breached.

A map with the locations of the four WWTPs is available as Figure 9-1.

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[132] Lopez, B. (2019). "Annual Financial Report For the Year Ended December 31, 2019". Finance Department, City of Puyallup. Available at: http://www.cityofpuyallup.org/ArchiveCenter/ViewFile/Item/122.

[133] BHC Consultants. (2016). *City of Puyallup Comprehensive Sewer Plan*. Available at: https://www.cityofpuyallup.org/DocumentCenter/View/91/Sanitary-Sewer-Comprehensive-Plan-Part-1-PDF?bidId=.

[134] BHC Consultants. (2016). *City of Puyallup Comprehensive Sewer Plan*. Available at: https://www.cityofpuyallup.org/DocumentCenter/View/91/Sanitary-Sewer-Comprehensive-Plan-Part-1-PDF?bidId=.

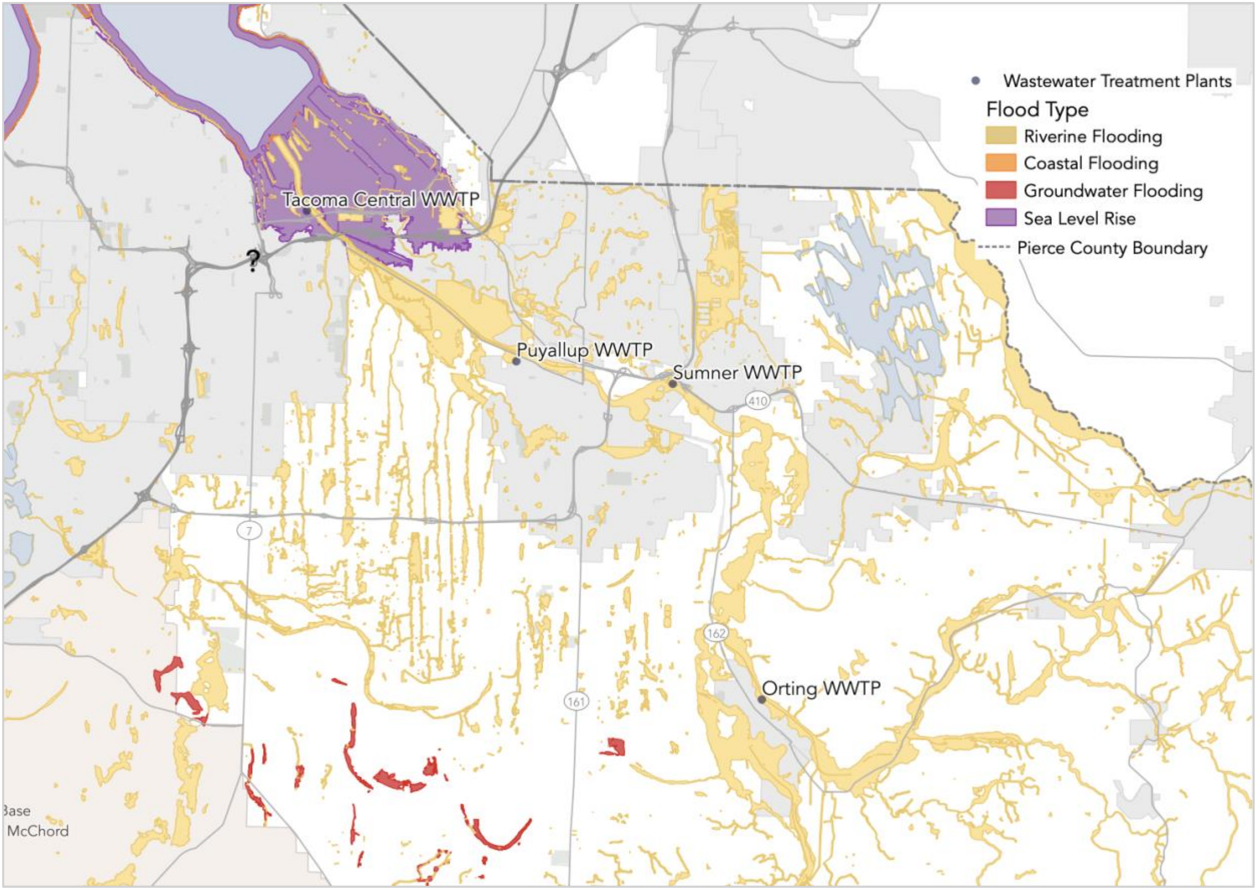
[135] Sumner Regional Wastewater Treatment Facility. (2018). *Annual Report 2018*. Available at: https://sumnerwa.gov/wp-content/uploads/2018/09/WWTF-2018-Report-for-PDF.pdf.

[136] BHC Consultants, LLC . (2018). *Sanitary Sewer Comprehensive Plan - Draft*. Prepared for City of Sumner. April. Available at: https://sumnerwa.gov/wp-content/uploads/2018/11/c-Sumner-GSP-04-24-18-Draft-for-SEPA-Package-Reduced.pdf.

[137] City of Orting. (2017). *2017 Comprehensive Plan.* Available at: https://www.cityoforting.org/home/showdocument?id=6.

[138] Washington State Department of Ecology. (2011). *Fact Sheet for NPDES Permit WA0020303 City of Orting Wastewater Treatment Plant.* Available at: https://apps.ecology.wa.gov/paris/DownloadDocument.aspx?id=19410.

Figure 9-1. Location of the Four Wastewater Treatment Plants



Source: Created by ECONorthwest

9.3 WWTP Overflows

9.3.1 Overview of WWTP Operations and Overflows

At a WWTP, wastewater first passes through primary clarifiers for primary treatment.[139] The clarifiers remove particulate and floatable matter from the wastewater which are then segregated into inorganic and organic matter. The inorganic matter is sent to landfills while the organic matter is converted into biosolids. These biosolids are used as agricultural and landscaping inputs.

Once the wastewater is rid of the particulate matter, it undergoes secondary treatment where dissolved and suspended particles are removed using microorganisms (the activated sludge process). Secondary treatment occurs in aeration basins and secondary clarifiers. The remaining effluent then passes through UV or chemical disinfectors and is finally discharged into local waterways.

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[139] City of Puyallup website, "Water Treatment Process". Available at: https://www.cityofpuyallup.org/380/Water-Treatment-Process.

There are three ways that flooding at WWTPs could occur: either due to levee breach, levee overtopping, or overland flow. None of the WWTPs in Pierce County use combined sewer overflows (CSOs), so that is not a potential cause of flooding in the wastewater system.[140] The flooding types differ in terms of how much time WWTP operators would have to prepare and evacuate from the WWTP. If flooding was due to a levee breach there would be very little time to prepare the WWTP and for any needed evacuations. Flooding due to levee overtopping or overland flow would allow for relatively more preparation time, although actions would still need to occur quickly to prepare the plant for flooding. Preparation actions that the WWTPs could take include:

- Closing flood wall gates before the floodwaters arrive (if time is sufficient and the WWTP has flood walls).
- Shutting off power to prevent impacts to electrical equipment.
- Activating surface water pump stations (if available) to pump water away from the WWTP.

Discharge of untreated wastewater would occur if the WWTP is inoperable during the flooding period. Water still enters the WWTP but is not able to be treated (unless clarifiers are still functioning which would result in partial treatment by removing floating materials). Flooding also overloads the system with excess water and overflows can occur if the floodwaters exceed the piping capacity.

9.3.2 Flooding and Overflow Risks and Preventive Measures

Although all four WWTPs are located within the 100-year floodplain, they have varying risks of flooding due to their distances from the river and flood mitigation infrastructure, such as floodwalls and water pumps. In addition, the impact of flooding and any associated discharges will vary depending on the flooding type, volume of water, and velocity of water. This section describes the measures that each WWTP has implemented to reduce flooding and its impacts on plant infrastructure and processes. None of the four WWTPs are planning any additional improvements to their flood mitigation infrastructure at this time.

9.3.2.1 Tacoma CTP

Tacoma CTP is located on the Puyallup River immediately upstream from the Port of Tacoma and Commencement Bay. Although Tacoma CTP is technically protected by the 100-year flood levees built by the U.S. Army Corps of Engineers (USACE), sediment accumulation on the bottom of the Puyallup River has raised river levels so that the levee no longer meets 100-year flood design standards.[141] Accordingly, the WWTP is at risk of flooding from levee breach or overtopping.

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[140] Washington Department of Ecology website, "Combined sewer overflows". Available at: https://ecology.wa.gov/Regulations-Permits/Permits-certifications/Combined-Sewer-Overflows

[141] City of Tacoma Environmental Services. (2017). *Central Treatment Plant Flood Protection Plan*.

Given the risk of flooding, Tacoma CTP has implemented numerous local flood protection actions. Tacoma CTP has installed 2,700 feet of steel sheet pile floodwall around the plant that is managed by a floodwall manual developed in collaboration with USACE.[142] The height of the floodwall has been designed for a statistical 500-year flood event.[143] In addition to the floodwall, the plant depends on a pump station and two trailer mounted pumps to move any surface water collecting in the facility to a location outside the floodwall. The plant is also equipped with five flood gates, three automatic and two manual, and drainage valves that are closed once they identify that there is a high risk of flooding or when flooding begins.[144] The staff conduct regular drills to ensure all these mitigation measures function appropriately. Tacoma CTP also has a peak flow treatment facility to accommodate higher and faster wastewater flows during storms.[145]

A major flooding event could potentially destroy equipment at the plant and cause millions of gallons of untreated wastewater to overflow into Commencement Bay and Puget Sound. Electrical components, such as transformers, switch gears, receptacles, switches, circuit breakers, wiring, Programmable Logic Controllers, motors, chemical processors, controls, and others, would fail and need to be replaced. Once the floodwater had receded, the standing water and sewage would have to be pumped out of the facilities and treated. During the time the treatment plant was inoperable, potentially millions of gallons of raw sewage would be released into the Puyallup River and Commencement Bay.

9.3.2.2 Puyallup WPCP

Puyallup WPCP lies less than 0.25 miles from the Puyallup River. The WWTP is protected by the River Road levee. Due to cost limitations, Puyallup WPCP decided to protect individual structures and buildings through mitigation measures instead of constructing floodwalls around the entire plant.[146]

The Puyallup WPCP was close to flooding in 2009 but did not experience any damage during that event. Since then, based on recommendations made by Gray and Osborne, Inc. in 2016,[147] the plant erected floodwalls around certain plant facilities and relocated essential activities like the activated sludge process to a higher elevation to reduce the impact of flooding. The plant also moved its electrical equipment, wiring, and conduits to heights above the 100-year flood

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142 City of Tacoma Environmental Services. (2017). "Central Treatment Plant Flood Protection Plan".

143 Matthews, T. (2015). "Tacoma floodwall aims to protect wastewater treatment plant, Commencement Bay". *Tacoma Daily Index*. June 11. Available at: https://www.tacomadailyindex.com/blog/tacoma-floodwall-aims-to-protect-wastewater-treatment-plant-commencement-bay/2426302

144 City of Tacoma Environmental Services. (2017). "Central Treatment Plant Flood Protection Plan".

145 City of Tacoma website, "Central Wastewater Treatment Plant". Available at: https://www.cityoftacoma.org/government/city_departments/environmentalservices/wastewater/wastewater_system/ctp.

146 Direct Communication with Daniel Messier, Puyallup Wastewater Treatment Plant, on December 7, 2020.

147 Grey and Osborne, Inc. (2016). *Water Pollution Control Plant Flood Mitigation Predesign Report*. Prepared for City of Puyallup. August.

level and adopted ultraviolet treatment for its disinfection process to reduce damage from flooding. In the case of flooding, plant staff would place covers on manholes and drains, some of which are equipped with knife gates to prevent the inflow of surface waters. Because of these investments, the Puyallup WPCP is protected to a 100-year flood standard.

If floodwaters enter the facility for any reason, the secondary clarifiers and the activated sludge process would stop operating because they would be underwater. The material from the primary clarifiers would be in the flood waters, resulting in discharge of sewage material. If discharges occurred the facility would shut down. Puyallup WPCP could either shut down the pumps coming into the facility, which would cause backup from into the pipes, or they could accept the sewage and let it run into the floodwaters.

9.3.2.3 Sumner WWTP

Sumner WWTP is located at the confluence of the White River and the Puyallup River and is located less than 500 feet from both. There are dikes surrounding the facility, but a 100-year flood would overtop those protection systems. The White River is also susceptible to sedimentation over time which increases the height of the riverbed, and therefore also the risk of flooding. In response to this risk, the WWTP raised the existing floodwall surrounding the facility by 3 feet in 2011.[148] The floodwalls protect the WWTP from a 100-year flood, but not a 500-year flood. The facility also has pumps to remove any effluent created during flooding.

If the floodwalls fail or floodwaters otherwise enter the WWTP there would be damage to electrical and motor-controlled system. The plant would need to shut down which would release raw or partially treated wastewater into the floodwaters. Damage to the WWTP could be exacerbated by the high levels of silt and debris that could damage aerations tanks and clarifiers. The White River is also subject to the operation of the U.S. Army Corps of Engineer's Mud Mountain Dam and the Cascade Water Alliance's operation of Lake Tapps. Catastrophic failure of these facilities could also impact Sumner's ability to continue WWTP operations.

9.3.2.4 Orting WWTP

Orting WWTP lies approximately 500 feet from Carbon River. The plant relies heavily on the 500-year flood levees on the Carbon River to protect it from riverine flooding. The Orting WWTP has double protection from levees that are designed to withstand a 500-year flood event.[149] Accordingly, Orting WWTP is largely protected from flooding unless a significant rain event occurs directly over the WWTP and results in water pooling at the plant.

If floodwaters enter the plant, flood pumps owned and maintained by the City of Orting would pump water away from machinery and equipment. This water may be pumped into the solid waste lagoons or be treated along with wastewater. In the rare case where overflows did occur, the plant is designed to contain overflows within the system so there would not be overflows onto private property.

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[148] Direct Communication with Jason Van Gilder, Sumner Wastewater Treatment Plant, on January 7, 2021.

[149] Direct Communication with JC Hungerford, Orting Wastewater Treatment Plant, on January 6, 2021.

9.4 WWTP Flood Impacts

Flooding at the WWTPs and any associated discharge of raw or partially treated sewage could create significant financial, health, and environmental costs. There would be direct costs to the WWTP from the flooding and any associated damage to the facilities infrastructure. These costs include replacement and repair of broken infrastructure as well as cleanup costs. Severe flooding could also impact surrounding properties, human health, and the environment if raw or partially treated wastewater is released into the floodwaters. The WWTP could also be liable for fines associated with wastewater discharges in the event of an overflow. In extreme events where the WWTPs are closed for a period time due to damage there could be severe impacts on economic activity if businesses are unable to function normally due to a loss of wastewater treatment capacity.

All four WWTPs have preventative and mitigative measures to protect against a 100-year flood. Flood damage would only occur if infrastructure like floodwalls failed to be implemented in a timely fashion – and each WWTP has policies in place to guard against that occurring. Tacoma CTP is designed to withstand a 500-year flood through floodwalls. Orting WWTP has 500-year flood protection through the levees, but the facility itself is not protected from a levee break or overtopping. Sumner WWTP and Puyallup WPCP are not protected to a 500-year flood standard.

Given the low risk of flood impacts at all four of the WWTPs, in the case of a 100-year flood the expected value of any flood related costs is near zero. The damages and costs of flooding would only occur if there was a flood larger than what the facility is designed for or if flood mitigation measures such as floodwalls or levees fail. The flood related impact described herein would therefore only be relevant in those situations.

9.4.1 Direct Impacts to the WWTPs

The mitigation measures employed by the WWTPs reduce the risk of flooding but if flooding occurs, the WWTPs face significant costs from damage to infrastructure. The most vulnerable infrastructure are electrical machinery that is sensitive to interaction with water, clarifiers and pumps that could be clogged by high levels of silt and debris, and any materials that are not bolted down and could be swept away with floodwaters. This analysis did not include engineering cost estimates of the repair costs, which would vary depending on the associated flood damage, so detailed costs are not reported.

The prior 2010 Economic Analysis for the Pierce County Rivers Flood Hazard Management Plan obtained estimates of costs of repairs for a situation in which the facility was completely flooded. This information is available for Tacoma CTP, Puyallup WPCP, and Sumner WWTP (Orting WWTP was not considered in this analysis). That report suggests that the costs, adjusted for inflation, are:

- Tacoma CTP: $50 million to $150 million[150]
- Puyallup WPCP: $3.7 million to $6.3 million[151]
- Sumner WWTP: $3.7 million to $7.5 million

Tacoma's CTP has been flooded with three feet or more of water at least twice in the last 15 years with resulting damage to electrical and pumping systems.[152] Electrical components like transformers, switches, circuit breakers, and motors could fail and need to be replaced. A severe flood may also inundate underground tunnels that house conveyance systems and controls. If impacted, it would take months to restore these systems and bring them online. Once floodwaters recede, the plant would need to pump the standing water and sewage out of the facility to be treated. The costs associated with this type of event would be in the millions of dollars for Tacoma CTP. During the design of the floodwall project, Tacoma's CTP estimated that the cost associated with a severe flooding event could be as high as $10 million.[153]

The measures employed by Puyallup WPCP have strengthened it against a 100-year flood, but a more severe flood would inundate the facility buildings.[154] The primary treatment process is located at a higher elevation and would not be affected. The activated sludge process and the secondary treatment process are at highest risk since they are located at ground level. If these processes are impacted, the plant could take weeks or months to restore them to permit standards. In this type of event, the damage to the infrastructure would cost the plant millions of dollars to repair.

Sumner WWTP and Orting WWTP have not prepared cost estimates associated with a hypothetical flood inundation scenario. Like Tacoma CTP and Puyallup WPCP, the primary costs would likely be replacing damaged electrical components and treatment equipment, as well as the labor and machinery needed for clean up activities.

9.4.2 Impacts of Overflows

If any of the WWTPs were inundated it would likely result in overflows by overwhelming the treatment system and due to the plant needing to shut down as part of flooding emergency operations. In these instances, raw or partially treated wastewater would be released into the surrounding floodwaters and system discharge sites. The untreated wastewater would then flow on other properties and contaminate the water, which would impact the local ecosystem and well as pose a threat to human health.

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[150] The costs for Tacoma CTP represent the costs for repair of major pieces of equipment, emergency service premiums, City labor and contractor labor in an upstream levee breach scenario.

[151] The costs for Puyallup WPCP and Sumner WWTP are the costs attributable to replacing electrical components and equipment and hauling sludge for off-site treatment.

[152] Direct Communication with Lance Bunch, Tacoma Central Wastewater Treatment Plant, on December 8, 2020.

[153] Direct Communication with Lance Bunch, Tacoma Central Wastewater Treatment Plant, on December 8, 2020.

[154] Direct Communication with Daniel Messier, Puyallup Wastewater Treatment Plant, on December 7, 2020.

9.4.2.1 Impact on Surrounding Properties

Wastewater overflows would impact properties beyond the WWTPs by contaminating them with sewage, sludge, and other wastewater discharge. Structures that flood, in particular those like basements that can retain water for long periods of time, would require significant water removal and cleanup to disinfect the area and prevent the spread of disease. Any wastewater that comes into contact with textiles, wood products, or other absorptive materials generally has to be destroyed and there would be costs associated with disposal and replacement.[155] The financial cost of the impact on properties that receive overflow wastewater would depend on the number of properties impacted, the concentration of the overflow relative to the floodwaters, as well as on the height and extent of damage from floodwaters. In addition to replacement and repair costs, there would also be odors and aesthetic impacts to property owners and residents.

9.4.2.2 Impact on Human Health

Overflows impact human health by introducing bacteria, viruses, parasites, into the environment that can cause illness and disease.[156] Humans can be exposed to contamination through drinking water sources, swimming, outdoor watering, consuming shellfish, or inhalation and skin absorption, such as from being in a structure that is contaminated. Exposure to contaminated water or other substances can result in gastroenteritis, cholera, dysentery, infectious hepatitis, and cryptosporidiosis.

In addition to the health costs of illness and treatment, people may be indirectly impacted by the health risks of overflows. Overflows can close shellfish harvesting, fishing, and recreation sites due to the risk of exposure. This can impact tourism and potentially even affect the value of waterfront homes if there is a frequent risk of overflows or long-term residual impacts.[157]

9.4.2.3 Impact on the Environment

Any overflows due to flooding at the four WWTPs would flow into receiving waterbodies, specifically the Puyallup River, the White River, the Carbon River, or Commencement Bay. Although some of the contaminated water would be distributed into the floodplain away from the mainstem and tributaries of the river, some would likely reach areas natural riverine areas. When the contaminated water reaches natural areas it threatens the health of aquatic species and the habitat that that river provides. Overflows contaminate water with pathogens and toxic

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[155] U.S. Environmental Protection Agency website, "National Pollutant Discharge Elimination System (NPDES): Sanitary Sewer Overflow (SSO) Frequent Questions". Available at: https://www.epa.gov/npdes/sanitary-sewer-overflow-sso-frequent-questions

[156] U.S. Environmental Protection Agency website, "National Pollutant Discharge Elimination System (NPDES): Sanitary Sewer Overflow (SSO) Frequent Questions". Available at: https://www.epa.gov/npdes/sanitary-sewer-overflow-sso-frequent-questions

[157] U.S. Environmental Protection Agency website, "National Pollutant Discharge Elimination System (NPDES): Sanitary Sewer Overflow (SSO) Frequent Questions". Available at: https://www.epa.gov/npdes/sanitary-sewer-overflow-sso-frequent-questions

materials, pollute the water with household and industrial debris, and increase nutrient loads that can affect water quality, such as dissolved oxygen or algae levels.

There is little evidence that levels of these pollutants in overflows are major causes of aquatic life impairment. There is some evidence that fish kills can occur in small streams when overflows reduce oxygen levels.[158] These same impacts are unlikely to occur in a flood event because of the volume of water will dilute contaminants unless the overflow is isolated to a small, fish-bearing water area.

9.4.2.4 Fines and Penalties

In the event of an overflow release due to flooding, fines and penalties are at the discretion of the Washington State Department of Ecology, who would make the determination based on the circumstances and extent of the damage. Because an overflow event would be the result of a catastrophic flood (larger than a 100-year flood) or system failure, it is unclear if any fines or penalties would be issued.

King County, north of Pierce County, experienced a catastrophic wastewater spill when the West Point WWTP flooded and experienced a power disruption in 2019.[159] Around 235 million gallons of untreated wastewater including 30 million gallons of raw sewage was released into Puget Sound, causing an estimated $25 million of damage. King County paid a fine of $361,000, the largest penalty issued by the Washington Department of Ecology to a public WWTP.

In addition to fines there can also be regulatory judgments requiring WWTPs to make costly upgrades to prevent future violations. These plant upgrades can be in the millions of dollars. It is possible that Washington Department of Ecology would require facility upgrades in the event an overflow occurred at one of the four WWTPs.

9.5 Impacts to Businesses and Residents of Unmitigated Flood Event

In a worst-case scenario flood event, a WWTP could close and would stop operations for a period of time. This would likely only occur if there was significant damage to machinery which could take anywhere from days to months to repair. If the plant is still partially functional, the WWTP could continue to receive wastewater and discharge it as raw or partially treated. If the plant is not partially functional or if the WWTP chooses not to receive wastewater due to the impacts of discharges then it could stop receiving wastewater. If that occurred, people and businesses would be unable to discharge into the system. This wastewater service disruption would result in associated costs for businesses and residents who would need to

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[158] U.S. Environmental Protection Agency. (2004). "Chapter 5: Environmental Impacts of CSOs and SSOs". *Report to Congress on the Impacts and Control of CSOs and SSOs.* Available at: https://www3.epa.gov/npdes/pubs/csossoRTC2004_chapter05.pdf

[159] State of Washington Department of Ecology. (2017). *West Point treatment plant fined and required to make significant investments.* September 1. Available at: https://ecology.wa.gov/About-us/Get-to-know-us/News/2017/Sep-01-West-Point-treatment-plant-fined-and-requir

stop introducing wastewater into the system (e.g., flushing toilets, doing laundry, etc.). More severe costs for residents could occur if there is sewage backup into their property due to flood-caused system failures.

Closures of WWTPs could create sewage backup that could stall economic activity in the service areas resulting in economic losses for the county and create costs for residents. The magnitude of these impacts is uncertain as it would depend on the severity of damage to the WWTP infrastructure, the amount of time it would take to repair these damages, and the extent of sewage leakage into the environment.

There have been no instances of wastewater backup or disruption of service for residents in Pierce County due to flooding. Because there are not combined sewer systems in Pierce County there is not the risk of backups into homes due to flooding.[160] The flood protection measures in place at each of the WWTPs make future occurrences unlikely. Examples from elsewhere can inform what the potential damages and costs could be if this unlikely event were to occur in Pierce County. In September 2020, flooding caused by rainfall in Washington D.C. overwhelmed the sewer system and flooded approximately 30 homes in the community of Edgefield. The responsible wastewater agency, DC Water, distributed $1.5 million for clean-up. Affected residents are eligible for up to $5,000 per household and can receive a $6,000 reimbursement to purchase a backwater valve. In some instances, residents reported difficulties obtaining reimbursement from their insurance provider.[161]

9.5.1 Tacoma CTP Response

In the case of a flood, Tacoma's CTP would store sewage until it maxes out its storage capacity, after which it would release the millions of gallons of raw sewage into Puyallup river and Commencement Bay.[162] Release of sewage into the river during the time it would take to restore operations, which could be as long as a few months, would create significant environmental contamination. Such an event would cost the plant over $100,000 in fines with additional costs of clean up. If the facility is shut down for a longer duration, the City could reduce the environmental impacts by requesting the customers to limit their use of the sanitary system and/or imposing surcharges in the service are.[163]

9.5.2 Puyallup WPCP Response

If Puyallup WPCP was flooded and the facility had to shut down, the headworks would not be able to accept sewage and it would be pumped directly into the Puyallup River.[164]

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[160] Combined sewers are designed to collect rainwater runoff, domestic sewage, and industrial wastewater in the same pipe.

[161] Williams, E.C. (2020). "D.C. Water Pledges Financial Relief For Edgewood Sewage Overflow Cleanup, But Some Say It's Coming Too Late". *DCist*. September 17. Available at: https://dcist.com/story/20/09/17/dc-water-edgewood-flooding-sewage-backup-cleanup-funds/

[162] Direct Communication with Lance Bunch, Tacoma Central Wastewater Treatment Plant, on December 8, 2020.

[163] Direct Communication with Lance Bunch, Tacoma Central Wastewater Treatment Plant, on December 8, 2020.

[164] Direct Communication with Daniel Messier, Puyallup Wastewater Treatment Plant, on December 7, 2020.

Compromised infrastructure could also result in leakage of untreated wastewater that would then mix with the floodwaters and flow on to private and public properties. Puyallup WPCP does not anticipate that it would disrupt service and would instead incur fines associated with overflows until the plant could return to full operations.

9.5.3 Sumner WWTP Response

Sumner WWTP anticipates minimal impacts to properties from sewage leaks due to flooding because there are no down gradient, developed properties between the plant and the two rivers, the White River and Puyallup River. Businesses and residents would continue be able to use the wastewater system and would not be impacted.

9.5.4 Orting WWTP Response

Orting WWTP does not anticipate impacts to properties from sewage leaks due to flooding. The treatment plant would accommodate the raw sewage in its wastewater lagoons until it could be treated.[165] Businesses and residents would continue be able to use the wastewater system and would not be impacted.

9.6 Summary of Impacts of Flooding to WWTPs

The WWTPs at Puyallup, Tacoma, Sumner, and Orting have taken measures to fortify against a 100-year flood event. Flooding could damage the WWTP infrastructure disrupting the treatment process and leading to WWTP closures that could last up to months. In the meantime, raw untreated sewage would mix with floodwaters and contaminate public and private properties creating health risks for people and costs of clean up for the county. The service areas for the WWTPs may face economic losses from the sewage leak and any restrictions on use of the sanitary system. Businesses may not be operational, residences may be contaminated, and roads and transportation may be damaged.

The duration and magnitude of these impacts would depend on the severity of the flood and the time it would take to repair the WWTP infrastructure. Assuming a catastrophic worst-case scenario where all four WWTPs are compromised, a severe flooding event would impact facilities that serve 121,400 customers with economic impacts and cause damages and costs in the hundreds of millions of dollars.

[165] Direct Communication with JC Hungerford, Orting Wastewater Treatment Plant, on January 6, 2021.

Appendix A. Technical Memorandum

See attached for Appendix A. Technical Memorandum produced by ESA, entitled: "Pierce County Flood Risk Assessment and Economic Analysis: Flood Hazard Areas and Bridge and Road Flood Risks"

Final

PIERCE COUNTY FLOOD RISK ASSESSMENT AND ECONOMIC ANALYSIS

Flood Hazard Areas and Bridge and Road Flood Risks

Prepared for
ECONorthwest

January 2022

Final

PIERCE COUNTY FLOOD RISK ASSESSMENT AND ECONOMIC ANALYSIS

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Cover photo:
February 6, 2020 flooding on SR162 by
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1.0 INTRODUCTION

1.1 Overview

Pierce County Planning and Public Works, Surface Water Management Division is undertaking a study to complete a Flood Risk Assessment and Economic Analysis of the county-wide benefits associated with implementing the 2023 Pierce County Comprehensive Flood Hazard Management Plan. The assessment will estimate the flood damage impacts of not implementing this Plan as well as a hazard profile (past flood events and flood characteristics), vulnerability analysis, such as public safety and health, critical facilities, land use and structures, development trends, repetitive loss areas, and an insurance analysis.

This report documents analyses that were performed to contribute to the Flood Risk Assessment. The following analyses were performed:

- Existing flood hazards - ESA consolidated GIS data on flood hazards in Pierce County to map the extent of all major flood hazards, which included river flooding, coastal flooding, groundwater flooding, urban flooding areas and major creek flooding in the county.
- Future flood hazards - ESA conducted a planning-level analysis of future flood hazards based on relative sea level rise to the extent existing data allow.
- Flood risk to bridges - ESA assessed flood risk to bridges along transportation corridors within the 100-year floodplain and other flood-prone areas in the County by evaluating the potential for bridge damages to occur during the 100-year flood event when required freeboard heights are violated and the potential for bridge failure due to the depth and velocity of floodwaters during the 100-year flood event.
- Flood risk to roadways – ESA assessed flood risk to roads along transportation corridors within the 100-year floodplain and other flood-prone areas in the County by estimating the length of roads at risk of flood overtopping. The overtopped road lengths were further analyzed to estimate embankment and pavement damages. In addition to estimating roadway damages from overtopping flood flows, the potential for roadway failure was also estimated.

1.2 Key Findings

The following are key findings from this study:

- Existing flood hazard areas - A total of 91,318 acres of flood hazard areas are estimated within Pierce County, approximately 76-percent represent riverine flooding, 24-percent coastal flooding, and 0.9-percent groundwater flooding.
- Future flood hazard areas – An analysis of future flood hazard areas was limited to future projections of relative sea level rise (RSLR). Based on data provided by the University of Washington Climate Impacts Group (CIG) and their Interactive Sea Level Rise Data Visualizations on-line tool, the 13 shoreline segments in Pierce County had Year 2100 RSLR projections ranging from 8.4 to 8.8 feet and an average RSLR increase of 8.6 feet, using the 0.1% probability projection, and the high greenhouse gas scenario. There are an estimated 6,651 acres of new coastal flood hazard areas from the 2100 RSLR event; these new flood hazard areas represent an 8.5 percent increase in flood hazard areas within Pierce County. This analysis was initially conducted at the direction of the County to use the 0.1% probability sea level rise scenario, to assume the "worst case" for SLR in 2100; however, the County made a subsequent decision to revert back to the use of the 1.0% probability sea level rise scenario using data available to the County. Therefore, the data and findings in this report regarding future flood hazard areas are provided for reference only.
- Flood risk to bridges - There are 466 bridges in Pierce County and 255 of these bridges are over waterways. Pierce County is responsible for maintaining 94 bridges or 37-percent of the bridges over waterways in the County. Only 14 bridges have freeboard violations: five of these bridges are owned by WSDOT; two bridges are owned by railroads; two bridges are owned by the City of Sumner; and five bridges are owned by Pierce County. Approximately 21-percent of bridges in the County have a slight chance of floods overtopping the bridge deck and roadway approaches and approximately 73-percent of the roadway approaches to bridges in the County have a slight chance of overtopping. Pierce County bridges over waterways that have chance of overtopping are estimated to have a total value of $128 million and an associated value of $185 million for roadway approaches to bridges. Bridge and roadway approaches having a slight chance of flood overtopping have a value of $40 million and $183 million, respectively. For both bridges and roadway approaches, the greatest flood risk is associated with urban minor arterial bridges, with an estimated 77-percent and 38-percent of the total value of infrastructure exposed to flood risk for bridges and roadway approaches, respectively.
- Flood risk to roadways – The total length of roads within SFHAs is 265,091-feet and an estimated 44%, or 115,673-feet, of road length is overtopped at the 1% Annual Exceedance Probability (AEP). A relative comparison was conducted of roadway flood overtopping by sub planning area and the range of heights at which BFEs are higher than road elevations, on a cumulative basis. For example, roads within the Gig Harbor / Key Peninsula Basin are estimated to experience the least amount of flood overtopping with only a cumulative 482-feet of overtopping length, while the Mid Puyallup Basin experiences the most road overtopping with a cumulative length of overtopping estimated at 38,278-feet. For road segments where BFEs "overtop" the estimated elevation of the road surfaces, an estimated $250 million in road embankment damages and $461 million in associated pavement damages are estimated to occur during 1% AEP flood conditions, with total roadway damages estimated to be $711 million in 2021 dollars.

2.0 EXISTING AND FUTURE FLOOD HAZARDS

2.1 Existing Flood Hazards

ESA obtained available GIS flood hazard area data in Pierce County for the 100-year (1-percent-annual-chance exceedance) and 500-year (0.2-percent-annual-chance exceedance) flood events. The data were obtained as GIS shapefiles from the Pierce County Spatial Services website.[1] The metadata were also obtained from the Pierce County website.[2] Flood hazard data for Pierce County were also obtained from the Washington Department of Ecology[3] to provide a cross-check on and clarification of the Pierce County dataset.

2.1.1 Flood Hazard Types

ESA consolidated GIS data on flood hazards in Pierce County to map the extent of the floodplain by each flood hazard type; these hazard types included; groundwater flooding, riverine (non-coastal) flooding, and coastal flooding. While urban flooding was initially considered as a flood type, the County requested this flood type not be mapped out separately.[4] ESA did not conduct any new primary data collection. A summary of the Pierce County flood hazard types by FEMA flood hazard zones is provided in Table 2-1 in acres of floodplain land area.

[1] Pierce County Open GeoSpatial Data Portal, 2020. Regulated Floodplain 2017. https://gisdata-piercecowa.opendata.arcgis.com/datasets/regulated-floodplain-2017 [last accessed December 23, 2020]

[2] Pierce County, 2020. Pierce_GDB.WTRPRG.Regulated_Floodplain. https://matterhorn.co.pierce.wa.us/GISmetadata/pdbswm_regulated_floodplain.html [last accessed December 23, 2020]

[3] Washington Department of Ecology, 2020. ECY_Pierce_Co_2017_Public_Risk_Data https://waecy.maps.arcgis.com/home/webmap/viewer.html?webmap=c2d9eebb88a94cb594431a4e3bdb79ec&extent=-122.952,46.7547,-121.2656,47.3721 [last accessed December 23, 2020]

[4] Pierce County, 2020. Project coordination call with Pierce County, ECONorthwest, and ESA, October 20.

Table 2-1. Summary of Pierce County Flood Hazard Types by FEMA Flood Hazard Zones

Type of Flooding	100-Year (acres)	500-Year (acres)	Protected by Levee (acres)	Grand Total (acres)
Groundwater Flooding				
Zone X (shaded)		513		513
Zone A	264			264
Riverine Flooding				
Zone X (shaded)		14,544		14,544
Zone AE	18,435			18,435
Zone A	34,715			34,715
Zone AH	506			506
Zone AO	271			271
Zone X (PROTECTED BY LEVEE)			616	616
Coastal Flooding				
Zone VE	18,542			18,542
Zone AE Coastal	2,912			2,912
Grand Total	**75,645**	**15,057**	**616**	**91,318**

The resulting floodplain acreages are associated with the "Regulatory" data attribute, which are "flood zones used for enforcement of development regulations". [5] The floodplain acreage is partitioned by the 100-year and 500-year flood frequencies, and by the "Regulatory" attribute and associated value "Protected by Levee". The "Protected by Levee" value indicates "secluded areas" that are near significant levees that effect the floodplain but do not meet the federal standard (44 Code of Federal Regulations 65.10) to show an area protected by the levee.[6] Levee seclusion mapping will maintain the flood hazard information as depicted on the current effective FIRM (the FIRM in effect before the ongoing update) with map notes explaining that these flood hazards will be updated at a later time when the updated levee analysis and mapping approach is applied. [7]

Of the total 91,318 acres of flood floodplains within Pierce County, approximately 76-percent represent riverine flooding, 24-percent coastal flooding, and 0.9-percent groundwater flooding. The FEMA flood hazard zones associated with each flood type are defined by FEMA[8] as follows:

[5] Pierce County, 2020. Pierce_GDB.WTRPRG.Regulated_Floodplain. https://matterhorn.co.pierce.wa.us/GISmetadata/pdbswm_regulated_floodplain.html [last accessed December 23, 2020]

[6] Pierce County, 2020. Pierce_GDB.WTRPRG.Regulated_Floodplain. https://matterhorn.co.pierce.wa.us/GISmetadata/pdbswm_regulated_floodplain.html [last accessed December 23, 2020]

[7] FEMA, 2020. Levee Seclusion Mapping: Information for Local Community Officialshttps://www.fema.gov/media-library-data/1420584854603-6678e6f57914ac22e27d95e91243d989/Levee_Seclusion_Mapping.pdf [last accessed December 23, 2020]

[8] FEMA, 2020. Glossary of Terms frequently used by FEMA. https://www.fema.gov/about/glossary [last accessed December 23, 2020]

- Zone A – Areas subject to inundation by the 1-percent-annual-chance flood event generally determined using approximate methodologies. Because detailed hydraulic analyses have not been performed, no Base Flood Elevations (BFEs) or flood depths are shown.

- Zone AH – Areas subject to inundation by 1-percent-annual-chance shallow flooding (usually areas of ponding) where average depths are between one and three feet. Base Flood Elevations (BFEs) derived from detailed hydraulic analyses are shown in this zone.

- Zone AO – Areas subject to inundation by 1-percent-annual-chance shallow flooding (usually sheet flow on sloping terrain) where average depths are between one and three feet. Average flood depths derived from detailed hydraulic analyses are shown in this zone.

- Zone AE - Areas subject to inundation by the 1-percent-annual-chance flood event determined by detailed methods. Base Flood Elevations (BFEs) are shown.

- Zone AE Coastal – Areas that experience lesser wave conditions during storm events, compared to Zone VE, or areas that are well sheltered from waves.[9]

- Zone VE - Areas subject to inundation by the 1-percent-annual-chance flood event with additional hazards due to storm-induced velocity wave action. Base Flood Elevations (BFEs) derived from detailed hydraulic analyses are shown.

- Zone X (Shaded) - Areas between the limits of the base flood and the 0.2-percent-annual-chance (or 500-year) flood.

- Zone X (PROTECTED BY LEVEE) – In areas with levee systems, when an updated levee analysis and mapping approach has not been completed, a new FIRM may show an area of seclusion. Seclusion mapping is one option when completion of an updated levee analysis will cause a significant delay in the issuance of a new FIRM. Pending completion of the updated analysis and mapping, the area of seclusion can retain the flood hazard information from the current effective FIRM (if the seclusion FIRM has not yet been published) or retain the flood hazard information from the previous effective FIRM (if the seclusion FIRM has been published).[10]

- Several modifications were made to the Pierce County flood hazard data to provide the simplified results shown in Table 2.1; these modifications included:

1. Created an attribute for "Flood Frequency" and associated the "X (PROTECTED BY LEVEE)" and "X (SHADED)" values in the "Regulatory" attribute with the "500-Year" value and all remaining values to the "100-Year" value.

2. Created an attribute for "Flooding Type" and associated:
    a. all "Coastal" values in the "PC_Flood" attribute to "Coastal Flooding";

[9] FEMA, 2020. Coastal Flood Insurance Rate Maps https://www.fema.gov/flood-maps/coastal/insurance-rate-maps#:~:text=The%20coastal%20areas%20designated%20as%20Zone%20AE%20are,where%20the%201-percent-annual-chance%20wave%20height%20equals%201.5%20feet. [last accessed December 23, 2020]

[10] https://www.piercecountywa.gov/DocumentCenter/View/78140/FEMA-MT1-Technical-Guidance-Feb-2018?bidId=

   b. all “GRD_WAT” values in the “PC_Flood” attribute to “Groundwater Flooding”, and;
   c. all remaining values in the “PC_Flood” attribute to “Riverine Flooding”.
3. Associated the attribute "PC_Flood" and value "RSF" to the “Riverine Flooding” value in the “Flood Hazard Type” attribute, 100- or 500-year based on "Regulatory" attribute of A, or 0.2 PCT and X SHADED, respectively.

4. Changed "Insurance_1" values for "FID" 5341 and 5342 from "AE" to "VE" because "Regulatory" attribute shows "VE" and not "AE Coastal".

5. Changed the value of "0.2 PCT" in the "Regulatory" attribute to the value of "Zone X (shaded)".

6. Excluded the two polygons with the value of "See King County DFIRM " in the "Regulatory" attribute from the County floodplains by flood type summary. These two polygons are identified as FID 937 and 5008 and their locations were compared to the Ecology floodplain dataset to determine if they should be included or excluded from the County floodplains summary. FID 937 is in the Ecology flood zone “Area Not Included” and is entirely developed, including part of SR-167 (Figure 2.1) and FID 5008 is in the Ecology flood zone “Area Not Included” and is mostly developed residential on hillside (Figure 2-2).

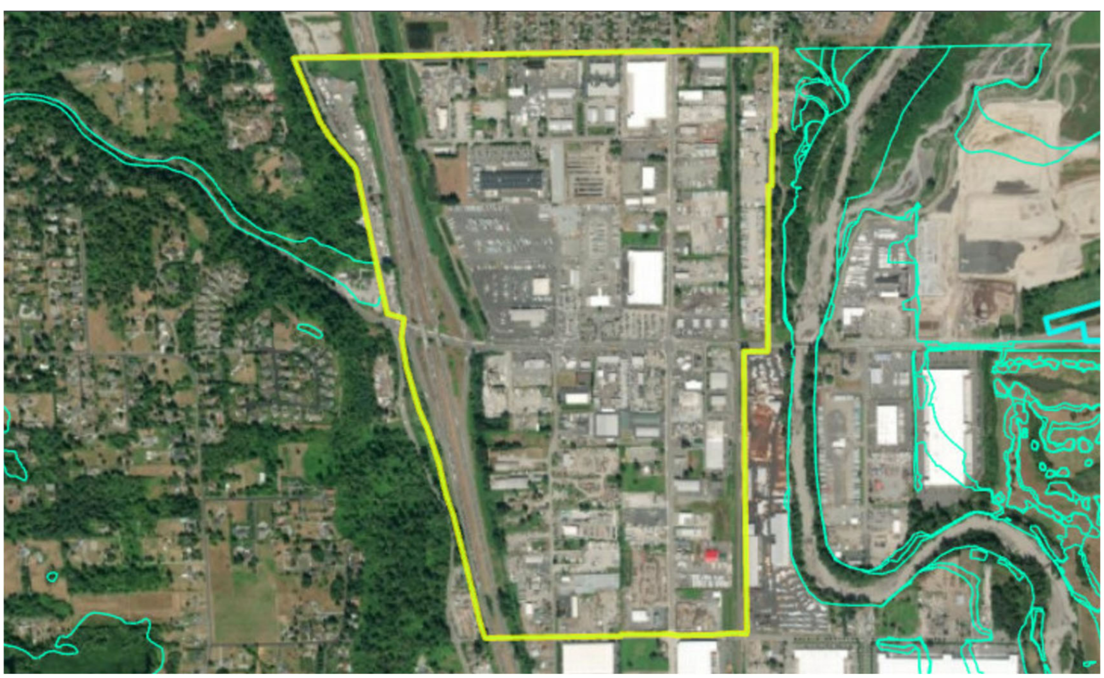

Figure 2-1. Pierce County “Regulatory” Attribute and “See King County DFIRM” Value (FID 937)

FID 5008 is in the Ecology flood zone “Area Not Included” and is mostly developed residential on hillside (Figure 2-2). Therefore, since both of these areas appear to be out of designated floodplains, they were excluded from the County floodplain summary.

Figure 2-2. Pierce County “Regulatory” Attribute and “See King County DFIRM” Value (FID 5008)

7. These two polygons have the value “X PROTECTED BY LEVEE” in the “Regulatory” attribute; FID 5302 is in the Ecology flood zone “Area Protected by Levee”, and includes mixed use residential, commercial, and farming along the Puyallup River (Figure 2-3).

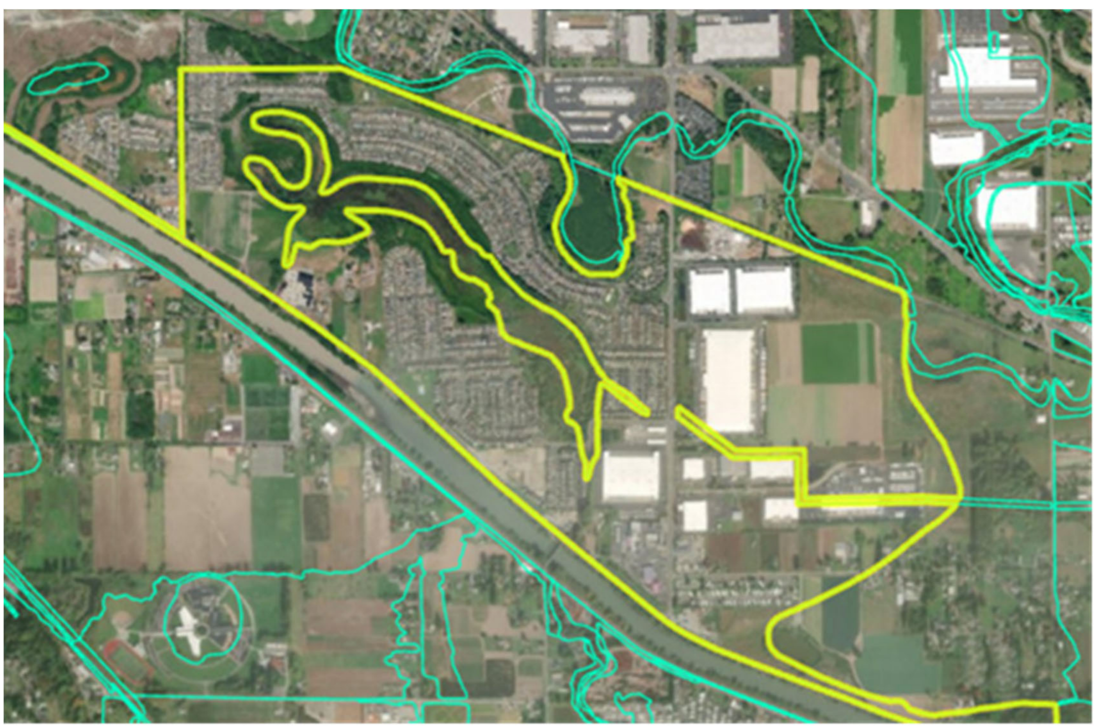

Figure 2-3. Pierce County "Regulatory" Attribute and "X PROTECTED BY LEVEE" Value (FID 5302)

FID 5349 is in the Ecology flood zone "Area Protected by Levee" and consists of farmland in Orting (Figure 2-4). These two areas are called out separately in the summary table under Riverine Flooding.

Figure 2-4. Pierce County "Regulatory" Attribute and "X PROTECTED BY LEVEE" Value (FID 53492)

2.1.2 Farmland in Floodplains

As directed by ECONorthwest, ESA utilized the WSDA agricultural land use data [11] and performed GIS analyses to estimate the number of acres of farmland located within the regulatory 100-year floodplains and by flood hazard type (Table 2-2).

[11] Washington State Department of Agriculture, 2020. AGR Agricultural Land Use, https://agr.wa.gov/departments/land-and-water/natural-resources/agricultural-land-use [last accessed October 20, 2020]

Table 2-2. Summary of Pierce County Farmland Acreage by FEMA Flood Hazard Zones

Land Cover / Crop (acres)	0.20%	A	AE	AE Coastal	AH	AO	VE	X (Shaded)	X Protected by Levee	Grand Total
Berry	3	15	43		7	20		11	7	106
Cereal Grain		19						29		48
Commercial Tree	11	4	37					6		59
Developed	188	15	285		7			2	151	648
Flower Bulb										0
Hay/Silage	16	298	368		3			417		1,101
Nursery			86		3			4		92
Oilseed			5		2					6
Orchard	1		4							5
Other	65	128	278	9	20	4		4	11	519
Pasture	154	562	681		7			1,284		2,687
Shellfish			698	967			7,671			9,337
Turfgrass	20	4	143		3			10		180
Vegetable	68	107	358		123			118	78	852
Vineyard								0		0
Grand Total	**527**	**1,153**	**2,985**	**976**	**174**	**24**	**7,671**	**1,884**	**247**	**15,640**

2.1.3 Flood-Prone Soils

ESA assessed the viability of using NRCS soils data to delineate flood-prone lands within Pierce County. Previous work has demonstrated the utility of soils data for flood hazard assessments to augment FEMA flood hazard data in rural areas where flood insurance studies have not been conducted.[12] ESA obtained GIS data from the gNATSGO database.[13] The value for flooding frequency is derived from the gSSURGO map unit aggregated attribute table field Flooding Frequency - Dominant Condition (flodfreqdcd). A summary of these data is in Table 2-3.

[12] Coulton, K.G., 2014. *Using Soils Data to Map "Natural" Floodplains*, AWRA Water Resources Impact magazine, Volume 16, Number 2, March, pages 9-12.

[13] Natural Resources Conservation Service, 2019. USA Soils Flooding Frequency, October 1. Updated: Aug 26, 2020. https://www.arcgis.com/home/item.html?id=e606abaf878340748710d4268ea06653

Table 2-3. Summary of Pierce County NRCS Flood-Prone Soils and FEMA Flood Hazard Zones

Type of Flooding	Flood Frequency Class (acres)				No Soil Data (acres)	Grand Total (acres)
	None	Rare	Occasional	Frequent		
0.2 PCT	317	3	562	840	97	1,819
A	9,554	778	1,991	8,140	14,516	34,979
AE	2,221	26	2,658	6,683	6,848	18,435
AE Coastal	89		311	9	2,503	2,912
AH	56		269	138	43	506
AO	16		5	236	14	271
See King County FIRM	1,014		271	158	9	1,452
VE	1,118		14	30	17,380	18,542
X (SHADED)	5,813	81	277	5,162	1,906	13,238
X PROTECTED BY LEVEE	6		553	58	0	616
Non-FEMA	660,460	7,740	12,670	13,520	187,016	881,405
Grand Total	**680,664**	**8,627**	**19,580**	**34,973**	**230,332**	**974,175**

The flood-prone soils data provide an estimate of flood frequency as one of seven classes:

1. None: No reasonable possibility of flooding; one chance out of 500 of flooding in any year or less than 1 time in 500 years.

2. Very Rare: Flooding is very unlikely but is possible under extremely unusual weather conditions; less than 1 percent chance of flooding in any year or less than 1 time in 100 years but more than 1 time in 500 years.

3. Rare: Flooding is unlikely but is possible under unusual weather conditions; 1 to 5 percent chance of flooding in any year or nearly 1 to 5 times in 100 years.

4. Occasional: Flooding is expected infrequently under usual weather conditions; 5 to 50 percent chance of flooding in any year or 5 to 50 times in 100 years.

5. Frequent: Flooding is likely to occur often under usual weather conditions; more than a 50 percent chance of flooding in any year (i.e., 50 times in 100 years), but less than a 50 percent chance of flooding in all months in any year.

6. Very Frequent: Flooding is likely to occur very often under usual weather conditions; more than a 50 percent chance of flooding in all months of any year.

2.2 Future Flood Hazards

NOTE: The data, methods, and results presented in this report section were developed based on direction from Pierce County to assume the "worst case" for SLR in 2100 [14] and that led to the use of the 0.1% probability sea level rise scenario. However, this approach was superseded by Pierce County in March 2021 due to a decision to revert back to the use of the 1.0% probability sea level rise scenario using data available to the County. [15] Therefore, the information presented in this report section has been superseded but is provided for informational purposes and to document the work performed by ESA.

Pierce County requested an assessment of the "probability of future [flood] events" as part of this study. ESA therefore conducted a planning-level analysis of future flood hazards based on relative sea level rise to the extent existing data allow. With regard to future flood hazards due to climate change, existing data are readily available to analyze future relative sea level rise in Puget Sound; however, the data necessary to analyze future inland flood hazards from changing storm conditions are not as available and methods are more complex, and this analysis was assumed to be beyond the scope of this planning-level study. Therefore, ESA performed an analysis to determine the shoreline areas in the county that may be affected by future sea level rise.

2.2.1 State Sea Level Rise Projections

In 2018 as part of the Washington Coastal Resilience Project (WRCP), [16] an updated assessment of projected sea level rise for Washington State was prepared, which includes projections for sea level rise at various locations along the open coast and the Puget Sound shoreline. The report presents different sea level rise values based on two global greenhouse gas emissions scenarios:

High Emissions Scenario (Representative Concentration Pathway (RCP) 8.5) – This scenario assumes a future where there are no significant local or global efforts to limit or reduce emissions. This scenario assumes "high population and relatively slow income growth with modest rates of technological change and energy intensity improvements, leading in the long-term to high energy demand and GHG emissions".[17]

[14] Pierce County, 2020. Pierce County Flood Economics Check-In via Ring Central Video Meeting, October 29.

[15] Marshall, L., 2021. Email correspondence with K. Coulton/ESA, March 15.

[16] Miller, I.M., Morgan, H., Mauger, G., Newton, T., Weldon, R., Schmidt, D., Welch, M., Grossman, E., 2018. Projected Sea Level Rise for Washington State – A 2018 Assessment. A collaboration of Washington Sea Grant, University of Washington Climate Impacts Group, University of Oregon, University of Washington, and US Geological Survey. Prepared for the Washington Coastal Resilience Project. updated 07/2019 https://cig.uw.edu/resources/special-reports/sea-level-rise-in-washington-state-a-2018-assessment/ [last accessed December 28, 2020]

[17] Riahi, K., Rao, S., Krey, V. et al., 2011. RCP 8.5—A scenario of comparatively high greenhouse gas emissions. Climatic Change 109, 33. https://doi.org/10.1007/s10584-011-0149-y https://link.springer.com/article/10.1007/s10584-011-0149-y#citeas [last accessed February 19, 2021]

Low Emissions Scenario (RCP 4.5) – This scenario assumes more aggressive emissions reduction actions corresponding to the aspirational goals of the 2015 Paris Agreement, which calls for limiting mean global warming to less than 2 degrees Celsius and achieving net-zero greenhouse gas emissions in the second half of the century. This scenario is considered challenging to achieve and would include updated climate policies, concerted action by all countries, and a shift to a lower emissions service and information economy.

The 2018 assessment provides a range of probabilistic projections of sea level rise, which was an update specifically designed to help inform decision-makers. A second WRCP report[18] discusses how coastal managers can properly apply the projections. The report provides guidance on the different probabilistic projections as follows:

High Probability Projections (>83%) – These projections are for risk-tolerant situations where infrastructure can accommodate sea level rise impacts or where projects have significant flexibility or adaptability. This range of probabilities would be appropriate for a beach path, where the consequences of flooding would be minimal.

Mid-Range Probability Projections (83% - 17%) – This is the most likely to occur range, with the 50% probability projection representing the most likely future amount of sea level rise based on all model projections. This scenario should be used for assets or projects that are not particularly risk-averse or risk-tolerant.

Low-Range Probability Projections (<17%) – These projections are for assets or projects that are more risk-averse and where sea level rise will have substantial consequences. This scenario is a more conservative approach and should be used for critical infrastructure, such as sewage treatment plants or emergency response infrastructure, or others that would be seriously compromised by flooding.

Extreme Low Probability Projections (0.1%) – This projection is designed as the physical upper limit for sea level rise. The scenario should be used only as the worst-case scenario for extremely conservative decisions. This amount of sea level rise is unlikely to be revised upward with future scientific updates.

Table 2-4 shows the 2018 assessment projections for the State of Washington with the probabilities identified in the columns. While the assessment provides projections through 2150, it is important to note that sea level rise is expected to continue for centuries, because the earth's climate, cryosphere[19], and ocean systems will require time to respond to the emissions that have already been released to the atmosphere. Although sea level rise is typically presented as a range in the amount of sea level rise that will occur by a certain date (e.g., 1-2 feet of sea level rise by 2050), it can also be presented as a range of time during which a certain amount of sea level rise is projected to occur (e.g., 1.5 feet of sea level rise between 2040 and 2070). Even if emissions are reduced to

[18] Raymond et al, 2020. How to Choose: A Primer for Selecting Sea Level Rise Projections for Washington State,

[19] The cryosphere is the portions of the Earth's surface where water is in solid form, like glaciers and ice caps.

levels consistent with the low-emissions-based projections, sea level will continue to rise to higher levels, just at a later date.

Table 2-4 Absolute Sea Level Rise Projections for Washington State [20]

PROJECTED ABSOLUTE SEA LEVEL CHANGE (feet, averaged over each 19-year time period)						
Time Period	Greenhouse Gas Scenario	Central Estimate (50%)	Likely[5] Range (83-17%)	Higher magnitude, but lower likelihood possibilities		
				10% probability of exceedance	1% probability of exceedance	0.1% probability of exceedance
2050 (2040-2059)	Low	0.6	0.4 - 0.8	0.9	1.2	1.8
	High	0.7	0.5 - 0.9	1.0	1.3	2.0
2100 (2090-2109)	Low	1.6	1.0 – 2.2	2.5	4.1	7.2
	High	2.0	1.4 - 2.8	3.1	4.8	8.3
2150 (2140-2159)	Low	2.5	1.5 - 3.8	4.4	8.5	16.2
	High	3.4	2.3 - 4.9	5.6	10.0	18.3

The 2018 assessment also provided local estimates of relative sea level rise (RSLR), which combine estimates of absolute sea level rise and vertical land movement. Where the land is uplifting, the RSLR is less than in areas where the land is subsiding. The assessment provides estimates of RSLR for 171 locations along Washington's coastline.

2.2.2 Pierce County Sea Level Rise Projections

Future flood hazards from RSLR were analyzed for the Puget Sound shoreline areas of Pierce County. ESA relied on data from the University of Washington Climate Impacts Group (CIG) and their Interactive Sea Level Rise Data Visualizations on-line tool[21] to estimate RSLR. Pierce County provided direction to ESA to analyze sea level rise in 2100 using the 0.1% probability projection,

[20] Miller, I.M., Morgan, H., Mauger, G., Newton, T., Weldon, R., Schmidt, D., Welch, M., Grossman, E., 2018. Projected Sea Level Rise for Washington State – A 2018 Assessment. A collaboration of Washington Sea Grant, University of Washington Climate Impacts Group, University of Oregon, University of Washington, and US Geological Survey. Prepared for the Washington Coastal Resilience Project. updated 07/2019 http://www.wacoastalnetwork.com/wp-content/uploads/2020/02/SLR-Report-Miller-et-al-2018.pdf [last accessed November 7, 2021]

[21] Climate Impacts Group, 2020. Interactive Sea Level Rise Data Visualizations, College of the Environment, University of Washington, Seattle WA. https://cig.uw.edu/our-work/applied-research/wcrp/sea-level-rise-data-visualization/ [last accessed December 23, 2020]

and the high greenhouse gas scenario. [22,23] While the 0.1% probability projection is considered extremely conservative, analyzing this high amount of sea level rise will provide an upper physical bound for the amount of sea level rise that the County could experience, based on existing models.

The Pierce County shoreline is divided into 13 segments within the CIG tool. A “dashboard” from the CIG tool is shown in Figure 2-5 for Puget Sound shorelines within the WRIA (Water Resource Inventory Area) 10 Puyallup-White area in Pierce County. The dashboard shows the projected amount of sea level rise over time with a resulting RSLR value of 8.8-feet by 2100. The 13 shoreline segments in Pierce County had 2100 RSLR projections ranging from 8.4 to 8.8 feet and an average RSLR increase of 8.6 feet, relative to the average sea level for the time period 1991 to 2009.

For the purposes of this project, the average RSLR increase of 8.6 feet was assumed to be representative of RSLR for all Puget Sound shorelines within Pierce County.

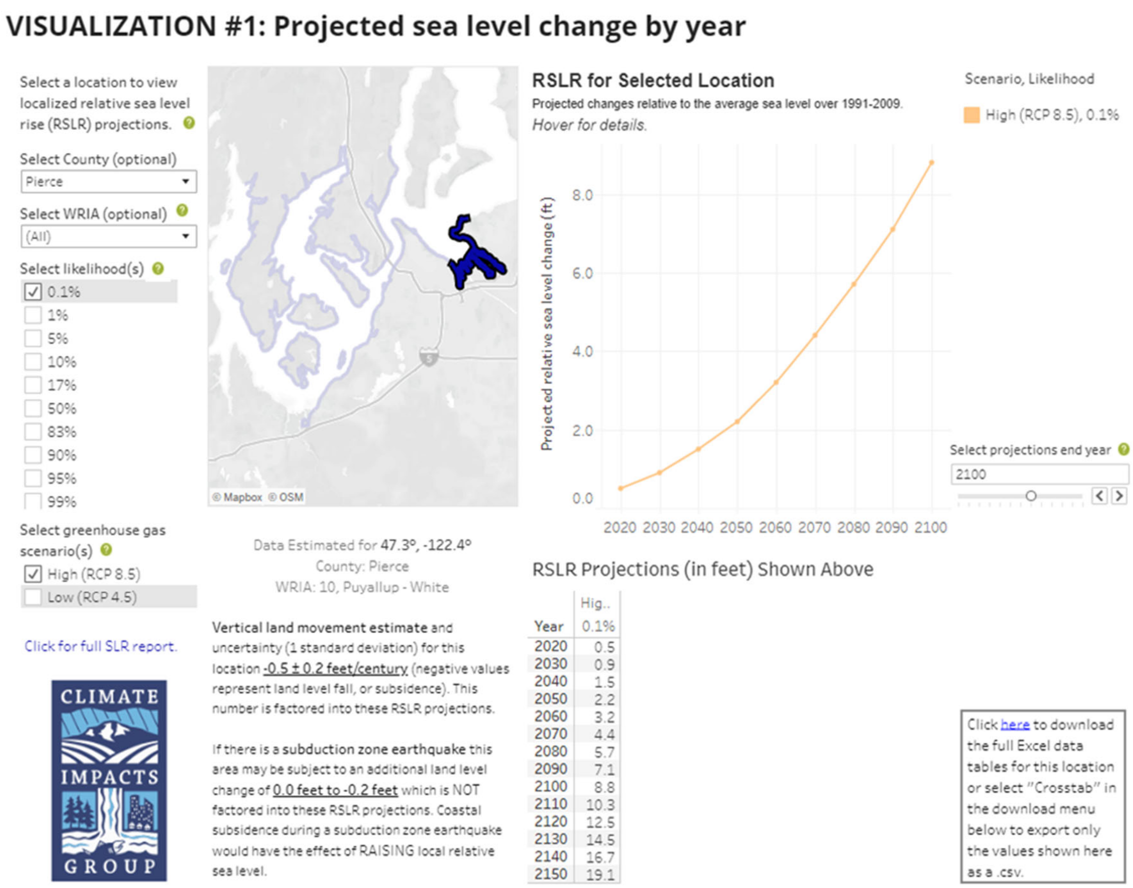

Figure 2-5. Example Climate Impacts Group Relative Sea Level Rise (RSLR) Data Visualization Result

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[22] Walker, B., 2020. Personal correspondence via email to Kevin Coulton, Monday, September 28, 2020 10:33 AM

[23] Pierce County, 2020. Pierce County Flood Economics check-in conference call, with ECONorthwest and ESA, October 29.

2.2.3 Future Tidal Datums

There are seven active NOAA tide stations within Pierce County; however, only one station (9446484) has established tidal datums that include the NAVD88 datum, allowing a correlation of relative tidal elevations to the absolute NAVD88 datum. Figure 2-6 show the relationships of all datums at NOAA Station 9446484.

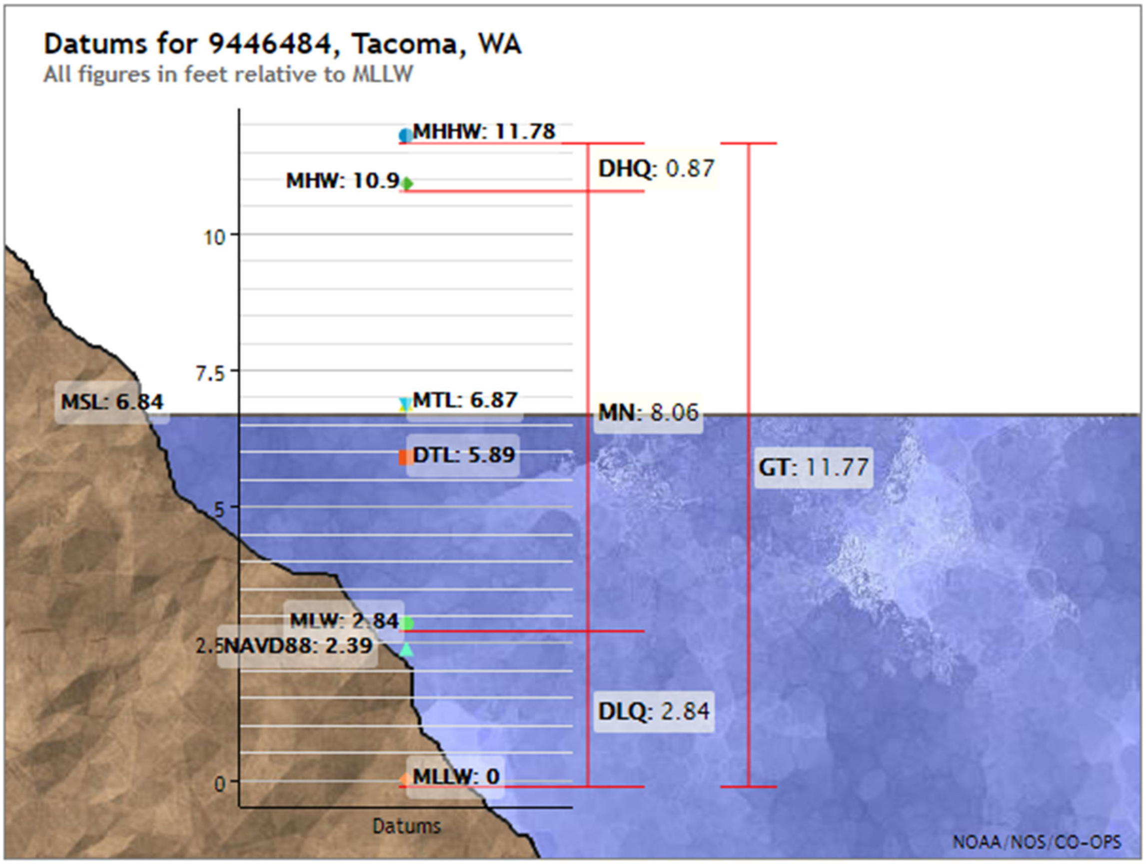

Figure 2-6. Tidal Datums for NOAA Tide Station 9446484, Tacoma WA

The datums for the Tacoma tide station were assumed to be applicable to all tidal waters in Pierce County and the RSLR increase of 8.6 feet was added to these datums to estimate future tidal datums in 2100 in the NAVD88 vertical datum (Table 2-5).

Table 2-5. Conversion of 2100 Relative Sea Level Rise Elevation from MSL to NAVD88

Datum	Current Elevation (ft. MLLW)	Current Elevation (ft, NAVD88)	2100 Elevation (ft, NAVD88)
MHHW	11.78	9.39	17.99
MHW	10.9	8.51	17.11
MTL	6.87	4.48	13.08
MSL	6.84	4.45	13.05
MLW	2.84	0.45	9.05
NAVD88	2.39	0.00	0.00
MLLW	0	-2.39	6.21

2.2.4 Future Extreme Water Elevations

FEMA does not presently address climate change related flood hazards in the National Flood Insurance Program (NFIP) for flood insurance purposes; however, several recent studies have been conducted in Washington State and were referenced for this work. The Washington Coastal Resilience Project (WCRP)[24] produced a report titled "Extreme Coastal Water Levels in Washington State: Guidelines to Support Sea Level Rise Planning". [25] The report states that, "Total water level (TWL) estimates for extreme events across a range of return frequencies are not yet available for locations in Puget Sound and the Strait of Juan de Fuca but are the focus of current research by the US Geological Survey". The report also assessed extreme coastal water levels near Tacoma and concluded that "…for many planning and decision-making applications…using the SWL return frequency information …would be adequate to characterize the coastal flood exposure". Another WCRP report titled "Guidelines for Mapping Sea Level Rise Inundation for Washington State"[26] presents a simplified "bathtub" approach for mapping sea level rise inundation, which maps everything below a certain elevation as inundated. The bathtub approach does not consider complex hydrodynamics including waves, currents, and land cover, but can be considered a good first order approximation of the areas that may be inundated with sea level rise.

ESA staff was involved in another study that took a similar approach. For example, a 2013 Climate Change Study was recommended by the Government Accountability Office (GAO) to assess the likely influence of climate change on the National Flood Insurance Program (NFIP).[27] A simplified approach was adopted in coastal areas for determination of future flood hazard zone changes, where the coastal floodplain was approximated by a plane slope and the changing landward extents of flooding were based on simple rules of proportionality with increased coastal flood elevations. The study also noted that "While waves contribute to the BFE, they do not ordinarily expand the SFHA, since wave breaking reduces wave height to zero at the inland limit of the SFHA."

Therefore, given the planning-level aspects of this study, the bathtub approach was deemed an acceptable approach to map future coastal hazards in Pierce County. Table 2-6 provides the average estimated extreme stillwater elevations by return period for Pierce County for both current and 2100 conditions, assuming the addition of 8.6 feet of RSLR to the various return period stillwater elevations.

[24] University of Washington, 2021. Climate Impacts Group, The Washington Coastal Resilience Project. https://cig.uw.edu/our-work/applied-research/wcrp/ [last accessed February 19, 2021]

[25] Miller, I.M., Yang, Z., VanArendonk, N., Grossman, E., Mauger, G. S., Morgan, H., 2019. Extreme Coastal Water Level in Washington State: Guidelines to Support Sea Level Rise Planning. A collaboration of Washington Sea Grant, University of Washington Climate Impacts Group, Oregon State University, University of Washington, Pacific Northwest National Laboratory and U.S. Geological Survey. Prepared for the Washington Coastal Resilience Project. [last accessed February 19, 2021]

[26] Norheim, R.A., G.S. Mauger, I.M. Miller, 2018. Guidelines for Mapping Sea Level Rise. Report prepared for the EPA National Estuary Program (NEP). Climate Impacts Group, University of Washington, Seattle. https://cig.uw.edu/publications/guidelines-for-mapping-sea-level-rise-inundation-for-washington-state/ [last accessed February 19, 2021]

[27] AECOM, 2013. The Impact of Climate Change and Population Growth on the National Flood Insurance Program through 2100, June. https://aecom.com/content/wp-content/uploads/2016/06/Climate_Change_Report_AECOM_2013-06-11.pdf [last accessed December 23, 2020]

Table 2-6. Current and Future Return Period Stillwater Elevations for Pierce County

Return Period	Current Elevation (ft, NAVD88)	2100 Elevation (ft., NAVD88)
10-year event	16.0	24.6
50-year event	16.6	25.2
100-year event	16.7	25.3
500-year event	17.0	25.6

2.2.5 Changes to Flood Hazard Zones due to Sea Level Rise

Since the effects of waves were not included in the bathtub approach, future coastal flood hazards from RSLR were based on an average present day 100-year stillwater elevation. This delineation of a future coastal flood hazard without wave action is similar to FEMA's guidance for mapping existing conditions 0.2 percent coastal flood hazards; i.e., "The Mapping Partner should show areas below the 0.2-percent-annual-chance SWEL that are not covered by any other flood zone as X Zone (shaded) on the FIRM."28

The average 100-year stillwater elevation of 13.0-ft NAVD88 was obtained by averaging the individual 100-year stillwater elevations from the 117 coastal transects used in the effective FEMA Flood Insurance Study for Pierce County, and this elevation was increased by the estimated average 8.6-ft of RSLR to establish a future 100-year stillwater elevation in Pierce County of 21.6-ft, NAVD88 by the year 2100. This 21.6-ft, NAVD88 elevation exceeds all effective total water elevations 29 in the County (that range from 12.0- to 20.9-ft, NAVD88) and therefore, this estimated future 100-year stillwater elevation was deemed appropriate to represent future coastal flooding from RSLR.

2.2.6 Findings

The increase in coastal flood hazards from the 2100 RSLR event was analyzed using a GIS. Figure 2-7 shows a mapping detail of RSLR mapping on Anderson Island. The green areas represent existing riverine flood hazard areas and orange areas represent existing coastal flood hazard areas. The areas with diagonal lines represent the new coastal flood hazard areas from the 2100 RSLR event created by imposing the 21.6-ft, NAVD88 elevation on the underlying DEM. As expected, all existing coastal flood hazard areas are inundated by the 2100 RSLR event and portions of the riverine flood hazard areas are inundated by the 2100 RSLR event. The blue areas represent new

[28] FEMA, 2019. Guidance for Flood Risk Analysis and Mapping: Coastal Floodplain Mapping, November. https://www.fema.gov/media-collection/guidance-femas-risk-mapping-assessment-and-planning [Note: This website is not currently working]

[29] The total water elevation equals the stillwater elevation plus wave height effects including wave setup and runup.

coastal flood hazard areas from the 2100 RSLR event created inland of existing riverine and coastal flood hazard areas.

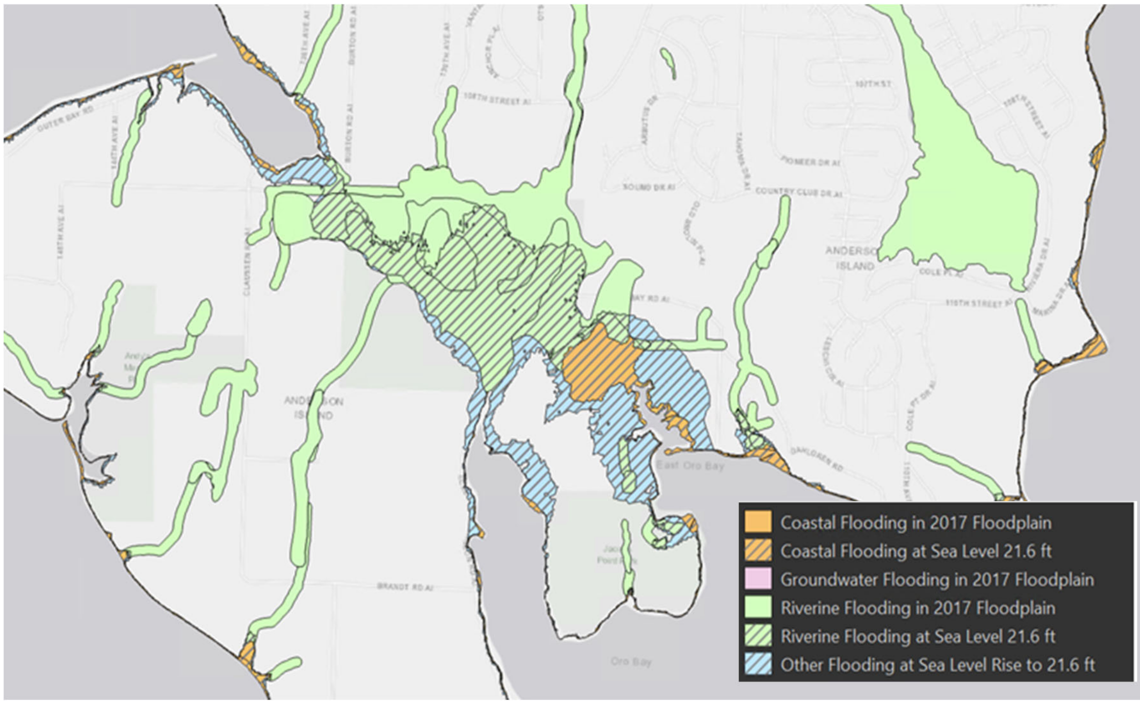

Figure 2-7. Relative Sea Level Rise Mapping Detail on Anderson Island

The resulting areas and a comparison of the current 2020 flood hazard areas to the future 2100 coastal flood hazard areas caused by RSLR are shown in Table 2-7. As expected, the 8.6-foot rise in sea level inundated all 861 acres of existing coastal flood hazard areas and inundated 2,419 acres of existing riverine flood hazard areas. All groundwater flood hazard areas are inland of the estimated inland limit of 2100 RSLR and were not affected. There are an estimated 6,651 acres of new coastal flood hazard areas from the 2100 RSLR event; these new flood hazard areas represent an 8.5 percent increase in flood hazard areas within Pierce County.

Table 2-7. Current and Future Flood Hazard Areas for Pierce County

Type of Flood Hazard Areas	2020 Flood Hazard Areas (acres)	2100 Sea Level Rise Flood Hazard Areas (acres)	Grand Total (acres)
Coastal Flood Hazard Areas	861	861	861
Groundwater Flood Hazard Areas	777	--	777
Riverine Flood Hazard Areas	76,520	2,419	76,528
New Sea Level Rise Flood Hazard Areas	--	6,651	6,651
Grand Total	**78,158**	**9,930**	**84,816**

2.2.7 Future Work

It is recognized that a more rigorous analysis of future flooding from sea level rise would include an assessment of storm surge and waves that may change due to sea level rise and future work may be considered to account for these processes. In another study, ESA developed a technical methods manual to relate future coastal conditions to existing FEMA flood hazard maps.[30] These methods go beyond the bathtub approach to consider that a change in sea level may result in a change to the shoreline geometry, due to waves dissipating their power at a higher elevation. This "morphology" response to sea level rise can result in a lateral shore migration and associated flood hazards greater than that caused by sea level rise alone and would therefore result in a different mapped extent of flood hazard areas. This methodology involves a higher level of effort to apply and was determined to be beyond the scope of the present study; however, it could be applied in the future to refine the bathtub analysis presented in this planning-level study.

[30] Battalio, R. T., P. D. Bromirski, D. R. Cayan, L. A. White (2016). Relating Future Coastal Conditions to Existing FEMA Flood Hazard Maps: Technical Methods Manual, Prepared for California Department of Water Resources and California Ocean Science Trust, Prepared by Environmental Science Associates (ESA), 114 pp.

3.0 BRIDGE FLOOD RISK ASSESSMENT

3.1 Introduction

This assessment of flood risk to bridges along transportation corridors within the 100-year floodplain and other flood-prone areas in Pierce County was guided by the following objectives:

- Analyze the potential flood risk to County bridge infrastructure in terms of damage and needed repairs. Utilize flood elevation data compiled in Task 2 together with existing hydraulic modeling and FEMA Flood Insurance Study data to analyze potential flood risk impacts to bridge infrastructure.

- Estimate the percentage of bridge infrastructure that may be damaged by flooding.

The following assumptions guided this work:

- Existing and available information either provided by WSDOT, ECONorthwest, Fehr and Peers, or obtained from public sources were utilized.

- Flood depth data developed in Task 2 and existing hydraulic modeling and FEMA Flood Insurance Study data were utilized to analyze potential impacts to bridge infrastructure.

- Published flood elevations at bridges were utilized to determine if design freeboard heights (distance between bridge low chord elevations and water elevations) are violated and if flood flows and/or floating debris may damage bridge structure.

- Flood risk to bridges was only analyzed for the 100-year flood event.

This remainder of this report section summarizes the objectives, methods, and results related to an evaluation of potential impacts to Pierce County bridge infrastructure.

3.2 Data

3.2.1 County, City, and WSDOT Bridge Data

Flood risk to bridges within the County were analyzed by identifying bridges that cross flood hazard areas and assessing the relationship of the bridge geometry (hydraulic opening) to 100-year flood elevations. Bridges within Pierce County were identified from the following data sources.

- Pierce County Bridges [31] - This dataset includes a summary of Pierce County bridges that are in mobility and maintained by Pierce County. This feature class does not contain bridges that are maintained by other jurisdictions such as Washington State Department of Transportation (WSDOT), railroads and cities.

- Supplemental (Non-Pierce County) Bridges [32] – This dataset includes railroad bridges, private road bridges, city bridges, national park bridges, JBLM bridges, pedestrian bridges. This feature class does not contain bridges owned or maintained by either the county or state. Supplemental bridges should not be considered complete. Bridges are added to this dataset as they are discovered while the road data is being maintained. A bridge is added to this data if it is not found in the WSDOT Bridge data or the Washington Bridge Inventory System (WBIS).

- WSDOT Bridge Structures (On) [33] - This dataset provides geospatial locations and general bridge information for structures Owned by or Managed by WSDOT Bridge Preservation Office (BPO). The WSDOT Bridge Structures (On) layer is a line dataset that represents a bridge/structure that carries a roadway over a feature.

These bridge data are limited to bridge locations over flood hazard areas that have BFEs and floodways established; i.e, AE Zone riverine flood hazard areas from Table 2-1.

- Rebuilt Bridges – Pierce County informed ESA that three bridges were in the process of being rebuilt and provided maps showing the old and new bridge alignments and associated road changes. [34] ESA obtained the following bridge data:

- City of Puyallup Milwaukee Bridge – ESA obtained the hydraulic report associated with the Milwaukee Bridge retrofit project [35]from the City of Puyallup City Engineer.[36]

- SR 167 Meridian Street Bridge (North Bound) – ESA obtained the bridge plans for the SR 167 Bridge project [37] from WSDOT. [38]

[31] Pierce County Open GeoSpatial Data Portal, 2020. Bridges. https://gisdata-piercecowa.opendata.arcgis.com/datasets/bridges [last accessed October 20, 2020]

[32] Pierce County Open GeoSpatial Data Portal, 2020. Bridges. https://gisdata-piercecowa.opendata.arcgis.com/datasets/bridges-supplemental [last accessed October 21, 2020]

[33] WSDOT, 2020. WSDOT GIS Data Download: Bridge Data - Bridge On Locations. https://www.wsdot.wa.gov/mapsdata/geodatacatalog/default.htm [last accessed October 21, 2020]

[34] Brake, R., 2020. rebuilt bridges, personal email correspondence between Kevin Coulton and Randy Brake, P.E., Pierce County, November 30.

[35] Northwest Hydraulic Consultants, 2020. Milwaukee Bridge Retrofit Bridge Hydraulic Study - Final Report, prepared for BergerABAM, February 11.

[36] Hunger, H., 2020. Puyallup - Milwaukie Bridge Hydraulics Report, personal email correspondence between Kevin Coulton and Hans Hunger, P.E., City Engineer, City of Puyallup, November 24.

[37] WSDOT, 2015. SR 167 Puyallup River Bridge Replacement, Sheets 78 to 151.

[38] Gaines, M., 2021. Email correspondence to K. Coulton/ESA, November 1.

- SR 162 McMillan Bridge – ESA obtained the bridge plans for the SR 162 Bridge project [39] from WSDOT. [40]

3.2.3 FHWA National Bridge Inventory Data

The FHWA National Bridge Inventory (NBI) provides nationwide data on bridges and associated roadway approaches. NBI data for Washington State were obtained [41] and the data were sorted to Pierce County and utilized to assess flood risk to County bridges and associated road approaches. The following data were utilized and are described in more detail in the FHWA recording and coding guide [42]:

Item 71 - Waterway Adequacy. This item appraises the waterway opening with respect to passage of flow through the bridge. Where overtopping frequency information is available, the information given in Table 3-1 describes overtopping frequency of a bridge deck or roadway approach.

Table 3-1. Flood Overtopping Frequency

Frequency	FHWA Description	Annual Exceedance Probability (AEP)	Assumptions
Remote	Greater than 100 years	1.0%	Assumed 100-year return period
Very Sight	Estimated at 50 years *	2.0%	Assumed 50-year return period
Slight	11 to 100 years	4.0%	Assumed 25-year return period
Occasional	3 to 10 years	20.0%	Assumed 5-year return period
Frequent	Less than 3 years	50.0%	Assumed 2-year return period

** This frequency was added to account for roadway functional classifications interloped between an overtopping frequency of slight and remote.*

The data also describe traffic delays, but these were not considered in this analysis. The overtopping frequency is associated with the functional classification of the road crossing the bridge.

[39] WSDOT, 2015. SR 162 Puyallup River Bridge Replacement, Puyallup River Bridge No. 162/6 Replacement, Sheets 2 to 101.

[40] Gaines, M., 2021. Email correspondence to K. Coulton/ESA, November 1.

[41] FHWA, 2021. Bridges & Structures, Download NBI Element Data 2020. https://www.fhwa.dot.gov/bridge/nbi/element2020.cfm [last accessed October 31, 2021]

[42] FHWA, 1995. Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges, Report No. FHWA-PD-96-001, December https://www.fhwa.dot.gov/bridge/mtguide.pdf [last accessed October 31, 2021]

Item 26 - Functional Classification of Inventory Route. The functional classification of bridge roadways in Pierce County are summarized as shown in Table 3-2.

Table 3-2. Functional Classifications of Bridge Roadways

Rural / Urban	FHWA Code	Description
Rural	01	Principal Arterial - Interstate
	02	Principal Arterial - Other
	06	Minor Arterial
	07	Major Collector
	08	Minor Collector
	09	Local
Urban	11	Principal Arterial - Interstate
	12	Principal Arterial – Other Freeways or Expressways
	14	Other Principal Arterial
	16	Minor Arterial
	17	Collector
	19	Local

Bridges are coded rural if not inside a designated urban area and the urban or rural designation is determined by the bridge location and not the character of the roadway.

Item 94 - Bridge Improvement Cost. These costs were assumed to represent the estimated value of the bridges in thousands of dollars. These costs include only bridge construction costs and exclude costs for roadway, right of way, detour, demolition, preliminary engineering, etc. The costs are associated with various years of improvement. For Pierce County bridges over waterways these years include: 2013, 2014, 2017, 2018, 2020, and 2023; these costs have not been adjusted to a 2021 cost basis.

Item 95 - Roadway Improvement Cost. These costs were assumed to represent the estimated value of roadway approaches to bridges in thousands of dollars. These costs include only roadway construction costs and exclude bridge, right-of-way, detour, extensive roadway realignment costs, preliminary engineering, etc. Similar to the bridge improvement costs, the roadway improvement costs are associated with the years: 2013, 2014, 2017, 2018, 2020, and 2023; these costs have not been adjusted to a 2021 cost basis.

3.3 Methods

Flood risk to bridges in Pierce County was assessed by evaluating the potential for bridge damages to occur during the 100-year flood event when required freeboard heights are violated and the potential for bridge failure due to the depth and velocity of floodwaters during the 100-year flood event.

3.3.1 Bridge Freeboard Violation

Flood risk to bridges was assumed to occur if bridge freeboard heights were violated and assuming flood flows and/or floating debris may damage the bridge structure. Bridge freeboard is the vertical opening clearance height between the lowest elevation of a bridge superstructure (low chord) and the design water surface elevation (Figure 3-1). An appropriate amount of freeboard allows for the passage of flood flows and floating flood debris through the structure.

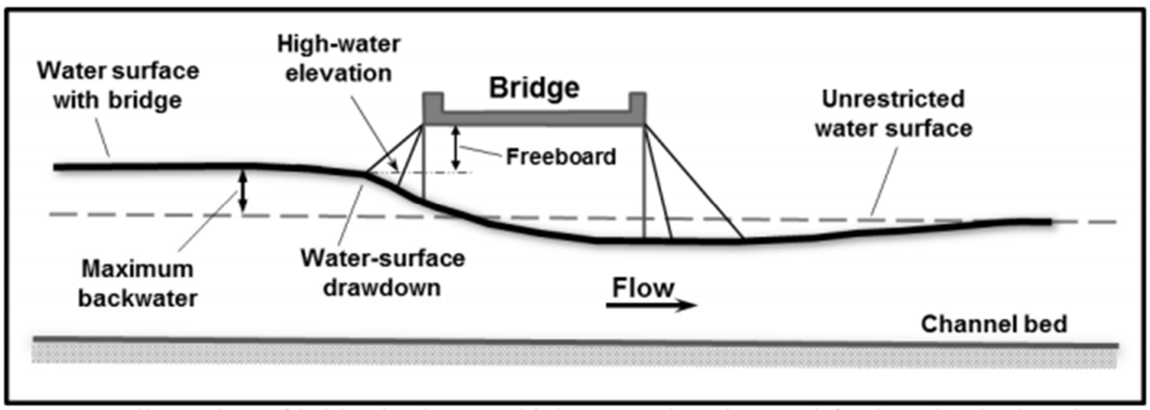

Figure 3-1. Bridge Freeboard Schematic [43]

The Pierce County Code (Chapter 18E.70.040)[44] specifies a 6.0-ft clearance is for bridges over floodways (B.15), but a 1.0-ft clearance for bridges over flood fringe areas (C.3) and coastal flood hazard areas (E.1). The King County Road Design and Construction Standards-2016 Section 6.02.F [45] was also referenced:

> *"For stream crossing locations where the 100-year peak flow exceeds 100 cubic feet per second (cfs), the height of bridge clearance above rivers and streams shall*

[43] South Carolina Department of Transportation, 2019. Hydraulic Design Bulletin No. 2019-4, Updated Hydraulic Bridge Design Criteria https://www.scdot.org/business/technicalPDFS/hydraulic/HDB_2019-4.pdf [last accessed April 29, 2021]

[44] Pierce County, 2020. Chapter 18E.70, FLOOD HAZARD AREAS, https://www.codepublishing.com/WA/PierceCounty/html/PierceCounty18E/PierceCounty18E70.html [last accessed October 20, 2020]

[45] King County Department of Transportation Road Services Division, 2016. King County Road Design and Construction Standards, revised November 28. https://www.kingcounty.gov/depts/local-services/roads/road-standards.aspx#2016 [last accessed October 20, 2020]

be a minimum three feet above the 100-year water surface elevation unless otherwise required by the County Road Engineer based on an evaluation of conveyance factors…".

Since the King County 3-ft bridge clearance requirement falls within the County 1-ft and 6-ft clearance requirement, the following freeboard criteria were established for the purposes of this study:

- bridges over FEMA regulatory floodways were deemed at risk if clearances were less than 6-ft;
- bridges over non-floodway channels were deemed at risk if clearances were less than 3-ft;
- bridges not over channels but in flood fringe areas or coastal flood hazard areas were deemed at risk if clearances were less than 1-ft.

Bridge low chord elevations were identified from the geometry associated with the hydraulic opening of the bridge structures which was obtained from hydraulic models provided by Pierce County and from engineering drawings of bridges rebuilt since the date the models were developed. Table 3-3 shows the hydraulic models that were obtained and reviewed to identify the bridge low chord elevations on the upstream side of each bridge.

Table 3-3. Summary of Hydraulic Models Used in the Bridge Damage Assessment

Model Name	Model Plan	Organization	Date
Lower-Middle Puyallup Com. Bay to RM 17	G2a - with levees	USCE	2006
Upper Puyallup River RM 17.4506 - 30.094	FEMA - floodway, with lateral weir	NHC	2002
Carbon w/ Levees	With Levees	NHC	2004
FEMA FIS South Prairie 2002	Base Flood NAVD88 - PF3	NHC	2002
White River FIS	Split Flow - NAVD	NHC	2005

These models were also used to obtain 100-year flood elevations at the bridges. The 100-year flood elevation at each bridge was subtracted from the bridge low chord elevation to estimate the bridge freeboard at the upstream side of each bridge. The freeboard estimate was compared to the freeboard criteria to determine if the bridge freeboard was violated and if the bridge was at risk during the 100-year flood event.

3.3.2 Bridge Flood Depths and Velocities

In addition to estimating flood risk to bridges from freeboard violations, the potential for bridge failure was also estimated. Potential failure was based on data summarized in Table 3-4 for combinations of flood depth and velocity at each bridge for the 100-year flood event.

Table 3-4. Bridge and Road Failure Flood Depth-Velocity Relationships [46]

Flood Velocities	Flood Depths	
	Bridge	Road Approach
Greater than 15 feet per second	2 feet below bridge low chord	2 to 4 feet and over
10 to 15 feet per second	1 foot below bridge low chord	2.5 to 4 feet and over
5 to 10 feet per second	At bridge floor level	Over 3 feet
2 to 5 feet per second	2 feet over bridge floor	Over 4 feet

3.3.2 FHWA National Bridge Inventory

The general methodology to assess flood risk to bridges in Pierce County using the NBI data was to identify the Pierce County bridges over waterways and their associated frequency of flood overtopping, then estimate the potential bridge and roadway value exposed to flood risk by the frequency of flood overtopping by assuming bridge and roadway improvement costs in the NBI database were reasonable estimates of infrastructure value.

3.4 Results

3.4.1 Bridge Freeboard Violation

A total of 44 bridges were identified from the hydraulic models and used in this analysis. All bridges are located over AE Zone flood hazard areas that have BFEs established and therefore all resulting bridge clearances were compared to a required 6-foot freeboard to assess flood risk. Only 14 bridges have freeboard violations: five of these bridges are owned by WSDOT; two bridges are owned by railroads; two bridges are owned by the City of Sumner; and, five bridges are owned by Pierce County. These bridges are shown in Table 3-5 from the greatest to least freeboard deficiency.

[46] USDA, 1969. TSC Technical Note – Watersheds UD-22, Economics – Floodwater Damages to Roads and Bridges, June 30. https://www.nrcs.usda.gov/wps/PA_NRCSConsumption/download?cid=nrcseprd410822&ext=pdf [last accessed October 20, 2021]

Table 3-5. Summary of Bridge Freeboard Deficiencies

Owner	Description	River	Bridge Low Chord Elevation (ft)	100 Year Flood Elevation (ft)	Flood Clearance (ft)	Required Freeboard (ft)	Freeboard Deficiency (ft)
City of Sumner	NE 8th / Stewart Road Bridge	White River (Stewart Rd)	70.96	70.65	0.31	6.00	(5.69)
Pierce County	Foothills Trail Bridge	Carbon River	308.99	307.83	1.16	6.00	(4.84)
WSDOT	SR 162 South Prairie Bridge 4	S Prairie Creek	366.84	365.67	1.17	6.00	(4.83)
WSDOT	SR 162 South Prairie Bridge 3	S Prairie Cr	355.46	352.69	2.77	6.00	(3.23)
Pierce County	Foothills Trail Pedestrian Bridge	South Prairie Ck (City)	441.11	438.31	2.80	6.00	(3.20)
WSDOT	SR 162 Carbon River Bridge	Carbon River	310.60	306.62	3.98	6.00	(2.02)
WSDOT	SR 162 South Prairie Bridge 1	S Prairie Creek	315.01	310.97	4.04	6.00	(1.96)
Pierce County	96th St. E. Bridge*	Puyallup River (96th St)	86.53	82.23	4.30	6.00	(1.70)
City of Sumner	142nd Ave Bridge	White River (Fryar Av)	58.21	53.91	4.30	6.00	(1.70)

Union Pacific Railroad	UP Railroad Bridge*	Rr Over Puyallup River	19.87	15.40	4.47	6.00	(1.53)
WSDOT	SR 162 South Prairie Bridge 5	S Prairie Cr	439.52	435.00	4.52	6.00	(1.48)
BNSF Railroad	BNSF RR Bridge*	Rr Over Puyallup River	17.14	12.12	5.02	6.00	(0.98)
Pierce County	Pedestrian / old railway bridge adjacent to SR 162 Bridge	Puyallup River	125.43	120.19	5.24	6.00	(0.76)
Pierce County	Milroy Bridge / 66th Ave / Clark St *	Puyallup River (66th Av)	32.20	26.75	5.45	6.00	(0.55)

Based on the flood depth and velocity combinations shown in Table 3-2, only two bridges are estimated to fail in Pierce County. These bridges also have the greatest freeboard violations of the 44 bridges described above. The bridges include the NE 8th / Stewart Road Bridge over the White River owned by the City of Sumner and the Foothills Trail Bridge over the Carbon River owned by Pierce County.

3.4.2 FHWA National Bridge Inventory

There are 466 bridges in Pierce County and 255 of these bridges are over waterways. Table 3-6 provides a summary of the 255 bridges over waterways by the entity responsible for maintenance and by the functional classification of the roadway. Pierce County is responsible for maintaining 94 bridges or 37-percent of the bridges over waterways in the County.

Table 3-7 shows the 255 bridges over waterways and their respective flood overtopping frequency. No bridges in the County have a frequent or occasional chance of overtopping. Some rural and urban collectors and local roadway approaches to bridges have an occasional chance of overtopping with traffic delays, but only at 5-percent of the total bridges over waterways. Approximately 21-percent of bridges in the County have a slight chance of floods overtopping the bridge deck and roadway approaches and approximately 73-percent of the roadway approaches to bridges in the County have a slight chance of overtopping.

Table 3-8 provides a summary of the values of bridge and roadway infrastructure at risk of flooding as a function of the chance of flood overtopping for both the bridge deck and roadway approaches, and by the functional classification of the roadway. Pierce County bridges over waterways that have chance of overtopping are estimated to have a total value of $128 million and an associated value of $185 million for roadway approaches to bridges. Bridge and roadway approaches having a slight chance of flood overtopping have a value of $40 million and $183 million, respectively. For both bridges and roadway approaches, the greatest flood risk is associated with urban minor arterial bridges, with an estimated 77-percent and 38-percent of the total value of infrastructure exposed to flood risk for bridges and roadway approaches, respectively.

Table 3-6. Pierce County Waterway Bridges and Maintenance Responsibilities

Maintenance Responsibility	Rural						Urban						Grand Total
	Principal Arterial - Interstate	Principal Arterial - Other	Minor Arterial	Major Collector	Minor Collector	Local	Principal Arterial - Interstate	Principal Arterial - Other	Other Principal Arterial	Minor Arterial	Collector	Local	
WSDOT	2	1	15	1			9	13	10	18	1		70
Pierce County			10	20	4	19			4	16	9	12	94
City or Municipality								1	14	7	8	3	33
State Park, Forest, or Reservation Agency												1	1
Other State Agencies						1							1
Other Local Agencies				1									1
U.S. Forest Service						14							14
National Park Service		1			7	11							19
U.S. Army					4	11						7	22
Grand Total	**2**	**2**	**25**	**22**	**15**	**56**	**9**	**14**	**28**	**41**	**18**	**23**	**255**

Table 3-7. Pierce County Waterway Bridges and Flood Overtopping Frequency

Description of Flood Overtopping Frequency	Rural						Urban						Total Bridges
	Principal Arterial - Interstate	Principal Arterial - Other	Minor Arterial	Major Collector	Minor Collector	Local	Principal Arterial - Interstate	Principal Arterial - Other	Other Principal Arterial	Minor Arterial	Collector	Local	
Bridge closed													
Occasional or frequent overtopping of bridge deck and roadway approaches with severe traffic delays													
Frequent overtopping of bridge deck and roadway approaches with significant traffic delays													
Occasional overtopping of bridge deck and roadway approaches with significant traffic delays													
Occasional overtopping of roadway approaches with significant traffic delays				1	1						2		4
Occasional overtopping of roadway approaches with insignificant traffic delays					1	6					1	1	9
Slight chance of overtopping bridge deck and roadway approaches			5	2	3	14	4	1	3	9	2	10	53
Slight chance of overtopping roadway approaches	2	2	20	19	9	34	5	13	25	32	13	12	186
Chance of overtopping is remote					1	2							3
Bridge not over a waterway			3	7	2	3	43	66	42	22	14	9	211
Total Bridges	**2**	**2**	**28**	**29**	**17**	**59**	**52**	**80**	**70**	**63**	**32**	**32**	**466**

Table 3-8. Summary of Bridge Costs by Flood Overtopping Frequency

	Rural						Urban						
Chance of Overtopping Bridge Deck	**Principal Arterial - Interstate**	**Principal Arterial - Other**	**Minor Arterial**	**Major Collector**	**Minor Collector**	**Local**	**Principal Arterial - Interstate**	**Principal Arterial - Other**	**Other Principal Arterial**	**Minor Arterial**	**Collector**	**Local**	**Grand Total**
Frequent													
Occasional													
Slight			$1,583,000	$1,550,000	$534,000	$4,891,000	$4,665,000	$464,000	$1,176,000	$13,980,000	$7,679,000	$3,867,000	**$40,389,000**
Very slight				$2,934,000					$699,000	$83,902,000			**$87,535,000**
Remote													
Grand Total	**$0**	**$0**	**$1,583,000**	**$4,484,000**	**$534,000**	**$4,891,000**	**$4,665,000**	**$464,000**	**$1,875,000**	**$97,882,000**	**$7,679,000**	**$3,867,000**	**$127,924,000**
	Rural						**Urban**						
Chance of Overtopping Roadway Approaches	**Principal Arterial - Interstate**	**Principal Arterial - Other**	**Minor Arterial**	**Major Collector**	**Minor Collector**	**Local**	**Principal Arterial - Interstate**	**Principal Arterial - Other**	**Other Principal Arterial**	**Minor Arterial**	**Collector**	**Local**	**Grand Total**
Frequent													
Occasional				$1,052,000	$8,000	$529,000						$134,000	**$1,723,000**
Slight	$1,696,000	$48,000	$6,105,000	$5,561,000	$577,000	$4,720,000	$20,216,000	$48,792,000	$11,179,000	$69,774,000	$11,913,000	$2,830,000	**$183,411,000**
Very slight													
Remote					$9,000								**$9,000**
Grand Total	**$1,696,000**	**$48,000**	**$6,105,000**	**$6,613,000**	**$594,000**	**$5,249,000**	**$20,216,000**	**$48,792,000**	**$11,179,000**	**$69,774,000**	**$11,913,000**	**$2,964,000**	**$185,143,000**

4.0 ROAD FLOOD RISK ASSESSMENT

4.1 Introduction

This assessment of flood risk to roads along transportation corridors within the 100-year floodplain and other flood-prone areas in Pierce County was guided by the following objectives:

- Analyze the potential flood risk to County road infrastructure in terms of damage and needed repairs. Utilize flood elevation data compiled in Task 2 together with existing hydraulic modeling and FEMA Flood Insurance Study data to analyze potential flood risk impacts to road and bridge infrastructure.

- Estimate the percentage of County roads that may be damaged by flooding.

The following assumptions guided this work:

- Existing and available information either provided by WSDOT, ECONorthwest, Fehr and Peers, or obtained from public sources were utilized.

- Flood depth data developed in Task 2 and existing hydraulic modeling and FEMA Flood Insurance Study data were utilized to analyze potential impacts to road infrastructure.

- Published flood elevations at roads were utilized to determine if flood overtopping of roads may occur damage road surfaces and embankments.

- Flood risk to roads was only analyzed for the 100-year flood event.

This remainder of this report section summarizes the objectives, methods, and results related to an evaluation of potential impacts to Pierce County road infrastructure.

4.2 Data

Flood risk to roads was analyzed by overlaying Pierce County GIS road data on terrain data, and then comparing the resulting road elevations to 100-year flood elevations to estimate damages from flood overtopping.
Roadway flood risk was estimated using the following datasets:

- Existing Flood Hazard Areas – The flood hazard areas estimated in Task 2 were used to identify roads within floodplains.

- Roads – This dataset represents center of roadway right-of-ways and easements throughout Pierce County.[47]

- LiDAR – Road alignments were overlaid on LiDAR terrain surface to estimate the elevation of the roadways.[48]

- Mobility Data – This dataset represents primarily unincorporated County roads that have various road classifications, types, and use attributes.[49]

The public datasets were analyzed in a GIS to develop geospatial data more specific for the analysis of road flood risk within flood hazard areas with BFEs. This work involved the following steps:

1. The BFE contour linework was used to create a flood surface within the respective floodplain boundaries having BFEs.

2. The County's roads layer was intersected with the BFE flood surface to clip the roads within the floodplain boundaries and assign floodplain hazard attributes.

3. LiDAR elevation values were added to the roads at 100-foot intervals using the DNR LiDAR surface (2011) and averaged over the length of the road segment to create an average road crest elevation for each road segment.

4. BFE values were added to the roads at the same 100-foot intervals using the BFE surface and averaged over the length of each road segment to create an average BFE for each road segment.

5. Average road crest elevations were subtracted from average BFEs to estimate the depth of overtopping (or no overtopping) for each 100-foot road segment.

The resulting geospatial dataset included road segments within BFE mapped areas with attributes for both BFE and road crest elevations at 100-foot intervals along the roads within flood hazard areas. The symbology shown in Figure 4-1 provides an example of these road segments and the associated elevation differences: i.e., red and orange denotes road surfaces lower than the associated BFE and green denotes road surfaces higher than the associated BFE. In this example the only red road segments are bridges; the road data for bridges was removed from the dataset because the LiDAR DTM flattens bridges to the water surface and erroneously indicates bridge road segments as being lower than BFEs.

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[47] Pierce County Open GeoSpatial Data Portal, 2020. Roads. https://gisdata-piercecowa.opendata.arcgis.com/datasets/roads?geometry=-122.225%2C47.025%2C-122.014%2C47.066 [last accessed October 21, 2020]

[48] Washington Department of Natural Resources, 2011. Lidar portal, Pierce County. https://lidarportal.dnr.wa.gov/ [last accessed October 29, 2020]

[49] Pierce County Open GeoSpatial Data Portal, 2020. Mobility Data. https://gisdata-piercecowa.opendata.arcgis.com/datasets/mobility-data [last accessed October 21, 2020]

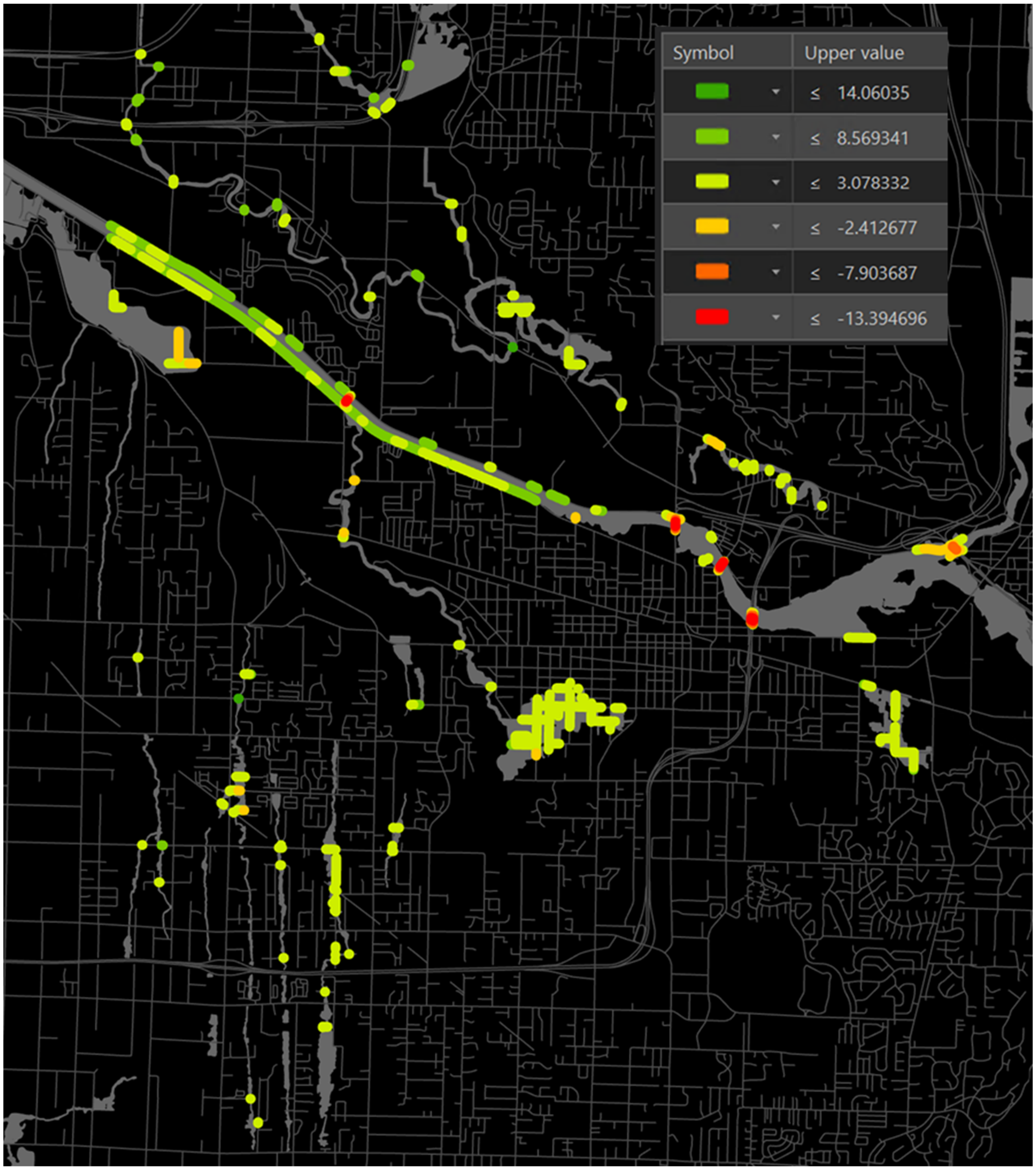

Figure 4-1. Example of Road Segments Showing BFE and Road Crest Elevation Differences

4.3 Methods

4.3.1 Roads at Risk of Flood Overtopping

Estimates of the length of roads at risk of flooding were made using a GIS analysis that provided data for a subsequent spreadsheet analysis. The general methodology involved the following steps:

1. Estimate the total length of roads in the County that are in all Special Flood Hazard Areas (SFHAs). This road length represents all roads in Pierce County that could potentially be damaged by floodwaters.

2. Estimate the length of roads that are in SFHAs with Base Flood Elevations (BFEs). This road length represents roads in Pierce County where flood overtopping can be evaluated because BFEs are available.

3. Estimate the length of roads overtopped during the 1-percent-exceedance flood event. This road length represents roads where flood overtopping was estimated through a GIS analysis identifying where BFEs exceeded roadway elevations. A detailed methodology was developed to estimate this flood overtopping condition and associated damages for these road lengths, and this is presented in Section 4.2.2.2.

4. Estimate the percentage of road lengths in SFHAs with BFEs that are overtopped. The difference in road lengths estimated in Steps 2 and 3 represents the proportion of roads in SFHAs that are overtopped.

5. Estimate the miles of road that are in SFHAs without Base Flood Elevations (BFEs). The difference road lengths estimated in Steps 1 and 2 represent the roads where flood overtopping will not be able to be directly estimated because no BFE data are available.

6. Estimate the miles of road that are in SFHAs without BFEs that are overtopped. The percentage of road lengths in SFHAs without BFEs is assumed to be similar to the percentage of road lengths in SFHAs with BFEs that are overtopped, as estimated in Step 4. These percentages were applied to the road lengths estimated in Step 5 to estimate the miles of road that are in SFHAs without BFEs that are overtopped.

The results of this general methodology are presented in Section 4.2.3.

4.3.2 Road Damages from Flood Overtopping

The length of roads overtopped during the 1-percent-exceedance flood event, as identified in Step 3 in the general methodology above, were further analyzed using a spreadsheet to estimate embankment and pavement damages that may occur from the 1% AEP flood. This methodology relied primarily on data and procedures from the FHWA [50] (hereafter FHWA), and specifically the nomograph shown in Figure 4-2, to estimate embankment and pavement damages. It is recognized that a 2nd edition of HEC-17 is available [51]; however, this edition does not include the "Computation of Economic Losses" section that was referenced in the first edition for this methodology. The methodology included the following steps:

1. Estimate the length and depth of roadway flood overtopping by road segment. The results of the GIS analysis for Step 3 of the general methodology were summarized in 50-foot road segments and used in subsequent steps to assess embankment and pavement damages. Data from the GIS analysis were filtered to lengths and depths greater than zero.

2. Estimate a duration of flood overtopping. Only static data were estimated for road overtopping lengths and depths. An estimate of the duration of roadway flood overtopping would require detailed unsteady hydraulic modeling, which was beyond the scope of this study. Therefore, an overtopping duration by depth relationship was assumed to occur as shown by the dashed lines on Figure 4-2, with durations ranging from zero to 20-hours for depth up to 6-feet. A maximum duration of 20 hours for an overtopping depth of 6-feet was assumed reasonable based on random observations of 1% AEP flood hydrographs generated for unsteady hydraulic modeling for rivers in Pierce County.

3. Estimate the percent loss of embankment and pavement. Flood overtopping depths were used to enter the FHWA nomograph with the associated assumed durations used as a pivot line to estimate the percent loss of embankment and pavement. The relationship of depth to percent loss, shown by the dashed lines on the nomograph, were converted to polynomial equations using Excel charting techniques and the equations were input to the spreadsheet to provide cell calculations to estimate the percent loss of embankment and pavement.

4. Estimate embankment and pavement widths. The road classifications from the County GIS data were used to estimate embankment and pavement widths. Table 4-1 provides a summary of the embankment and pavement widths by road classification, with associated assumptions and comments. Embankment widths were assumed to be the combined with of lane and shoulder widths. Interstate and non-interstate lane and shoulder widths were obtained from WSDOT [52] and lane and shoulder widths Limited Access Highways, Major Roads, Other Major Roads, and Local Roads were also obtained from WSDOT [53].

[50] FHWA, 1981. The Design of Encroachments on Flood Plains Using Risk Analysis, Hydraulic Engineering Circular No. 17, April. https://ncspa.org/ncspa-dl/pre86/hy/HY-260.pdf [last accessed October 17, 2021]

[51] FHWA, 2016. Highways in the River Environment - Floodplains, Extreme Events, Risk, and Resilience, Hydraulic Engineering Circular, No. 17, 2nd Edition, June. https://www.fhwa.dot.gov/engineering/hydraulics/pubs/hif16018.pdf [last accessed October 17, 2021]

[52] WSDOT, 2021a. Design Manual M 22-01, Chapter 1232 Geometric Cross Section – Freeways, Exhibits 1232-1 and -2 Geometric Cross Section – Interstate and Non-Interstate, https://wsdot.wa.gov/publications/manuals/fulltext/M22-01/1232.pdf [last accessed October 17, 2021]

[53] WSDOT, 2021b. WSDOT Local Agency Guidelines M 36-63.40, Chapter 42 City and County Design Standards for All Routes, 42.5 Design Level D Standards for Two Way Roads and Streets, page 42-11, June. https://wsdot.wa.gov/publications/manuals/fulltext/M36-63/Lag42.pdf [last accessed October 17, 2021]

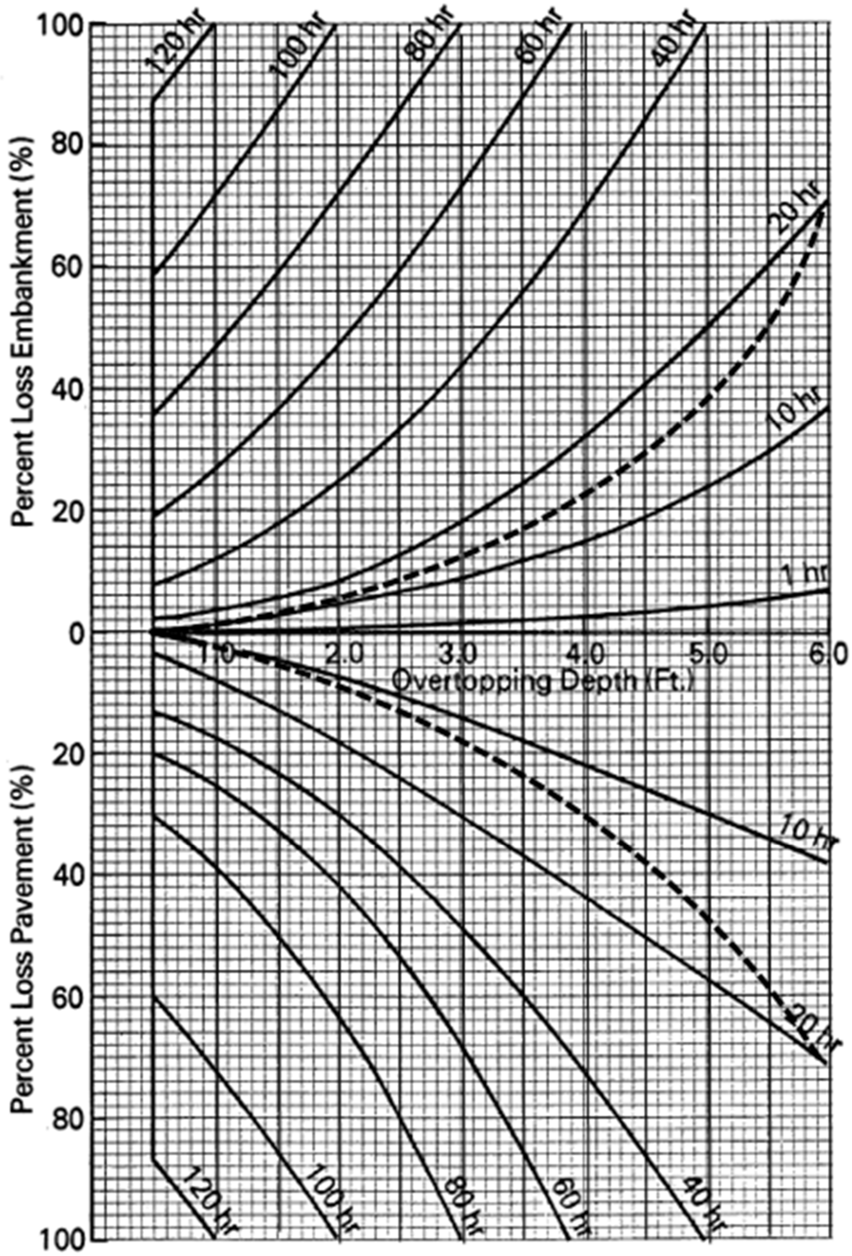

Figure 4-2. FHWA Nomograph for Estimation of Embankment and Pavement Percent Losses

Table 4-1. Summary of Embankment and Pavement Widths by Road Classification

Road Classification	Embank Width (Ew)	Pavement Width (Pw)	Assumptions/Comments
Interstates	76	56	(4) 12-ft Interstate lanes with 10-ft outside shoulders and 4-ft inside shoulders
Ramps	44	24	(2) 12-ft Interstate lanes with 10-ft outside shoulders
Other State Highways	70	52	(4) 11-ft Non-Interstate lanes with 9-ft outside shoulders and 4-ft inside shoulders
Limited Access Highways	40	24	Shouldered Principal Arterial with DHV 200 and over
Major Roads	36	24	Shouldered Principal Arterial with DHV below 200
Other Major Roads	32	24	Shouldered Minor Arterial with DHV below 100
Local Roads	26	20	Shouldered Collector with ADT 400 to 750

5. <u>Estimate an adjusted percent loss of embankment and pavement.</u> The FHWA method was developed using a default embankment width of 48-feet and a pavement width of 40-feet. The percent loss of embankment and pavement for each road segment was adjusted by dividing the default embankment and pavement widths by the width estimates for the associated road classifications; e.g., $48/E_w$ and $40/P_w$.

6. <u>Estimate the total volume of embankment and area of pavement subject to overflow.</u> The cross-sectional area of roadway embankment was approximated as a trapezoid shape with the top width equivalent to the embankment width by road classification and the embankment height was assumed to uniformly be 5-feet with 2:1 side slope (H:V). The roadway embankment volume subject to overflow was estimated as the cross-sectional area of roadway embankment multiplied by the length of roadway overtopping. The roadway pavement area subject to overflow was estimated as the pavement width multiplied by the length of roadway overtopping.

7. <u>Estimate the embankment and pavement damages.</u> Embankment damages were estimated by multiplying the total volume of embankment subject to overflow by both the adjusted percent loss of embankment and a unit cost of embankment material. Pavement damages were estimated by multiplying the total area of embankment subject to overflow by both the adjusted percent loss of pavement and a unit cost of pavement material. A unit cost for embankment material was estimated by assuming this material corresponded to the unit costs for "roadway excavation" and "asphalt concrete pavement", respectively, associated

with the Central Puget Sound Region and an urban classification defined by WSDOT [54]. Since this WSDOT publication is dated 2012, the Engineering News Record (ENR) Construction Cost Indices were used to estimate these unit costs for 2021. The ENR annual average cost index value of 9308 [55] was used as the cost index for 2012 and the cost index of 11849 [56] for April 2021 was used as the present-day cost index. The WSDOT 2012 unit costs for "roadway excavation" and "asphalt concrete pavement", of $12.00 and $5.25 respectively, were multiplied by the cost index factor resulting in estimated unit costs of $15.25 per cubic yard of excavation material and $6.68 per square foot of asphalt concrete pavement.

The methodology above provided damage estimates within flood hazard areas where BFEs have been defined. An additional effort was made to estimate road damage from flood overtopping in within flood hazard areas where BFEs have not been defined, with the combination of road damages within BFE and non-BFE areas representing all potential road damages within flood hazard areas of Pierce County. The methodology to estimate road damage from flood overtopping within flood hazard areas where BFEs have not been defined included the following steps:

1. <u>Estimate the length of roads within non-BFE flood hazard areas.</u> This estimate was made by subtracting the length of roads within BFE flood hazard areas from the length of roads within flood hazard areas (BFE and non-BFE areas).

2. <u>Estimate the length of roads overtopped within non-BFE flood hazard areas.</u> The length of roads overtopped within non-BFE flood hazard areas was assumed to be at a similar proportion as the length of roads overtopped within non-BFE flood hazard areas, so road lengths in non-BFE areas were multiplied by the percent of roads overtopped within BFE flood hazard areas.

3. <u>Estimate the damage to overtopped roads within non-BFE areas</u>. A unit cost of Damage per Foot of Road Length within BFE Areas was estimated by dividing the damage to Overtopped Roads within BFE Areas by the Length of Roads within BFE Flood Hazard Areas. This unit cost was multiplied by the Length of Roads Overtopped within non-BFE Flood Hazard Areas to estimate Damage to Overtopped Roads within non-BFE Areas

4. <u>Estimate the Combined Damage to Overtopped Roads in Flood Hazard Areas (BFE and non-BFE Areas).</u> The estimated damage to overtopped roads within non-BFE areas was combined with the

[54] WSDOT, 2012. Manual for Planning Level Cost Estimation (PLCE) Tool, Appendix B: Default Unit Prices, Exhibit B-1: Default Unit Costs for Central Puget Sound Region, December. https://www.wsdot.wa.gov/mapsdata/travel/pdf/PLCEManual_12-12-2012.pdf [last accessed October 17, 2021]

[55] Zevin, A., 2020. Using ENR's Cost Indexes. http://digital.bnpmedia.com/publication/?i=701229&article_id=3985354&view=articleBrowser&ver=html5 [last accessed October 17, 2021]

[56] Construction Cost Index History - As of September 2021. https://www.google.com/search?q=enr+cost+index+2021&hl=en&biw=1664&bih=900&ei=CLpUYdCiLceL-wSBxoyABw&oq=Engineering+News+Record+construction+Cost+Index&gs_lcp=Cgdnd3Mtd2l6EAEYBDIHCAAQRxCwAzIHCAAQRxCwAzIHCAAQRxCwAzIHCAAQRxCwAzIHCAAQRxCwAzIHCAAQRxCwAzIHCAAQRxCwAzIHCAAQRxCwA0oECEEYAFAAWABg5EJoAXACeACAAQCIAQCSAQCYAQDIAQjAAQE&sclient=gws-wiz [last accessed October 17, 2021]

4.4.3 Road Failure from Flood Overtopping

In addition to estimating roadway damages from overtopping flood flows, the potential for roadway failure was also estimated. Potential failure was based on data summarized in Table 4-2 (same as Table 2-1) for road approaches and bridges.

Table 4-2. Bridge and Road Failure Flood Depth-Velocity Relationships [57]

Flood Velocities	Flood Depths	
	Bridge	**Road Approach**
Greater than 15 feet per second	2 feet below bridge low chord	2 to 4 feet and over
10 to 15 feet per second	1 foot below bridge low chord	2.5 to 4 feet and over
5 to 10 feet per second	At bridge floor level	Over 3 feet
2 to 5 feet per second	2 feet over bridge floor	Over 4 feet

The estimation of flood overtopping depths has been described above. Flood velocities were estimated based on assumptions related to the overtopping flow and location of the point of maximum velocity across the road embankment. The methodology included the following steps:

1. Estimate the discharge per foot of width of overtopping. The flow over the roadway embankments was assumed to be unsubmerged at the downstream end and the flow was estimated using the equation [58]:

   $$Q = C\ Ew\ D\frac{3}{2} \qquad \text{[Equation 1]}$$

   Where E_w is the top width of the road embankment, D is depth of overtopping by road segment, and C is a coefficient assumed to be 3.04 which is generally associated with overtopping depth to embankment width ratios of less than 0.15 and overtopping depths 0.5-foot and greater. The discharge per foot of width of overtopping (q) was calculated as:

   $$q = Q/L \qquad \text{[Equation 2]}$$

[57] USDA, 1969. TSC Technical Note – Watersheds UD-22, Economics – Floodwater Damages to Roads and Bridges, June 30. https://www.nrcs.usda.gov/wps/PA_NRCSConsumption/download?cid=nrcseprd410822&ext=pdf [last accessed October 20, 2021]

[58] Chen, Y-H. and B.A. Anderson, 1987. Development of a Methodology for Estimating Embankment Damage Caused by Flood Overtopping, Transportation Research Record 1151, March. https://onlinepubs.trb.org/Onlinepubs/trr/1987/1151/1151-001.pdf [last accessed October 24, 2021]

Where L is the length of overtopped roadway segment.

2. Estimate the maximum velocity across the road embankment. The location of the maximum velocity of overtopping flow was assumed to occur at the depth of maximum discharge; i.e., at the critical depth (D_c) and the associated critical velocity (V_c) was assumed to be the maximum velocity. The relationship of critical velocity to critical depth is shown in Equations 3 and 4 below, where q is the discharge per foot of width of overtopping and g is the constant of gravitational acceleration.

$$Dc = \sqrt[3]{qx^2}/g \qquad \text{[Equation 3]}$$

$$Vc = \sqrt{gDc} \qquad \text{[Equation 4]}$$

For flow overtopping a roadway, the location of critical depth and velocity is near the leeward (downstream) edge of the embankment, as shown schematically in Figure 4-3 and in a photograph of an overtopped roadway in Figure 4-4.

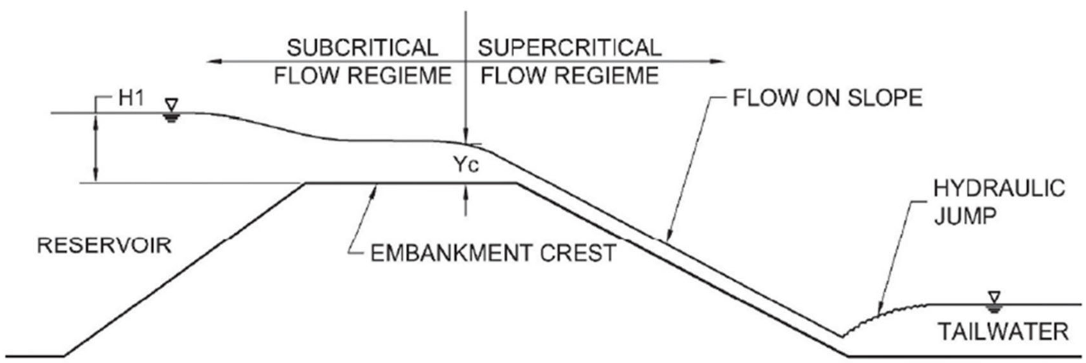

Figure 4-3. Location of Critical Depth Across an Overtopped Roadway Embankment [59]

Figure 4-4. Photograph of Roadway Flood Overtopping [52]

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[59] Marr, J.D.G, 2017. Design Considerations for Embankment Protection During Road Overtopping Events, Minnesota Department of Transportation, Research Project Final Report 2017-21, June. https://rosap.ntl.bts.gov/view/dot/32638/dot_32638_DS1.pdf? [last accessed October 24, 2021]

3. Estimate the Velocity-Stage Relationship and Risk of Failure. The velocity and stage relationships from Table 4-2 were input to a spreadsheet as the following IF functions:
   - If velocity is greater than 15 fps and depth is greater than 2.0-feet, then road failure.
   - If velocity is greater than 10 fps and depth is greater than 2.5-feet, then road failure.
   - If velocity is greater than 5 fps and depth is greater than 3.0-feet, then road failure.
   - If velocity is greater than 2 fps and depth is greater than 4.0-feet, then road failure.
4. Estimate the number of failed road segments. If any one function resulted in road failure, then the road segment was assumed to have failed.

4.4 Results

Roadway flood risk results are presented in terms of roadway embankment and pavement damage, and associated combined damage, and incidents of road failure.

4.4.1 Roads at Risk of Flooding Overtopping

Table 4-3 provides a summary of the estimated length of roadway flood overtopping within Pierce County by road classifications; these road lengths are shown in the blue shading. The table provides a relative comparison of roadway flood overtopping by road classification and the range of heights at which BFEs are higher than road elevations, on a cumulative basis. For example, interstates are estimated to experience flood overtopping with only a cumulative 77-feet of overtopping length, while local roads experience the most overtopping with a cumulative length of overtopping estimated at 89,666-feet.

Road lengths not overtopped, where BFEs are lower than estimated roadway elevations, are also shown in the grey shading. While the latter data are not utilized in subsequent estimates of roadway flood damage, including these data in the table also provides a relative comparison of the types of roads not overtopped and the range of heights at which road elevations are higher than BFEs.

The data at the bottom of the table provide the results of Steps 2, 3, and 4 in the general methodology. For example, the total length of roads within SFHAs is 265,091-feet and an estimated 44%, or 115,673-feet, of road length is overtopped at the 1% Annual Exceedance Probability (AEP). The ratio of length of roads overtopped to the length of all roads with BFEs provides the percentage of roads overtopped in SFHAs with BFEs.

Table 4-3. Summary of Roadway Flood Overtopping Depths by Road Classification

Flood Overtopping Depths	Road Classifications							Totals	%
Road Elevation Relative to BFE (feet)	Interstates	Ramps	Limited Access Highways	Other State Highways	Major Roads	Other Major Roads	Local roads	Total in BFE Area (feet)	% of BFE
<-8	0	0	0	0	0	0	92	92	0.03%
<-7	0	0	0	0	0	0	1,261	1,261	0.48%
<-6	0	0	0	0	0	0	3,764	3,764	1.42%
<-5	0	0	0	72	0	445	7,223	7,741	2.92%
<-4	0	174	0	145	0	987	13,604	14,910	5.62%
<-3	42	307	0	189	0	2,073	21,340	23,951	9.03%
<-2	77	383	224	233	65	6,385	36,569	43,936	16.57%
<-1	77	742	786	1,045	572	11,423	58,685	73,329	27.66%
<-0.5	77	907	1,026	2,422	1,219	14,556	72,917	93,124	35.13%
<0	77	952	1,290	4,145	1,904	17,638	89,666	115,673	43.64%
>0	350	944	1,823	26,717	2,008	43,503	74,073	149,419	56.36%
>0.5	350	944	1,588	25,158	1,719	39,626	58,672	128,058	48.31%
>1	350	901	1,493	24,720	1,563	36,850	43,942	109,818	41.43%
>2	350	876	1,234	21,657	1,383	30,538	27,138	83,175	31.38%
>3	106	859	1,074	15,283	1,247	25,329	17,095	60,993	23.01%
>4	67	859	1,067	8,311	1,067	16,245	11,324	38,940	14.69%
>5	67	859	826	3,181	825	8,893	6,617	21,269	8.02%
>6	5	637	782	2,382	745	6,668	2,914	14,133	5.33%
>7	0	583	782	2,063	554	5,964	1,229	11,174	4.22%
>8	0	548	782	605	509	5,412	911	8,767	3.31%
>9	0	523	541	38	494	5,047	751	7,393	2.79%
>10	0	461	521	19	450	4,922	624	6,998	2.64%
>11	0	391	521	0	388	4,795	493	6,588	2.49%
>12	0	328	521	0	388	4,651	423	6,312	2.38%
>13	0	304	521	0	388	4,499	324	6,036	2.28%
>14	0	263	521	0	388	4,249	281	5,702	2.15%
>15	0	263	521	0	381	4,116	241	5,521	2.08%
>16	0	263	521	0	329	4,078	161	5,351	2.02%
>17	0	263	521	0	272	4,040	156	5,252	1.98%
>18	0	263	521	0	261	3,981	156	5,182	1.95%
Total Length of Overtopped Roads in SFHAs with B	**77**	**952**	**1,290**	**4,145**	**1,904**	**17,638**	**89,666**	**115,673**	**43.64%**
Total Length of All Roads in SFHAs with BFEs	**427**	**1,896**	**3,114**	**30,862**	**3,912**	**61,141**	**163,740**	**265,091**	**100.00%**
% of Roads Overtopped in SFHAs with BFEs	**18.04%**	**50.20%**	**41.45%**	**13.43%**	**48.67%**	**28.85%**	**54.76%**	**43.64%**	**--**

Similar to Table 4-3, Table 4-4 provides a relative comparison of roadway flood overtopping by sub planning area and the range of heights at which BFEs are higher than road elevations, on a cumulative basis. For example, roads within the Gig Harbor / Key Peninsula Basin are estimated to experience the least amount of flood overtopping with only a cumulative 482-feet of overtopping length, while the Mid Puyallup Basin experiences the most road overtopping with a cumulative length of overtopping estimated at 38,278-feet.

Unlike Table 4-3 Table 4-4 continues with Steps 5 and 6 of the general methodology by applying the percentage of roads overtopped in SFHAs with BFEs, by sub planning area, to the total length of roads in SFHAs without BFEs to estimate the length of overtopped roads in SFHAs without BFEs. For example, for the Mid Puyallup Basin, the percentage of roads overtopped in SFHAs with BFEs is 34.70% and the total length of roads in SFHAs without BFEs is 46,773-feet resulting in an estimate of 16,229-feet of overtopped roads in SFHAs without BFEs.

The summary continues with the estimated length of non-overtopped roads in SFHAs without BFEs (the Total Length of Roads in SFHAs without BFEs minus the estimated length of overtopped roads in SFHAs without BFEs) and the total length of roads within the County.

Table 4-4. Summary of Roadway Flood Overtopping Depths by Sub Planning Area

Flood Overtopping Depths	Sub Planning Area									Sub Planning Area Totals
Road Elevation Relative to BFE (feet)	Chambers Bay / Clover Creek Basin	Clear / Clarks Creek Basin	Gig Harbor / Key Peninsula Basin	Hylebos-Browns Point-Dash Point Basin	Mid Puyallup Basin	Muck Creek Basin	Nisqually Basin	Upper Puyallup Basin	White River Basin	
<-8	0	0	0	0	92	0	0	0	0	92
<-7	0	40	0	0	1,221	0	0	0	0	1,261
<-6	146	290	0	0	3,328	0	0	0	0	3,764
<-5	286	803	0	0	5,810	95	0	273	474	7,741
<-4	1,019	2,486	0	0	9,547	165	0	691	1,002	14,910
<-3	1,918	3,391	0	727	13,877	226	0	1,864	1,947	23,951
<-2	5,345	6,464	0	1,275	20,426	236	0	6,463	3,728	43,936
<-1	12,890	10,292	142	1,592	27,561	362	0	15,008	5,483	73,329
<-0.5	17,187	12,558	292	2,676	32,247	628	187	19,782	7,567	93,124
<0	21,720	15,922	482	4,140	38,278	1,166	844	23,095	10,025	115,673
>0	9,355	30,177	1,366	6,632	72,041	3,961	8,490	12,612	4,785	--
>0.5	5,833	25,352	768	5,628	66,388	3,237	7,835	9,425	3,593	--
>1	3,554	20,438	546	4,390	61,529	2,834	6,914	6,883	2,729	--
>2	1,045	12,719	203	3,188	52,282	1,720	6,350	4,394	1,274	--
>3	96	9,659	138	977	39,464	1,401	6,193	2,251	815	--
>4	0	7,353	92	474	22,048	1,104	6,086	1,172	609	--
>5	0	4,324	10	390	8,711	782	6,086	542	424	--
>6	0	3,293	0	220	3,462	598	6,014	238	308	--
>7	0	3,103	0	58	1,373	587	5,769	35	249	--
>8	0	2,910	0	25	652	362	4,683	5	130	--
>9	0	2,434	0	20	77	291	4,456	0	115	--
>10	0	2,269	0	1	19	291	4,304	0	115	--
>11	0	2,020	0	1	19	276	4,194	0	79	--
>12	0	1,821	0	0	19	263	4,130	0	79	--
>13	0	1,628	0	0	19	242	4,072	0	75	--
>14	0	1,427	0	0	19	214	3,968	0	75	--
>15	0	1,369	0	0	19	147	3,911	0	75	--
>16	0	1,335	0	0	19	95	3,862	0	40	--
>17	0	1,330	0	0	19	24	3,838	0	40	--
>18	0	1,330	0	0	19	0	3,792	0	40	--
Total Length of Overtopped Roads in SFHAs with B	**21,720**	**15,922**	**482**	**4,140**	**38,278**	**1,166**	**844**	**23,095**	**10,025**	**115,673**
Total Length of All Roads in SFHAs with BFEs	**31,075**	**46,098**	**1,848**	**10,772**	**110,319**	**5,128**	**9,334**	**35,707**	**14,810**	**265,091**
% of Roads Overtopped in SFHAs with BFEs	**69.90%**	**34.54%**	**26.07%**	**38.44%**	**34.70%**	**22.74%**	**9.05%**	**64.68%**	**67.69%**	**43.64%**
Total Length of All Roads in County in SFHAs	**157,092**	**157,092**	**157,092**	**157,092**	**157,092**	**157,092**	**157,092**	**157,092**	**157,092**	**1,413,827**
Total Length of Roads in County in SFHAs without B	**126,016**	**110,994**	**155,244**	**146,320**	**46,773**	**151,964**	**147,758**	**121,385**	**142,281**	**1,148,735**
Estimated Length of Overtopped Roads in County	**88,081**	**38,335**	**40,473**	**56,241**	**16,229**	**34,562**	**13,365**	**78,510**	**96,311**	**462,107**
Estimated Length of Non-Overtopped Roads in	**37,936**	**72,658**	**114,771**	**90,079**	**30,544**	**117,402**	**134,393**	**42,875**	**45,971**	**686,628**
Total Length of Roads within County (feet)	**10,786,503**	**1,909,874**	**4,275,545**	**1,365,673**	**2,333,693**	**1,755,664**	**3,551,202**	**1,779,083**	**2,413,718**	**30,170,956**

4.4.2 Road Damages from Flood Overtopping

As shown in Table 4-5, for road segments where BFEs "overtop" the estimated elevation of the road surfaces, an estimated $250 million in road embankment damages and $461 million in associated pavement damages are estimated to occur during 1% AEP flood conditions, with total roadway damages estimated to be $711 million in 2021 dollars.

Table 4-5. Summary of Embankment and Pavement Damages by Sub Planning Area

Sub Planning Area	Embankment Damage	Pavement Damage	Combined Roadway Damage
Chambers Bay / Clover Creek Basin	$23,990,000	$55,121,000	$79,070,000
Clear / Clarks Creek Basin	$34,068,000	$65,285,000	$99,324,000
Gig Harbor / Key Peninsula Basin	$315,000	$295,000	$610,000
Hylebos-Browns Point-Dash Point Basin	$4,465,000	$8,562,000	$13,022,000
Mid Puyallup Basin	$145,630,000	$239,847,000	$385,434,000
Muck Creek Basin	$1,950,000	$2,881,000	$4,829,000
Nisqually Basin	$562,000	$252,000	$808,000
Upper Puyallup Basin	$21,253,000	$54,916,000	$76,154,000
White River Basin	$17,613,000	$34,756,000	$52,361,000
Grand Total	$249,843,000	$461,913,000	$711,607,000

4.4.3 Road Failure from Flood Overtopping

For road segments where the overtopping depth and velocity combinations exceed those identified in Table 4-2, road segments were assumed to fail. Table 4-6 provides a summary of estimated road failures by sub planning area.

Table 4-6. Summary of Estimated Road Failures by Sub Planning Area

Sub Planning Area	Road Length (ft)	Number of Road Failures	Length of Road Failures (ft)	Percentage of Road Failures (%)
Chambers Bay / Clover Creek Basin	31,072	102	1,680	5%
Clear / Clarks Creek Basin	46,092	144	3,328	7%
Gig Harbor / Key Peninsula Basin	1,847	0	0	0%
Hylebos-Browns Point-Dash Point Basin	10,769	134	664	6%
Mid Puyallup Basin	106,017	505	12,890	12%
Muck Creek Basin	5,127	11	176	3%
Nisqually Basin	9,329	0	0	0%
Upper Puyallup Basin	35,697	47	1,196	3%
White River Basin	14,807	81	1,680	11%
Grand Total	**260,758**	**1024**	**21,614**	**8%**

Chapter 19D.60

PIERCE COUNTY STORM DRAINAGE AND SURFACE WATER MANAGEMENT PLAN

The following documents are hereby incorporated by reference to this Plan:

A. Pierce County Storm Drainage and Surface Water Management Plan, James M. Montgomery Consulting Engineers, Inc., March 1991, and area updates as follows:
   1. Clover Creek Basin Plan, Pierce County Public Works, November 2002;
   2. Gig Harbor Basin Plan, Pierce County Public Works, November 2002;
   3. Muck Creek Basin Plan, Pierce County Public Works, April 2003;
   4. Mid-Puyallup Basin Plan, Pierce County Public Works, August 2005;
   5. Clear/Clarks Creek Basin Plan, Pierce County Public Works, November 2005;
   6. Hylebos Browns-Dash Point Basin Plan, Pierce County Public Works, May 2006;
   7. Key Peninsula-Islands Basin Plan, Pierce County Public Works, June 2006;
   8. White River Basin Plan, Pierce County Public Works, November 2013; and
   9. Nisqually River Basin Plan, Pierce County Public Works, January 2014.

B. Clover Creek Basin Drainage Plan, An Engineering Study for Flood Control in Pierce County, Washington, Consoer, Townsend & Associates Consulting Engineers, 1976.

C. Hylebos Basin Drainage Plan, Part A, Engineering Study for the Hylebos Flood Control Zone District, Consoer, Townsend & Associates Consulting Engineers, 1974.

D. 144th Street East Drainage Basin Plan, An Engineering Study for Flood Control in Pierce County, Washington, PRC Consoer Townsend, Inc., 1981.

E. Pierce County 2023 Comprehensive Flood Hazard Management Plan, Pierce County Public Works, October 2023 ~~Rivers Flood Hazard Management Plan, Pierce County Public Works, August 2012~~.
   ~~1. Pierce County Rivers Flood Hazard Management Plan, Pierce County Planning and Public Works, November 2018.~~

Code Revisor's Note: The Storm Drainage and Surface Water Management Plan was adopted by Ordinance No. 91-113 and codified as Chapter 19D.60 PCC by Ordinance No. 96-111.

Pierce County Council
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