UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
West Coast Region
1201 NE Lloyd Boulevard, Suite 1100
PORTLAND, OR 97232-1274

Refer to NMFS No:
WCRO-2020-02915

May 16, 2022

Jacalen Printz
Acting Chief, Regulatory Branch
Seattle District, U.S. Army Corps of Engineers
P.O. Box 3755
Seattle, Washington 98124-3755

Re: Endangered Species Act Section 7(a)(2) Biological Opinion and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Response for the Inland Group Culvert Replacement and Watercourse K Realignment and Relocation Project (HUC6 – 171100)

Dear Ms. Printz:

Thank you for your letter of October 16, 2020, requesting initiation of consultation with NOAA's National Marine Fisheries Service (NMFS) pursuant to section 7 of the Endangered Species Act of 1973 (ESA) (16 U.S.C. 1531 et seq.) for the Inland Group Culvert Replacement and Watercourse K Realignment and Relocation Project. This consultation was conducted in accordance with the 2019 revised regulations that implement section 7 of the ESA (50 CFR 402, 84 FR 45016).

NMFS also reviewed the likely effects of the proposed action on essential fish habitat (EFH), pursuant to section 305(b) of the Magnuson-Stevens Fishery Conservation and Management Act (16 U.S.C. 1855(b)), and concluded that the action would adversely affect the EFH of Pacific coast salmon. Therefore, we have included the results of that review in Section 3 of this document.

The enclosed document contains a biological opinion prepared by NMFS pursuant to section 7(a)(2) of the ESA on the effects of the Inland Group Culvert Replacement and Watercourse K Realignment and Relocation Project in the Lower Green River basin near Auburn, Washington. We have determined that the Corps' proposed action to permit the project will not jeopardize the continued existence of listed Puget Sound Chinook salmon and Puget Sound steelhead or result in the destruction or adverse modification of critical habitat for either species.

Please contact Kim Kratz of the Oregon Washington Coastal Office (503-231-2155) if you have any questions concerning this consultation, or if you require additional information.

Sincerelv.

Kim W. Kratz. Ph.D
Assistant Regional Administrator
Oregon Washington Coastal Office

cc: Kelly Werdick, COE
Daniel Krenz, COE
Kristin McDermott, COE
Jennifer Marriott, Wet.land

Endangered Species Act (ESA) Section 7(a)(2) Biological Opinion and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Response for the

Inland Group Culvert Removal and Replacement
Watercourse K Realignment and Relocation, and I Street NE Extension Project

NMFS Consultation Number: WCRO-2020-02915

Action Agency: United States Army Corps of Engineers

Affected Species and NMFS' Determinations:

ESA-Listed Species	Status	Is Action Likely to Adversely Affect Species?	Is Action Likely to Jeopardize the Species?	Is Action Likely to Adversely Affect Critical Habitat?	Is Action Likely to Destroy or Adversely Modify Critical Habitat?
Puget Sound Chinook Salmon (*Oncorhynchus tshawytscha*)	Threatened	Yes	No	Yes	No
Puget Sound steelhead (*O. mykiss*)	Threatened	Yes	No	Yes	No

Affected Essential Fish Habitat (EFH) and NMFS' Determinations:

Fishery Management Plan That Identifies EFH in the Project Area	Does Action Have an Adverse Effect on EFH?	Are EFH Conservation Recommendations Provided?
Pacific Coast Salmon	Yes	Yes

Consultation Conducted By: National Marine Fisheries Service
West Coast Region

Issued By:

Kim W. Kratz, Ph.D.
Assistant Regional Administrator
Oregon Washington Coastal Office

Date: May 16, 2022

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1. INTRODUCTION

This Introduction section provides information relevant to the other sections of this document and is incorporated by reference into Sections 2 and 3, below.

1.1. Background

The National Marine Fisheries Service (NMFS) prepared the biological opinion (opinion) and incidental take statement (ITS) portions of this document in accordance with section 7(b) of the Endangered Species Act (ESA) of 1973 (16 U.S.C. 1531 et seq.), and implementing regulations at 50 CFR 402, as amended.

We also completed an essential fish habitat (EFH) consultation on the proposed action, in accordance with section 305(b)(2) of the Magnuson-Stevens Fishery Conservation and Management Act (MSA) (16 U.S.C. 1801 et seq.) and implementing regulations at 50 CFR 600.

We completed pre-dissemination review of this document using standards for utility, integrity, and objectivity in compliance with applicable guidelines issued under the Data Quality Act (DQA) (section 515 of the Treasury and General Government Appropriations Act for Fiscal Year 2001, Public Law 106-554). The document will be available within two weeks at the NOAA Library Institutional Repository (https://repository.library.noaa.gov/welcome). A complete record of this consultation is on file at the Oregon Washington Coastal Office in Lacey, Washington.

1.2. Consultation History

The Corps requested informal consultation on October 16, 2020, for the Inland Group Culvert Replacement project. The Corps endorsed and advanced to NMFS the applicant's (Inland Construction Group) effects determination that the proposed action 'may affect, but is not likely to adversely affect' listed Puget Sound (PS) Chinook salmon and PS steelhead. On March 25, 2021, NMFS informed the Corps that it could not concur with the effects determination and suggested the Corps reconsider the project and request formal consultation. NMFS reengaged with the Corps regarding the Inland Group Project on July 8, 2021 and was informed by the Corps that due to construction constraints the project would be split up so that a critical component could be completed by the end of 2021. The Corps informed NMFS they would submit one component (floodplain reconnection project) of the project to be covered under the Corps' Fish Passage and Restoration Project Programmatic (FPRP III) (WCRO-2014-1857) and the Corps would request consultation for the remaining project components (I Street extension, Watercourse K relocation, and culvert replacement).

On July 29, 2021, the Corps submitted a notification to NMFS indicating the enhancement of Watercourse N and floodplain compensation components originally included in the October 16, 2020, request would be covered under FPRP III. On August 20, 2021, the Corps resubmitted their request for consultation for Inland Group Culvert Replacement, I Street extension project, and Watercourse K relocation. The August 20 submission included a memo explaining the changes to the project scope as well as updated project designs. On September 20, 21, and

October 4, 2021, via email, NMFS requested additional information from the Corps to complete its cursory review process. On October 28th, 2021, the Corps and the applicant provided written responses to NMFS's questions. On December 13, 2021, NMFS provided a draft description of the proposed action to the Corps for review to ensure NMFS understanding of the action was accurate and complete. The Corps and the applicant provided edits to the draft on December 30, 2021. On December 30, 2021, NMFS requested the Corps and the applicant clarify specific details of the proposed action and update supporting figures to reflect the most recent description. The Corps and the applicant responded on January 23, 2022. NMFS provided another draft to the Corps on February 17, 2022, and stated that NMFS would not be able to concur with the Corps' NLAA determination for PS Chinook salmon, PS steelhead and their associated critical habitats. NMFS suggested the Corps request formal consultation to move forward with the consultation process. The Corps requested formal ESA section 7 consultation via email on February 18, 2022. On February 22, 2022, NMFS determined information was complete and initiated formal consultation with the Corps. The action also triggers MSA consultation because EFH for Pacific Coast salmon may be affected.

1.3. Proposed Federal Action

Under the ESA, "action" means all activities or programs of any kind authorized, funded, or carried out, in whole or in part, by Federal agencies (50 CFR 402.02). Under MSA, federal action means any action authorized, funded, or undertaken, or proposed to be authorized, funded, or undertaken by a federal agency (50 CFR 600.910).

The Corps is proposing to permit under section 404 of the CWA, a street extension, culvert removal and replacement, and stream channel relocation project near Auburn, Washington. The purpose of the project is to provide additional transportation infrastructure to support an increase in vehicle traffic associated with the Copper Gate Apartments Project. The I Street NE extension project includes realigning an unnamed tributary to Auburn Drain (Green River basin) and replacing two steel pipe culverts with a stream simulation compliant box culvert on the realigned stream. A series of restoration measures would also be implemented as part of the proposed action including placement of large woody debris, new streambed substrate, revegetating and planting riparian areas, and replacing and restoring stream and wetland buffers.

The proponent would install approximately 2,000 linear feet of new road that would connect the existing I Street NE from its intersection with 45th Street NE to a new interchange with South 277th Street. This new road is proposed as an arterial roadway to help manage existing and an anticipated increase in vehicular traffic in this area, as a result of the Copper Gate Apartment Project. A total of 5.4 acres of new pollution generating impervious surfaces (PGIS), concrete and asphalt, would be installed as part of the proposed action.

Temporary sandbag dams would be placed up and downstream of the work site to isolate the work area and prevent water and fish from entering during construction. Prior to commencing work, the area would be evaluated by a Corps biologist for the presence of any water and fish. If any fish are found they would be captured and relocated to an appropriate downstream location with adequate water and flow. Water would be diverted around the project area until construction is complete. The sandbag dams would be removed once construction is complete.

The stream channel, known as Watercourse K, would be realigned within the designated right of way as part of the road construction to accommodate the extension of I Street. The relocation and realignment of Watercourse K would require filling 438 linear feet of the existing stream channel with 722 cubic yards of material to accommodate the proposed road extension. Once the original Watercourse K channel has been filled, a 467-foot long channel would be constructed. The new channel would be designed to have a maximum 3:1 slope on both west and east banks. A concrete wall, approximately 510-feet long and 5-feet tall, would be installed on the western edge of the new stream segment to prevent the stream from extending outside of the right of way easement.

As part of the stream relocation effort an existing 157-foot 24-inch steel pipe culvert would be fully removed. Another 65-foot long by 24-inch wide steel pipe culvert under the Port of Seattle access road would be upgraded to a Stream Simulation Compliant 3-foot tall by 12-foot wide by 60-foot long pre-cast concrete box culvert. The new culvert would be realigned to accommodate the extended road and the new stream channel. The new culvert would be designed to accommodate for natural flow conditions during high flow periods. While the stream currently supports little to no flow during certain periods of the year, the box culvert is designed to ensure stormwater and natural flows are conveyed without creating obstructions. Finally, once the stream has been relocated and realigned and the new culvert installed, new substrate and large wood would be placed that meet WDFW and WSDOT design requirements.

<u>Stormwater Management</u>

Over the long-term stormwater runoff volume would increase as a result of the I Street Extension and Copper Gate Apartments projects. The project area for both projects is divided into five different basins, each draining into different components of the proposed stormwater conveyance system (**Figure 1**). The stormwater runoff associated with the I Street Extension project originates from Basin 3 and 4 and would be conveyed to a detention pond to control flow rates (**Figure 1**). The detention pond would then drain into Watercourse L and subsequently into Watercourse K before draining into Auburn Drain and ultimately the Green River. The stormwater runoff generated from the developed surfaces of Basin 3 and 4 (**Table 1**) are analyzed in this Opinion because of the connection between Watercourse L and Watercourse K, Auburn Drain, and the Green River; while Watercourse L would not be modified by the proposed action it conveys stormwater runoff to areas classified to support listed species and critical habitat.

Stormwater treatment and management infrastructure described in the proposed action are designed to be in compliance with the City of Auburn Surface Water Management Manual (City of Auburn Dept. of Public Works 2014) and the 2014 Department of Ecology Stormwater Management Manual for Western Washington (SWMMWW) (Ecology 2014). The project is also required to obtain a National Pollutant Discharge Elimination System (NPDES) permit from Ecology and develop a Stormwater Pollution Prevention Plan (SWPPP) and a Temporary Erosion and Sediment Control Plan (TESCP) to ensure that water quality does not degrade during or immediately following construction.

Stormwater from Basins 3 and 4 would be conveyed to a detention pond and treated using a Modular Wetland system (MWS) (**Figure 2**). The MWS would be installed downstream of the outlet control and designed to the full 2-year release rate for detention facilities per the General Use Level Designation developed by Ecology (2017). The Corps determined through geotechnical evaluation that additional BMPs for Basin 3 and 4 including full dispersal (BMP T5.30), permeable pavement and sheet flow dispersion (BMP T5.15), and bioretention (BMP T7.30) were infeasible due to specific site characteristics including unsuitable native soil infiltration rates and absent native vegetated flow paths.

Stormwater facilities associated with the project would also be designed to meet Post Construction Soil Quality and Depth (BMP T5.13) requirements described in the SWMMWW (Ecology 2014). The purpose of this BMP is to ensure soil quality and depth post-construction provide important stormwater treatment functions including: water infiltration, nutrient, sediment, and pollutant adsorption; sediment and pollutant biofiltration; water interflow storage and transmission; and pollutant decomposition. These functions are dependent on site characteristics and are largely lost when development strips away native soil and vegetation and replaces it with minimal topsoil and sod. Not only are these important stormwater functions lost but such landscapes themselves become pollution generating pervious surface due to increased use of pesticides, fertilizers and other landscaping and household/industrial chemicals, the concentration of pet wastes, and pollutants that accompany roadside litter. Establishing soil quality and depth regains greater stormwater functions in the post development landscape, provides increased treatment of pollutants and sediments that result from development and habitation, and minimizes the need for some landscaping chemicals, thus reducing pollution through prevention. However, as stated previously native soil characteristic preclude full infiltration, which is why the project relies on a MWS to treat stormwater prior to discharge into Watercourse K.

Finally, stormwater management facilities would be designed to meet Minimum Requirements #6 and #7 of the SWMMWW (Ecology 2014). Minimum requirement #6 addresses runoff treatment and requires that stormwater facilities must be sized to treat the entire drainage area even if some areas are not pollution generating. Additionally, designs must take into account the volume of runoff predicted from a 24-hour, 6-month reoccurrence storm. Water quality detention facilities, including the MWS, must meet the full 2-year release rate for downstream facilities. Furthermore, direct discharge of untreated stormwater from PGIS is prohibited, except for discharge achieved by soil infiltration, dispersion of runoff through use of on-site stormwater management BMPs, or by infiltration through soils meeting SWMMWW (2014) soil suitability criteria. Minimum Requirement #7 addresses flow control of stormwater runoff. Specifically, projects must provide flow control to reduce the impacts of stormwater runoff from hard surfaces and land cover conversions. The detention pond and MWS provide on-site treatment and flow control meeting Ecology Minimum Requirements. However, this approach would not remove all pollutants from stormwater prior to discharge.

Table 1. Total acres of pervious and impervious surfaces associated with each catchment basin draining into Watercourse K.

Land Development	Basin 3 (acres)	Basin 4 (acres)	Total (acres)
Pervious	6.085	0.557	6.642
Impervious	10.043	2.804	12.847
Total	**16.128**	**3.361**	**19.489**

Modular Wetland Systems

The proposed action includes installation of a modular wetland system at the drainage point of the stormwater detention pond (**Figure 1**). A modular wetland system is used where direct infiltration into soil is not possible. The soil types at the project location preclude infiltration and a Bioclean modular wetland system would be installed to treat stormwater prior to discharging into Watercourse K and ultimately the Green River. According to Bioclean, a Modular Wetland Linear system removes[1]:

- 66% of dissolved zinc;
- 69% of total zinc;
- 38% of dissolved copper;
- 50% of total copper;
- 85% of TSS;
- 100% of trash;
- 45% of nitrogen;
- 95% of motor oil;
- 67% of ortho-phosphorus; and
- 64% of total phosphorus.

Ecology's General Use Designation for Basic (TSS) Enhanced and Phosphorus treatment[2] indicates that the Modular Wetland Linear system has the capability to remove:

- 99% of total suspended solids with influent concentrations of 270mg/L using a quarter scale model;
- 91% of TSS in laboratory conditions with influent concentrations of 84.6 mg/L at a flow rate of 3.0 gpm per square foot of media;
- 93% of dissolved copper in a quarter scale model with influent concentrations of 0.757 mg/L;
- 79% of dissolved copper in laboratory conditions with influent concentrations of 0.567 mg/L at a flow rate of 3.0 gpm per square foot of media;
- 80.5% of dissolved zinc in a quarter scale model with influent concentrations of 0.95 mg/L at a flow rate of 3.0 gpm per square foot of media; and

[1] https://biocleanenvironmental.com/wp-content/uploads/2020/03/Modular-Wetlands-Linear_Brochure_8-30-21_web-spread.pdf

[2] https://fortress.wa.gov/ecy/ezshare/wq/tape/use_designations/MWSlinearMODULARwetlandGULD.pdf

- 78% of dissolved zinc in laboratory conditions with influent concentrations of 0.75 mg/L at a flow rate of 3.0 gpm per square foot of media.

Additional Best Management Practices and Conservation Measures

Additional conservation measures include planting native tree and shrub species within the upland and riparian areas of the new stream channel (**Table 2**). The purpose of the planting is to restore areas temporarily impacted by the construction, provide vegetation along the stream channel that would at maturity, provide some shade and cover to fish species utilizing the stream, and provide a source of organic input to the stream ecosystem. The intent of this restoration/conservation measure is to ultimately increase habitat for fish and wildlife, protect the stream channel, and prevent colonization by non-native weedy plant species such as reed canarygrass (*Phalaris arundinacea*) and Himalayan blackberry (*Rubus armeniacus*).
In addition to the stormwater treatment BMPs, the following BMPs and conservation measures are included in the proposed action:

- All work would occur during the Washington Department of Fish Wildlife (WDFW) in-water work window of July 16 to September 30.
- Silt fencing, straw bales, straw wattles, and vegetated strips would be used to prevent silt and sediment from entering the stream channel during construction.
- Filter fabric, gravel, and check dams would be used on storm drains and catch basins in areas that may receive sediment-laden water from the work area.
- Soil and disturbed slopes would be stabilized using temporary or permanent seeding, mulching, nets, blankets, plastic coverings, sod, check dams, and triangular silt dikes.
- Pollutants would be controlled by regular inspection of vehicles and petroleum dispensing equipment for leaks, providing secondary containment for petroleum storage containers, ensuring proper chemical storage, and maintaining emergency spill containment and clean-up materials on-site.
- Control dust from construction activities.
- Containment of demolition material and debris, including collection and treatment of processed water and slurry.
- Control, containment, and treatment of water removed from the construction area.
- Restore areas outside of the stream channel temporarily disturbed with native shrubs and trees.

We considered, under the ESA, whether or not the proposed action would cause any other activities and determined that it would not.

Table 2. Tree and shrubs species included in the upland and riparian planting plan.

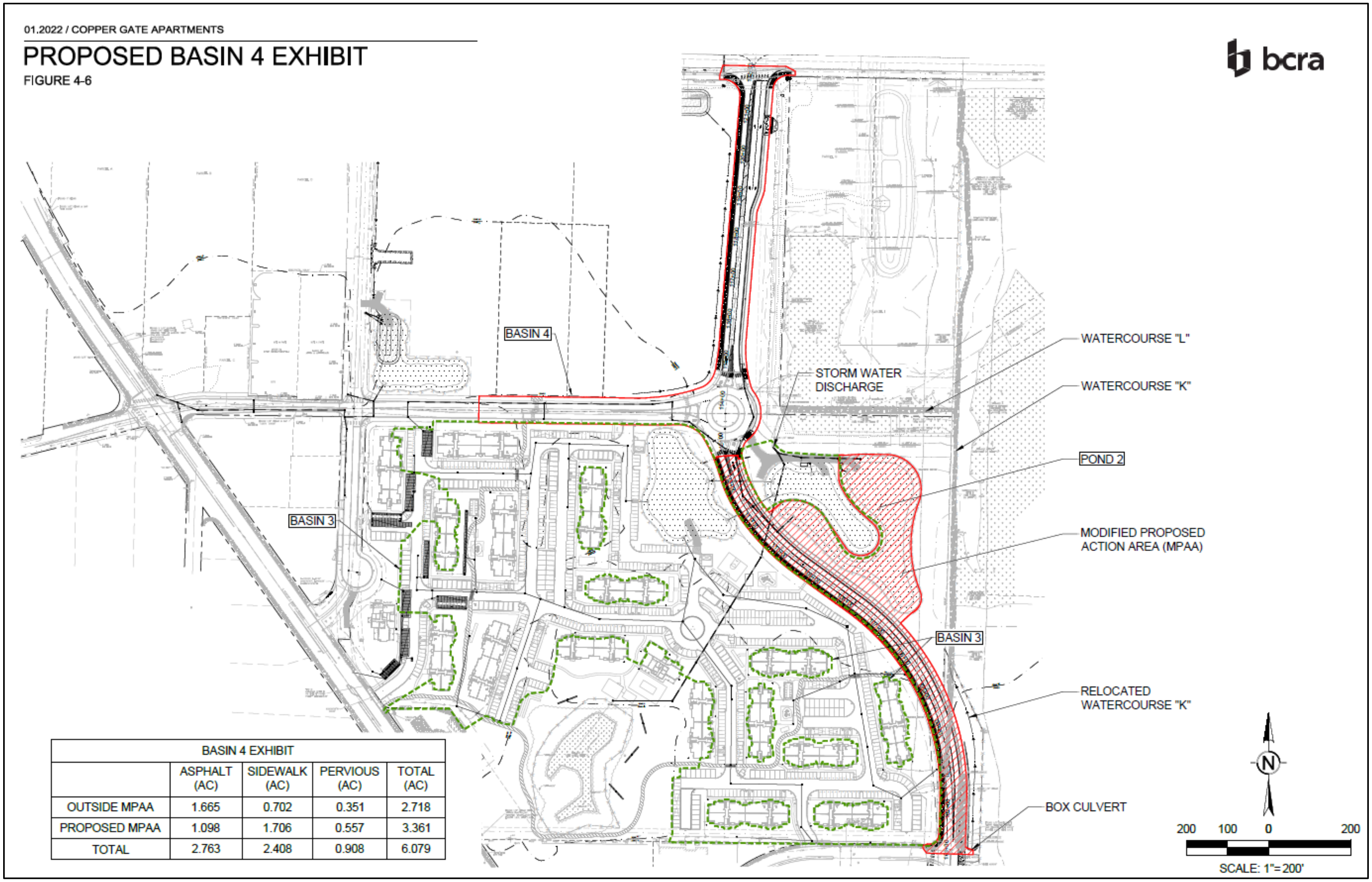
Planting Area	Common Name	Scientific Name
	Vine maple	*Acer circinatum*
Upland trees	Big leaf maple	*Acer macrophyllum*
	Western hazelnut	*Corylus cornuta*
	Douglas fir	*Pseudotsuga menziesii*
	Serviceberry	*Amelanchier alnifolia*
	Salal	*Gaultheria shallon*
Upland shrubs	Oceanspray	*Holodiscus discolor*
	Tall Oregon Grape	*Mahonia aquifolium*
	Sword Fern	*Polystichum munitum*
	Red elderberry	*Sambucus racemose*
	Common snowberry	*Symphoricarpos albus*
Wetland trees	Vine maple	*Acer circinatum*
	Cascara	*Rhamnus purshiana*
	Pacific crabapple	*Crataegus douglasii*
Wetland shrubs	Nootka rose	*Rosa nutkana*
	Salmonberry	*Rubus Spectabilis*
	Black twinberry	*Lonicera involucrate*
	Western Crabapple	*Malus fusca*
In-stream seasonal trees	Pacific willow	*Salix lasiandra*
	Sitka willow	*Salix sitchensis*
	Red twig dogwood	*Cornus sericea*
In stream seasonal shrubs	Pacific ninebark	*Physocarpus capitatus*
	Salmonberry	*Rubus spectabilis*

1.4. Action Area

"Action area" means all areas to be affected directly or indirectly by the Federal action and not merely the immediate area involved in the action (50 CFR 402.02).

The action area includes Watercourse K and the 1 mile of stream channel to Auburn Drain's confluence with the Green River (**Figure 3**). The action area also includes the riparian areas surrounding Watercourse K where culvert removal and replacement and stream realignment and relocation would occur. While the modular wetland system is an effective tool for reducing pollutant loads it does not remove 100% of all pollutants, therefore effluent would be expected to contain harmful levels of pollutants depending upon influent concentrations. The action area extends downstream to the Auburn Drain and the mainstem Green River due to the anticipated effects of the project to water quality discussed in section 2.4 below.

Information regarding current stormwater pollutant loads at the project site was not provided in the project initiation package therefore we cannot predict at what rate pollutant loads would be reduced before discharging into Watercourse K. Given this uncertainty, we assume that water treated via the detention pond and Modular Wetland would contain toxic stormwater and degrade water quality PBF in Auburn Drain and the Green River for the life of the project.



BASIN 4 EXHIBIT				
	ASPHALT (AC)	SIDEWALK (AC)	PERVIOUS (AC)	TOTAL (AC)
OUTSIDE MPAA	1.665	0.702	0.351	2.718
PROPOSED MPAA	1.098	1.706	0.557	3.361
TOTAL	2.763	2.408	0.908	6.079

Figure 1. Drainage basins associated with the I Street Extension, Watercourse K relocation, and culvert replacement projects. Basin 3 is outlined in green and basin 4 is outlined in red.

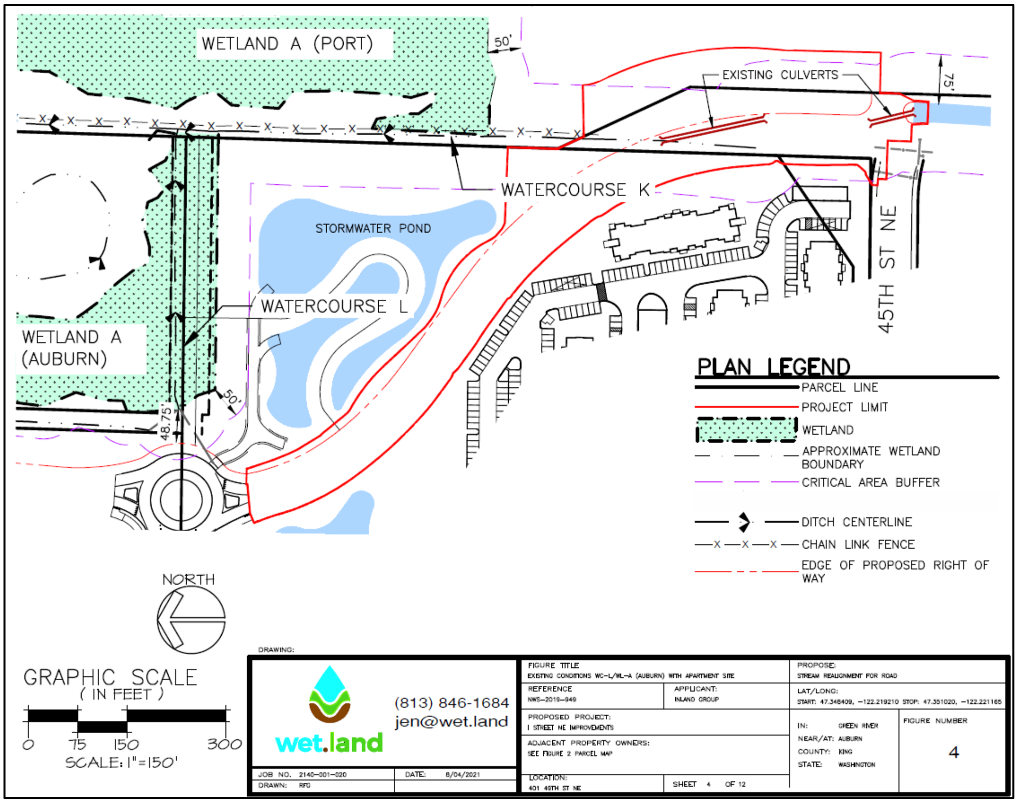


Figure 2. Locations of Watercourse K and L, and the stormwater detention pond.

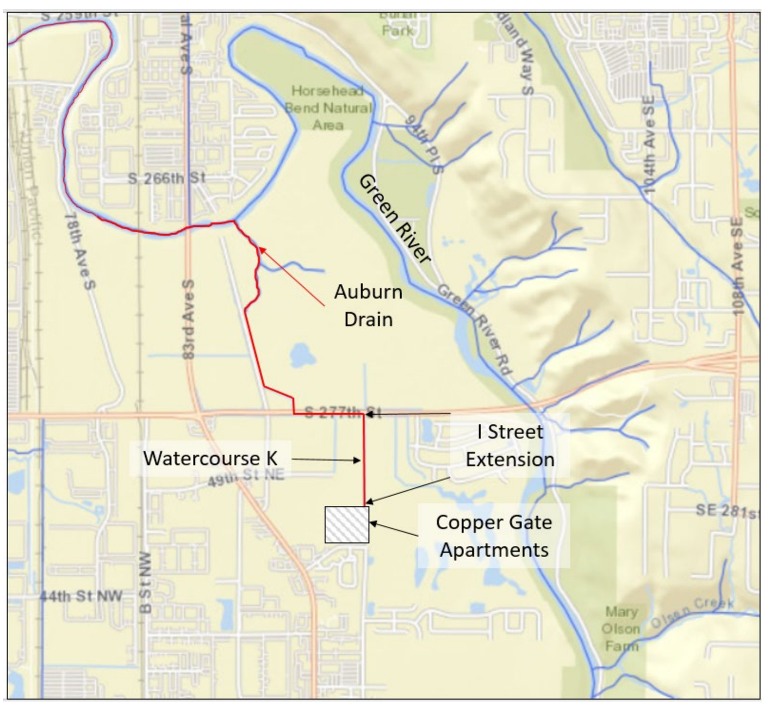


Figure 3. Action area including the construction site, Auburn Drain, and the Green River. The red area represents the flow path from the construction site to the Green River via Auburn Drain.

2. ENDANGERED SPECIES ACT: BIOLOGICAL OPINION AND INCIDENTAL TAKE STATEMENT

The ESA establishes a national program for conserving threatened and endangered species of fish, wildlife, plants, and the habitat upon which they depend. As required by section 7(a)(2) of the ESA, each Federal agency must ensure that its actions are not likely to jeopardize the continued existence of endangered or threatened species, or adversely modify or destroy their designated critical habitat. Per the requirements of the ESA, Federal action agencies consult with NMFS and section 7(b)(3) requires that, at the conclusion of consultation, NMFS provide an opinion stating how the agency's actions would affect listed species and their critical habitats. If incidental take is reasonably certain to occur, section 7(b)(4) requires NMFS to provide an ITS that specifies the impact of any incidental taking and includes reasonable and prudent measures (RPMs) and terms and conditions to minimize such impacts. The Corps determined the proposed action is not likely to adversely affect PS Chinook salmon and PS steelhead or their critical habitat.

2.1. Analytical Approach

This biological opinion includes both a jeopardy analysis and an adverse modification analysis. The jeopardy analysis relies upon the regulatory definition of "jeopardize the continued existence of" a listed species, which is "to engage in an action that reasonably would be expected, directly or indirectly, to reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing the reproduction, numbers, or distribution of that species" (50 CFR 402.02). Therefore, the jeopardy analysis considers both survival and recovery of the species.

This biological opinion relies on the definition of "destruction or adverse modification," which "means a direct or indirect alteration that appreciably diminishes the value of critical habitat as a whole for the conservation of a listed species" (50 CFR 402.02).

The designation(s) of critical habitat for (species) use(s) the term primary constituent element (PCE) or essential features. The 2016 critical habitat regulations (50 CFR 424.12) replaced this term with physical or biological features (PBFs). The shift in terminology does not change the approach used in conducting a "destruction or adverse modification" analysis, which is the same regardless of whether the original designation identified PCEs, PBFs, or essential features. In this biological opinion, we use the term PBF to mean PCE or essential feature, as appropriate for the specific critical habitat.

We use the following approach to determine whether a proposed action is likely to jeopardize listed species or destroy or adversely modify critical habitat:

- Evaluate the rangewide status of the species and critical habitat expected to be adversely affected by the proposed action.
- Evaluate the environmental baseline of the species and critical habitat.
- Evaluate the effects of the proposed action on species and their habitat using an exposure-response approach.

- Evaluate cumulative effects.
- In the integration and synthesis, add the effects of the action and cumulative effects to the environmental baseline, and, in light of the status of the species and critical habitat, analyze whether the proposed action is likely to: (1) directly or indirectly reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing the reproduction, numbers, or distribution of that species, or (2) directly or indirectly result in an alteration that appreciably diminishes the value of critical habitat as a whole for the conservation of a listed species.
- If necessary, suggest a reasonable and prudent alternative to the proposed action.

2.2. Rangewide Status of the Species and Critical Habitat

This Opinion examines the status of each species that is likely to be adversely affected by the proposed action. The status is determined by the level of extinction risk that the listed species face, based on parameters considered in documents such as recovery plans, status reviews, and listing decisions. This informs the description of the species' likelihood of both survival and recovery. The species status section also helps to inform the description of the species' "reproduction, numbers, or distribution" as described in 50 CFR 402.02. The Opinion also examines the condition of critical habitat throughout the designated area, evaluates the conservation value of the various watersheds and coastal and marine environments that make up the designated area, and discusses the function of the PBFs that are essential for the conservation of the species.

One factor affecting the status of ESA-listed species considered in this Opinion, and aquatic habitat at large, is climate change. Climate change is likely to play an increasingly important role in determining the abundance and distribution of ESA-listed species, and the conservation value of designated critical habitats in the Pacific Northwest. These changes will not be spatially homogeneous across the Pacific Northwest. The largest hydrologic responses are expected to occur in basins with significant snow accumulation, where warming decreases snow pack, increases winter flows, and advances the timing of spring melt (Mote et al. 2014; Mote et al 2016). Rain-dominated watersheds and those with significant contributions from groundwater may be less sensitive to predicted changes in climate (Tague et al. 2013; Mote et al. 2014).

During the last century, average regional air temperatures in the Pacific Northwest increased by 1-1.4°F as an annual average, and up to 2°F in some seasons (based on average linear increase per decade; Abatzoglou et al. 2014; Kunkel et al. 2013). Recent temperatures in all but two years since 1998 ranked above the 20th century average (Mote et al. 2014). Warming is likely to continue during the next century as average temperatures are projected to increase another 3 to 10°F, with the largest increases predicted to occur in the summer (Mote et al. 2014).

Decreases in summer precipitation of as much as 30 percent by the end of the century are consistently predicted across climate models (Mote et al. 2014). Precipitation is more likely to occur during October through March, less during summer months, and more winter precipitation will be rain than snow (ISAB 2007; Mote et al. 2013). Earlier snowmelt will cause lower stream flows in late spring, summer, and fall, and water temperatures will be warmer (ISAB 2007; Mote et al. 2014). Models consistently predict increases in the frequency of severe winter precipitation events (i.e., 20-year and 50-year events), in the western United States (Dominguez et al. 2012). The largest increases in winter flood frequency and magnitude are predicted in mixed rain-snow watersheds (Mote et al. 2014).

The combined effects of increasing air temperatures and decreasing spring through fall flows are expected to cause increasing stream temperatures; in 2015 this resulted in 3.5-5.3°C increases in Columbia Basin streams and a peak temperature of 26°C in the Willamette (NWFSC 2015). Overall, about one-third of the current cold-water salmonid habitat in the Pacific Northwest is likely to exceed key water temperature thresholds by the end of this century (Mantua et al. 2009).

The Northwest Fishery Science Center (NWFSC 2015) reported that model projections of climate conditions affecting Puget Sound salmonids were not optimistic, and recent and unfavorable environmental trends are expected to continue. A negative pattern in the Pacific Decadal Oscillation[3] has recently emerged, which adds uncertainty to the short-term duration of warming trends. However, the long-term trends of climate change and other environmental indicators suggest the continuation of warming ocean temperatures; fragmented or degraded freshwater spawning and rearing habitat; reduced snowpack; altered hydrographs producing reduced summer river flows and warmer water; and low marine survival for salmonids in the Salish Sea (NWFSC 2015). Overall, the marine heat wave in 2014-2016 had the most drastic impact on marine ecosystems in 2015, with lingering effects into 2016 and 2017. Conditions had somewhat returned to "normal" in 2018, but another marine heat wave in 2019 again set off a series of marine ecosystem changes across the North Pacific. One reason for lingering effects of ecosystem response is due to biological lags. These lags result from species impacts at larval or juvenile stages, which are typically most sensitive to extreme temperatures or changes in food supply. It is only once these species grow to adult size or recruit into fisheries that the impact of the heat wave is apparent. Any rebound in VSP parameters for PS steelhead are likely to be constrained under these conditions (NWFSC 2015; Ford 2022).

Higher temperatures will reduce the quality of available salmonid habitat for most freshwater life stages (ISAB 2007). Reduced flows will make it more difficult for migrating fish to pass physical and thermal obstructions, limiting their access to available habitat (Mantua et al. 2010; Isaak et al. 2012). Temperature increases shift timing of key life cycle events for salmonids and species forming the base of their aquatic foodwebs (Crozier et al. 2011; Tillmann and Siemann 2011; Winder and Schindler 2004). Higher stream temperatures will also cause decreases in dissolved oxygen (DO) and may also cause earlier onset of stratification and reduced mixing between layers in lakes and reservoirs, which can also result in reduced oxygen (Meyer et al. 1999; Winder and Schindler 2004; Raymondi et al. 2013). Higher temperatures are likely to cause several species to become more susceptible to parasites, disease, and higher predation rates (Crozier et al. 2008; Wainwright & Weitkamp 2013; Raymondi et al. 2013).

As more basins become rain-dominated and prone to more severe winter storms, higher winter stream flows may increase the risk that winter or spring floods in sensitive watersheds will damage spawning redds and wash away incubating eggs (Goode et al. 2013). Earlier peak stream flows will also alter migration timing for salmon smolts, and may flush some young salmon and

[3] https://www.ncdc.noaa.gov/teleconnections/pdo/.

steelhead from rivers to estuaries before they are physically mature, increasing stress and reducing smolt survival (McMahon and Hartman 1989; Lawson et al. 2004).

In addition to changes in freshwater conditions, predicted changes for coastal waters in the Pacific Northwest as a result of climate change include increasing surface water temperature, increasing but highly variable acidity, and increasing storm frequency and magnitude (Mote et al. 2014). Elevated ocean temperatures already documented for the Pacific Northwest are highly likely to continue during the next century, with sea surface temperature projected to increase by 1.0-3.7ºC by the end of the century (IPCC 2014). Habitat loss, shifts in species' ranges and abundances, and altered marine food webs could have substantial consequences to anadromous, coastal, and marine species in the Pacific Northwest (Tillmann and Siemann 2011; Reeder et al. 2013).

Moreover, as atmospheric carbon emissions increase, increasing levels of carbon are absorbed by the oceans, changing the pH of the water. A 38 percent to 109 percent increase in acidity is projected by the end of this century in all but the most stringent CO_2 mitigation scenarios, and is essentially irreversible over a time scale of centuries (IPCC 2014). Regional factors appear to be amplifying acidification in Northwest ocean waters, which is occurring earlier and more acutely than in other regions and is already impacting important local marine species (Barton et al. 2012; Feely et al. 2012). Acidification also affects sensitive estuary habitats, where organic matter and nutrient inputs further reduce pH and produce conditions more corrosive than those in offshore waters (Feely et al. 2012; Sunda and Cai 2012).

Global sea levels are expected to continue rising throughout this century, reaching likely predicted increases of 10-32 inches by 2081-2100 (IPCC 2014). These changes will likely result in increased erosion and more frequent and severe coastal flooding, and shifts in the composition of nearshore habitats (Tillmann and Siemann 2011; Reeder et al. 2013). Estuarine-dependent salmonids such as chum and Chinook salmon are predicted to be impacted by significant reductions in rearing habitat in some Pacific Northwest coastal areas (Glick et al. 2007). Historically, warm periods in the coastal Pacific Ocean have coincided with relatively low abundances of salmon and steelhead, while cooler ocean periods have coincided with relatively high abundances, and therefore these species are predicted to fare poorly in warming ocean conditions (Scheuerell and Williams 2005; Zabel et al. 2006). This is supported by the recent observation that anomalously warm sea surface temperatures off the coast of Washington from 2013 to 2016 resulted in poor coho and Chinook salmon body condition for juveniles caught in those waters (NWFSC 2015). Changes to estuarine and coastal conditions, as well as the timing of seasonal shifts in these habitats, have the potential to impact a wide range of listed aquatic species (Tillmann and Siemann 2011; Reeder et al. 2013).

The adaptive ability of these threatened and endangered species is depressed due to reductions in population size, habitat quantity and diversity, and loss of behavioral and genetic variation. Without these natural sources of resilience, systematic changes in local and regional climatic conditions due to anthropogenic global climate change will likely reduce long-term viability and sustainability of populations in many of these ESUs (Ford 2022). New stressors generated by climate change, or existing stressors with effects that have been amplified by climate change, may also have synergistic impacts on species and ecosystems (Doney et al. 2012). These conditions will possibly intensify the climate change stressors inhibiting recovery of ESA-listed species in the future.

2.2.1. Status of ESA-Listed Fish Species

For Pacific salmon, steelhead, and certain other listed fish species, we commonly use the four "viable salmonid population" (VSP) criteria (McElhany et al. 2000) to assess the viability of the populations that, together, constitute the species. These four criteria (spatial structure, diversity, abundance, and productivity) encompass the species' "reproduction, numbers, or distribution" as described in 50 CFR 402.02. When these parameters are collectively at appropriate levels, populations can adapt to various environmental conditions and sustain in the natural environment.

"Spatial structure" refers both to the spatial distributions of individuals in the population and the processes that generate that distribution. A population's spatial structure depends on quality and spatial configuration critical habitat, and the dispersal characteristics and dynamics of individuals in the population.

"Diversity" refers to the distribution of traits within and among populations. These range in scale from DNA sequence variation in single genes to complex life history traits (McElhany et al. 2000).

"Abundance" generally refers to the number adults in the naturally produced (i.e., the progeny of naturally spawning parents) in the environment (e.g., on spawning grounds).
"Productivity," as applied to viability factors, refers to the entire life cycle (i.e., the number of naturally-spawning adults produced per parent). When progeny replace or exceed the number of parents, a population is stable or increasing. When progeny fail to replace the number of parents, the population is declining. McElhany et al. (2000) use the terms "population growth rate" and "productivity" interchangeably when referring to production over the entire life cycle. They also refer to "trend in abundance," which is the manifestation of long-term population growth rate.

For species with multiple populations, once the biological status of a species' populations has been determined, we assess the status of the entire species using criteria for groups of populations, as described in recovery plans and guidance documents from technical recovery teams. Considerations for species viability include having multiple populations that are viable, ensuring that populations with unique life histories and phenotypes are viable, and that some viable populations are both widespread to avoid concurrent extinctions from mass catastrophes and spatially close to allow functioning as metapopulations (McElhany et al. 2000).

The summaries that follow describe the status of ESA-listed PS Chinook salmon and PS steelhead that occur within the geographic area of the proposed action analyzed in this Opinion. More detailed information on the status and trends of these listed resources, and their biology and ecology, are in the listing regulations and critical habitat designations published in the Federal Register (Table 1).

Status of Puget Sound Chinook Salmon

The PS Chinook salmon evolutionarily significant unit (ESU) was listed as threatened on June 28, 2005 (70 FR 37160) (Table 1). NMFS adopted a recovery plan for this ESU in January 2007. The recovery plan consists of two documents: the Puget Sound salmon recovery plan (Shared Strategy for Puget Sound 2007) and a supplement by NMFS (2006). The recovery plan adopts ESU and population level viability criteria recommended by the Puget Sound Technical Recovery Team (PSTRT) (Ruckelshaus et al. 2002). The PSTRT's biological recovery criteria will be met when all of the following conditions are achieved:

- The viability status of all populations in the ESU is improved from current conditions, and when considered in the aggregate, persistence of the ESU is assured;
- Two to four Chinook salmon populations in each of the five biogeographical regions of the ESU achieve viability, depending on the historical biological characteristics and acceptable risk levels for populations within each region;
- At least one population from each major genetic and life history group historically present within each of the five biogeographical regions is viable;
- Tributaries to Puget Sound not identified as primary freshwater habitat for any of the 22 identified populations are functioning in a manner that is sufficient to support an ESU-wide recovery scenario; Production of Chinook salmon from tributaries to Puget Sound not identified as primary freshwater habitat for any of the 22 identified populations occurs in a manner consistent with ESU recovery; and
- Populations that do not meet the viability criteria for all VSP parameters are sustained to provide ecological functions and preserve options for ESU recovery.

On October 4, 2019, NMFS published notice of NMFS' intent to initiate a new 5-year status review for 28 listed species of Pacific salmon and steelhead and requesting updated information from the public to inform the status review (84 FR 53117). On March 24, 2020, NMFS extended the public comment period, from the original March 27, 2020, through May 26, 2020 (85 FR 16619). The Northwest Fishery Science Center (NWFSC), and NMFS' West coast Regional Office (WCRO) are currently preparing the final status review documents, with anticipated completion in spring of 2022. In this section, we utilize some of the information in the draft viability risk assessment (Ford, 2022), in order to provide the most recent information for our evaluation in this Opinion.

Where possible, particularly as new material becomes available, the latest final status review information (NMFS 2016) is supplemented with more recent information and other population specific data that may not have been available during the status review, so that NMFS is assured of using the best available information for this Opinion.

Spatial Structure and Diversity: The Puget Sound Chinook salmon ESU includes all naturally spawning populations of Chinook salmon from rivers and streams flowing into Puget Sound including the Straits of Juan De Fuca from the Elwha River, eastward, including rivers and streams flowing into Hood Canal, South Sound, North Sound and the Strait of Georgia in Washington. The ESU also includes the progeny of numerous artificial propagation programs (NWFSC 2015). The PSTRT identified 22 extant populations, grouped into five major geographic regions, based on consideration of historical distribution, geographic isolation, dispersal rates, genetic data, life history information, population dynamics, and environmental and ecological diversity. The PSTRT distributed the 22 populations among five major biogeographical regions, or major population groups (MPG), that are based on similarities in hydrographic, biogeographic, and geologic characteristics.

Three of the five MPGs (Strait of Juan de Fuca, Georgia Basin, and Hood Canal) contain only two populations each, both of which must be recovered to viability to recover the ESU (NMFS 2006b). Under the Puget Sound Salmon Recovery Plan, the Suiattle and one each of the early, moderately early, and late run-timing populations in the Whidbey Basin Region, as well as the White and Nisqually (or other late-timed) populations in the Central/South Sound Region must also achieve viability (NMFS 2006b).

The Technical Recovery Team (TRT) did not define the relative roles of the remaining populations in the Whidbey and Central/South Sound Basins for ESU viability. Therefore, NMFS developed additional guidance which considers distinctions in genetic legacy and watershed condition, among other factors, in assessing the risks to survival and recovery of the listed species by the proposed actions across all populations within the PS Chinook ESU. In doing so, it is important to take into account whether the genetic legacy of the population is intact or if it is no longer distinct within the ESU. Populations are defined by their relative isolation from each other and by the unique genetic characteristics that evolve, as a result of that isolation, and adaption to their specific habitats. If these populations still retain their historic genetic legacy, then the appropriate course, to ensure their survival and recovery, is to preserve that genetic legacy and rebuild those populations. Preserving that legacy requires both a sense of urgency and the actions necessary and appropriate to preserve the legacy that remains. However, if the genetic legacy is gone, then the appropriate course is to recover the populations using the individuals that best approximate the genetic legacy of the original population, reduce the effects of the factors that have limited their production, and provide the opportunity for them to readapt to the existing conditions.

In keeping with this approach, NMFS further classified PS Chinook populations into three tiers based on a systematic framework that considers the population's life history and production and watershed characteristics (NMFS 2010) (Figure 3). This framework, termed the Population Recovery Approach, carries forward the biological viability and delisting criteria described in the Supplement to the Puget Sound Salmon Recovery Plan (Ruckelshaus et al. 2002; NMFS 2006b). The assigned tier indicates the relative role of each of the 22 populations comprising the ESU to the viability of the ESU and its recovery. Tier 1 populations are most important for preservation, restoration, and ESU recovery. Tier 2 populations play a less important role in recovery of the ESU. Tier 3 populations play the least important role. When we analyze proposed actions, we evaluate impacts at the individual population scale for their effects on the viability of the ESU. We expect that impacts to Tier 1 populations would be more likely to affect the viability of the ESU, as a whole, than similar impacts to Tier 2 or 3 populations, because of the relatively greater importance of Tier 1 populations to overall ESU viability and recovery. NMFS has incorporated this and similar approaches in previous ESA section 4(d) determinations and Opinions on Puget Sound salmon fisheries and regional recovery planning (NMFS 2005b; 2005d; 2008f; 2008e; 2010a; 2011a; 2013b; 2014b; 2015c; 2016f; 2017b; 2018c; 2019b; 2021e).

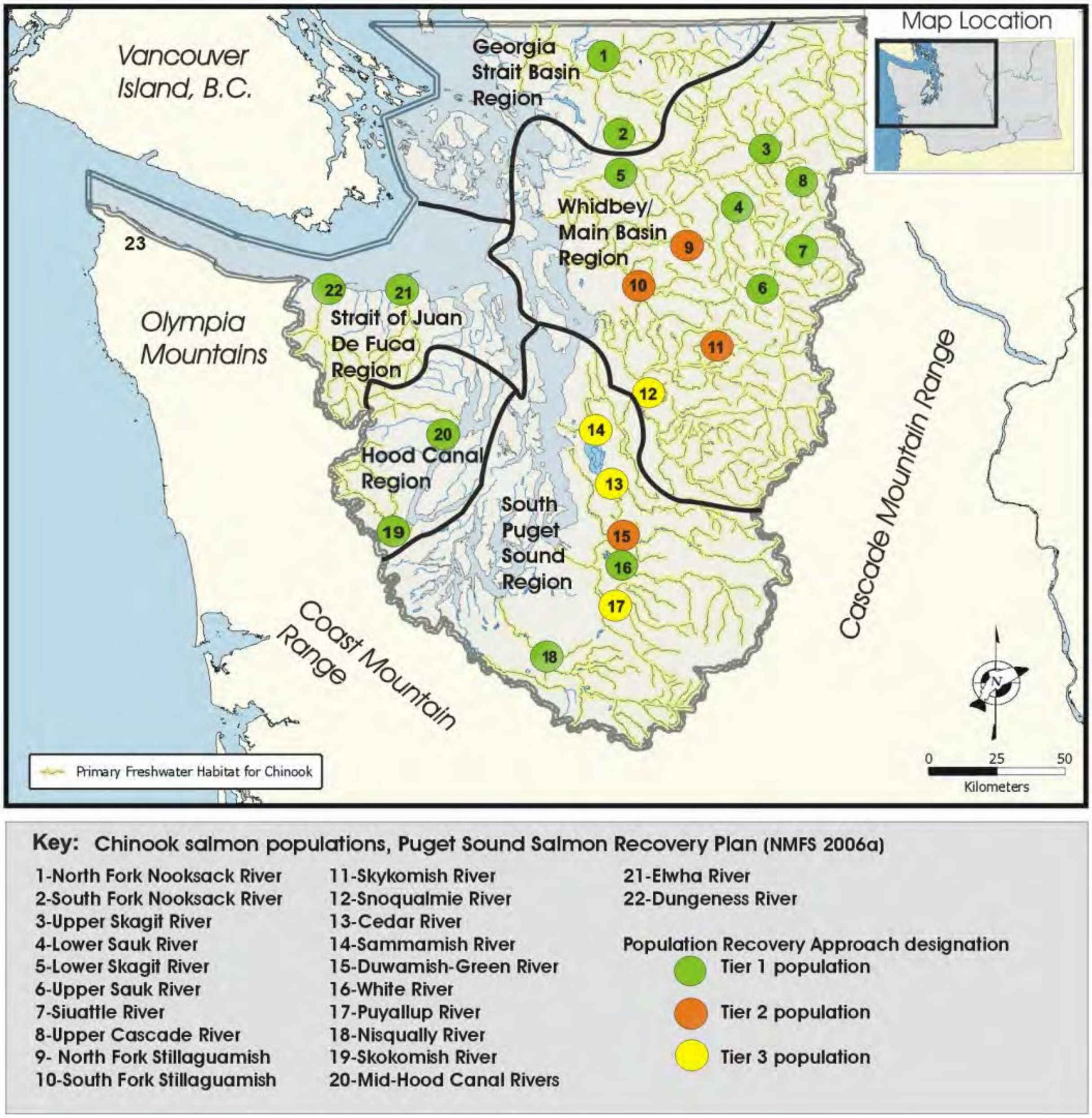


Figure 3. Puget Sound Chinook populations with tiered recovery designations.

The ESU also includes Chinook salmon from certain artificial propagation programs. Artificial propagation (hatchery) programs (26) were added to the listed Chinook salmon ESU in 2005, as part of the final listing determinations for 16 ESUs of West Coast Salmon and Final 4(d) Protective Regulations for Threatened Salmonid ESUs (70 FR 37160). In October of 2016, NMFS proposed revisions to the hatchery programs included as part of some Pacific salmon ESUs and steelhead DPSs listed under the ESA (81 FR 72759). NMFS issued its final rule in December of 2020, which includes 25 hatchery programs as part of the listed Puget Sound Chinook salmon ESU (85 FR 81822).

Since 1999, most PS Chinook populations have mean natural-origin spawner escapement levels well below levels identified as required for recovery to low extinction risk. Long-term, natural-origin mean escapements for eight populations are at or below their critical thresholds.[4] Both populations in three of the five biogeographical regions are below or near their critical threshold: Georgia Strait, Hood Canal and Strait of Juan de Fuca. When hatchery spawners are included, aggregate average escapement is over 1,000 for one of the two populations in each of these three regions, reducing the demographic risk to the populations in these regions. Additionally, hatchery spawners help two of the remaining three of these populations achieve total spawner abundances above their critical threshold, reducing demographic risk. Nine populations are above their rebuilding thresholds,[5] seven of them in the Whidbey/Main Basin Region. In 2018 NMFS and the NWFSC updated the rebuilding thresholds for several key Puget Sound populations. These thresholds represent the Maximum Sustained Yield estimate of spawners based on available habitat. The new spawner-recruit analyses for several populations indicated a significant reduction in the number of spawners that can be supported by the available habitat when compared to analyses conducted 10 to 15 years ago. This may be due to further habitat degradation or improved productivity assessment or, more likely, a combination of the two. For example, the updated rebuilding escapement threshold for the Green River is 1,700 spawners compared to the previous rebuilding escapement threshold of 5,523[6] spawners. So, although several populations are above the updated rebuilding thresholds, indicating that escapement is sufficient for the available habitat in many cases, the overall abundance has declined.

Measures of spatial structure and diversity can give some indication of a population's resilience to sustain itself. Spatial structure can be measured in various ways, but here we assess the proportion of natural-origin spawners (wild fish) vs. hatchery-origin spawners on the spawning grounds (Ford, 2022).

Since 1990, there is a general declining population trend in the proportion of natural-origin spawners across the ESU (Table 4). While there are several populations that have maintained high levels of natural-origin spawner proportions, mostly in the Skagit and Snohomish basins, many others maintain high proportions of hatchery-origin spawners (Table 4). It should be noted that the pre-2005-2009 estimates of mean natural-origin fractions occurred prior to the widespread adoption of mass marking of hatchery produced fish. Estimates of hatchery and natural-origin proportions of fish since the implementation of mass marking are considered more robust. Several of these populations have long-standing or more recent conservation hatchery programs associated with them—North Fork (NF) and South Fork (SF) Nooksack, NF and SF

[4] After taking into account uncertainty, the critical threshold is defined as a point below which: (1) depensatory processes are likely to reduce the population below replacement; (2) the population is at risk from inbreeding depression or fixation of deleterious mutations; or (3) productivity variation due to demographic stochasticity becomes a substantial source of risk (NMFS 2000).

[5] The rebuilding threshold is defined as the escapement that will achieve Maximum Sustainable Yield (MSY) under current environmental and habitat conditions (NMFS 2000), and is based on an updated spawner-recruit assessment in the Puget Sound Chinook Harvest Management Plan, December 1, 2018. Thresholds were based on population-specific data, where available.

[6] The historic Green River escapement goal was established in 1977 as the average of estimated natural spawning escapements from 1965-1974. This goal does not reflect the lower productivity associated with the current condition of habitat. Reference the source for the historical objective from MUP (PSIT and WDFW 2017)(Green River MUP).

Stillaguamish, White River, Mid-Hood Canal, Dungeness, and the Elwha. These conservation programs are in place to maintain or increase the overall abundance of these populations, helping to conserve the diversity and increase the spatial distribution of these populations in the absence of properly functioning habitat. With the exception of the Mid-Hood Canal program, these conservation hatchery programs culture the extant, native Chinook salmon stock in these basins. With the exception of the NF and SF Stillaguamish, the remainder of the populations included in these conservation programs are identified in NMFS (2006b) as essential for the recovery of the Puget Sound Chinook salmon ESU (Table 4).

Table 4. Five-year mean of fraction of natural-origin spawners[7] (sum of all estimates divided by the number of estimates) (Ford, 2022).

Population	1995-1999	2000-2004	2005-2009	2010-2014	2015-2019
NF Nooksack R. spring	0.28	0.11	0.19	0.14	0.13
SF Nooksack R. spring	0.26	0.55	0.57	0.42	0.45
Low. Skagit R. fall	0.94	0.91	0.86	0.92	0.84
Up. Skagit R. summer	0.91	0.87	0.84	0.95	0.91
Cascade R. spring	0.98	0.92	0.89	0.94	0.86
Low. Sauk R. summer	0.94	0.97	0.95	0.91	0.98
Up. Sauk R. spring	0.99	1.00	0.98	0.97	0.99
Suiattle R. spring	0.99	0.97	0.99	0.99	0.97
NF Stillaguamish R. summer/fall	0.59	0.70	0.40	0.43	0.45
SF Stillaguamish R. summer/fall	0.59	0.70	0.40	0.54	0.46
Skykomish R. summer	0.49	0.52	0.76	0.69	0.62
Snoqualmie R. fall	0.81	0.89	0.81	0.78	0.75
Sammamish R. fall	0.29	0.36	0.16	0.07	0.16
Cedar R. fall	0.61	0.59	0.82	0.78	0.71
Green R. fall	0.55	0.47	0.43	0.39	0.30
White R. spring	0.54	0.79	0.43	0.32	0.15
Puyallup R. fall	0.88	0.79	0.52	0.41	0.32
Nisqually R. fall	0.80	0.61	0.30	0.30	0.47
Skokomish R. fall	0.40	0.46	0.45	0.10	0.16
Mid-Hood Canal fall	0.76	0.79	0.61	0.33	0.89
Dungeness R. summer	1.00	0.32	0.43	0.25	0.25
Elwha R. fall	0.41	0.53	0.35	0.06	0.05

In addition, spatial structure, or geographic distribution, of the White, Skagit, Elwha,[8] and Skokomish populations has been substantially reduced or impeded by the loss of access to the upper portions of those tributary basins due to flood control activities and hydropower development. Habitat conditions conducive to salmon survival in most other watersheds have been reduced significantly by the effects of land use, including urbanization, forestry,

[7] Estimates of hatchery and natural-origin spawning abundances, prior to the 2005-2009 period are based on pre-mass marking of hatchery-origin fish and, as such, may not be directly comparable to the 2005-2009 forward estimates.

[8] Removal of the two Elwha River dams and restoration of the natural habitat in the watershed began in 2011.

agriculture, and development (NMFS 2005a; SSPS 2005; NMFS 2008c; 2008d; 2008b). It is likely that genetic and life history diversity has been significantly adversely affected by this habitat loss.

Between 1990 and 2021, the proportion of natural-origin spawners has trended downward across the ESU, with the Whidbey Basin the only MPG with consistently high fractions of natural-origin spawner abundance. All other MPG have either variable or declining spawning populations with high proportions of hatchery-origin spawners (NWFSC 2015; Ford, 2022). Overall, the new information on abundance, productivity, spatial structure and diversity since the 2015 status review supports no change in the biological risk category (NWFSC 2015; Ford, 2022).

Abundance and Productivity: The abundance of the PS Chinook salmon over time shows that individual populations have varied with increasing or decreasing abundance. Generally, many populations experienced increases in total abundance during the years 2000-2008, and more recently in 2015-2017, but general declines during 2009-2014, and a downturn again in the two most recent years available for the current status review, 2017-2018. Abundance across the Puget Sound ESU has generally increased since the last status review, with only 2 of the 22 populations (Cascade and North Fork and South Fork Stillaguamish) showing a negative percent change in the 5-year geometric mean natural- origin spawner abundances since the prior status review (Table). However, 15 of 20 populations with positive percent change in the 5-year geometric mean natural-origin spawner abundances since the prior status review have relatively low population abundances of <1000 fish, so some of these increases represent small changes in total abundance (Ford, 2022). Also, given lack of high confidence in survey techniques, particularly with small populations, there is substantial uncertainty in quantifying fish and detecting trends in small populations (Gallagher et al. 2010).

Table 5. Extant PS Chinook salmon populations in each biogeographic region and percent change between the most recent two 5-year periods (2010-2014 and 2015-2019). Five-year geometric mean of raw natural-origin spawner counts. In parentheses, 5-year geometric mean of raw total spawner estimates (i.e., hatchery and natural) are shown. Percent change between the most recent two 5-year periods is shown on the far right (Ford, 2022).

Biogeographic Region	Population (Watershed)	2010-2014	2015-2019	Population trend (% change)
Strait of Georgia	**North Fork Nooksack River**	136 (1205)	137 (1553)	Positive 1% (29)
	South Fork Nooksack River	13 (35)	42 (106)	Positive 223% (203)
Strait of Juan de Fuca	**Elwha River**	71 (1349)	134 (2810)	Positive 89% (108)
	Dungeness River	66 (279)	114 (476)	Positive 73% (71)
Hood Canal	**Skokomish River**	136 (1485)	265 (2074)	Positive 95% (40)
	Mid Hood Canal River	80 (295)	196 (222)	Positive 145% (-25)
Whidbey Basin	Skykomish River	1698 (2462)	1736 (2806)	Positive 3% (14)
	Snoqualmie River	839 (1082)	856 (1146)	Positive 2% (6)
	North Fork Stillaguamish River	417 (996)	302 (762)	Negative 28% (-23)
	South Fork Stillaguamish River	34 (68)	37 (96)	Positive 9% (41)
	Lower Skagit River	1416 (1541)	2130 (2640)	Positive 50% (71)
	Upper Sauk River	854 (880)	1318 (1330)	Positive 54% (51)
	Lower Sauk River	376 (416)	635 (649)	Positive 69% (56)
	Suiattle River	376 (378)	640 (657)	Positive 70% (74)
	Upper Cascade River	298 (317)	185 (223)	Negative 38% (-30)
Central/South Puget Sound Basin	North Lake Washington/ Sammamish River	82 (1289)	126 (879)	Positive 54% (-32)
	Green/Duwamish River	785 (2109)	1822 (6373)	Positive 132% (202)
	Puyallup River	450 (1134)	577 (1942)	Positive 28% (71)
	White River	652 (2161)	895 (6244)	Positive 37% (189)
	Cedar River	699 (914)	889 (1253)	Positive 27% (37)
	Nisqually River	481 (1823)	766 (1841)	Positive 59% (1)

Trends in abundance over longer time periods are generally slightly negative. Fifteen-year trends in log natural-origin spawner abundance were computed over two time periods (1990-2005 and 2004- 2019) for each Puget Sound Chinook salmon population. Trends were negative in the latter period for 16 of the 22 populations and for four of the 22 populations (SF Nooksack, SF Stillaguamish, Green and Puyallup) in the earlier period. Thus, there is a general decline in natural-origin spawner abundance across all MPGs in the recent fifteen years. Upper Sauk and Suiattle (Whidbey Basin MPG), Nisqually (Central/South MPG) and Mid-Hood Canal (Hood Canal MPG) are the only populations with positive trends, though Mid-Hood Canal has an extremely low population size. Further, no change in trend between the two time periods was detected in SF Nooksack (Strait of Georgia MPG), Green and Nisqually (Central/South MPG). The average trend across the ESU for the 1990-2005 15-year time period was 0.03 (Figure 4). The average trend across the ESU for the later 15-year time period (2004-2019) was -0.02. The previous status review in 2015 (NWFSC 2015) concluded there were widespread negative trends for the total ESU despite that escapements and trends for individual populations were variable. The addition of the data to 2018 now also shows even more substantially either flat or negative trends for the entire ESU in natural-origin Chinook salmon spawner population abundances (Ford, 2022).

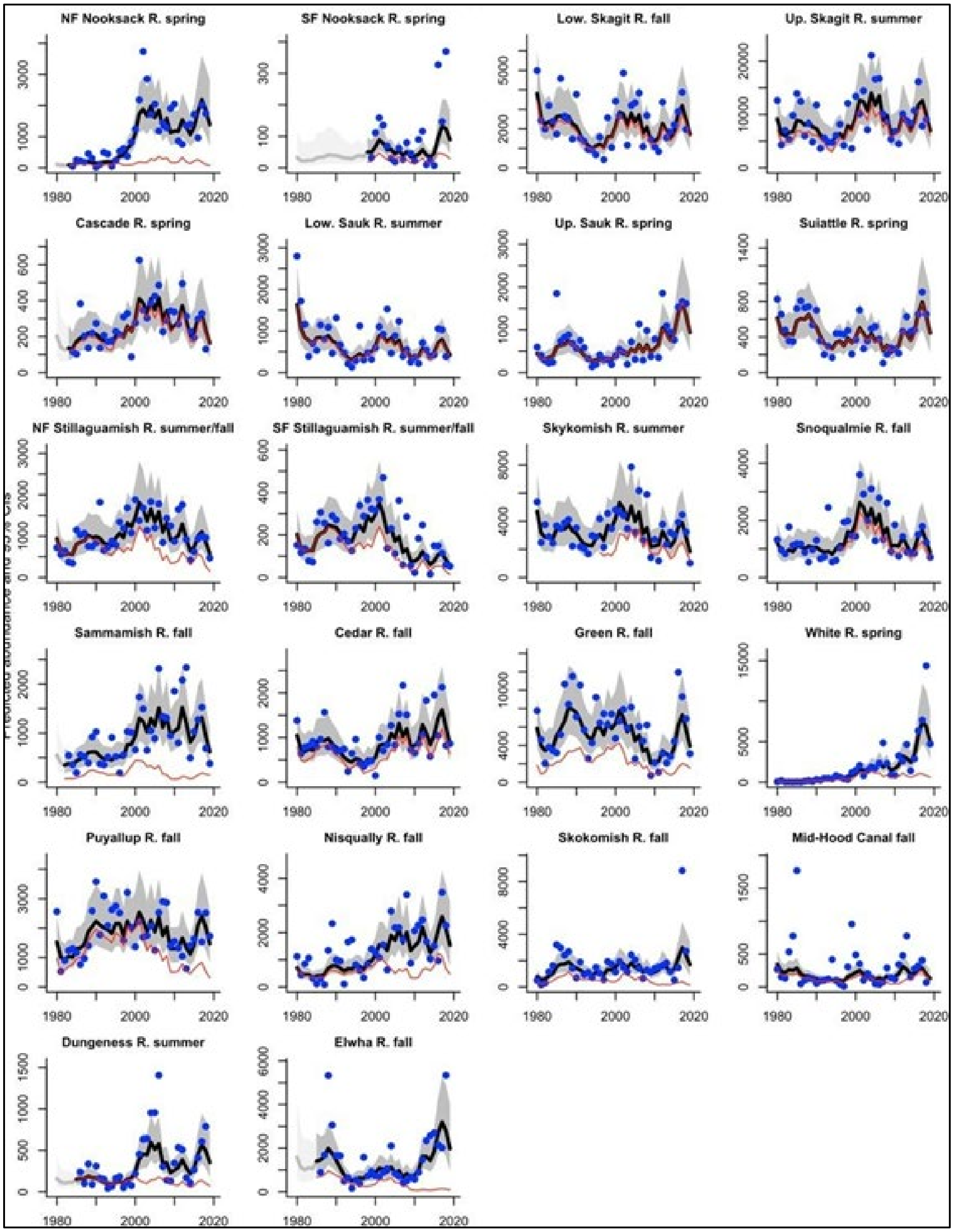


Figure 4. Smoothed trend in estimated total (thick black line, with 95 percent confidence internal in gray) and natural (thin red line) PS Chinook salmon population spawning abundance. In portions of a time series where a population has no annual estimate but smoothed spawning abundance is estimated from correlations with other populations the smoothed estimate is shown in light gray. Points show the annual raw spawning abundance estimates. For some trends the smoothed estimate may be influenced by earlier data points not included in the plot (Ford, 2022).

Across the Puget Sound ESU, 10 of 22 Puget Sound populations show natural productivity below replacement in nearly all years since the mid-1980's (Figure 4). These include the North and South Forks Nooksack in the Strait of Georgia MPG, North and South Forks Stillaguamish and Skykomish in Whidbey Basin MPG, Sammamish, Green and Puyallup in the Central/South MPG, the Skokomish in the Hood Canal MPG, and Elwha in the Strait of Juan de Fuca MPG. Productivity in the Whidbey Basin MPG populations was above zero the mid-late 1990's, with the exception of Skykomish and North and South Forks Stillaguamish populations. White River population in the Central/South MPG was above replacement from the early 1980's to 2001, but has dropped in productivity consistently since the late 1980's. In recent years, only 5 populations have had productivities above zero. These are Lower Skagit, Upper Skagit, Lower Sauk, Upper Sauk, and Suiattle, all Skagit River populations in the Whidbey Basin MPG. This is consistent with, and continues the decline reported in the 2015 Status Review (NWFSC 2015).

All Puget Sound Chinook salmon populations continue to remain well below recovery levels (Ford, 2022). Most populations also remain consistently below the spawner-recruit levels identified by the TRT as necessary for recovery. Across the ESU, most native-origin populations have slightly increased in abundance since the last status review in 2016, but have small negative trends over the past 15 years (Figure 5). Productivity remains low in most populations. Hatchery-origin spawners are present in high fractions in most populations outside the Skagit watershed, and in many watersheds the fraction of spawner abundances that are natural-origin have declined over time. Habitat protection, restoration and rebuilding programs in all watersheds have improved stream and estuary conditions despite record numbers of humans moving into the Puget Sound region in the past two decades. Bi-annual four-year work plans document the many completed habitat actions that were initially identified in the Puget Sound Chinook salmon recovery plan. However, the expected benefits from restoration actions is likely to take years or decades to produce significant improvement in natural population viability parameters (see Roni et al. 2010).

Development of a monitoring and adaptive management program was required by NMFS in the 2007 Supplement to the Shared Strategy Recovery Plan (NMFS 2006b), and since the last review the Puget Sound Partnership has completed this, but this program is still not fully functional for providing an assessment of watershed habitat restoration/recovery programs, nor does it fully integrate the essentially discrete habitat, harvest and hatchery programs. A recent white paper produced by the Salmon Science Advisory Group, of the Puget Sound Partnership concludes there has been "a general inability of monitoring to link restoration, changes in habitat conditions, and fish response at large-scales" (PSP 2021). A number of watershed groups are in the process of updating their Recovery Plan Chapters and this includes prioritizing and updating recovery strategies and actions, as well as assessing prior accomplishments. Overall, recent information on PS Chinook salmon abundance and productivity since the 2016 status review indicates a slight increase in abundance but does not indicate a change in biological risk to the ESU despite moderate inter-annual variability among populations and a general decline in abundance over the last 15 years (Ford, 2022).

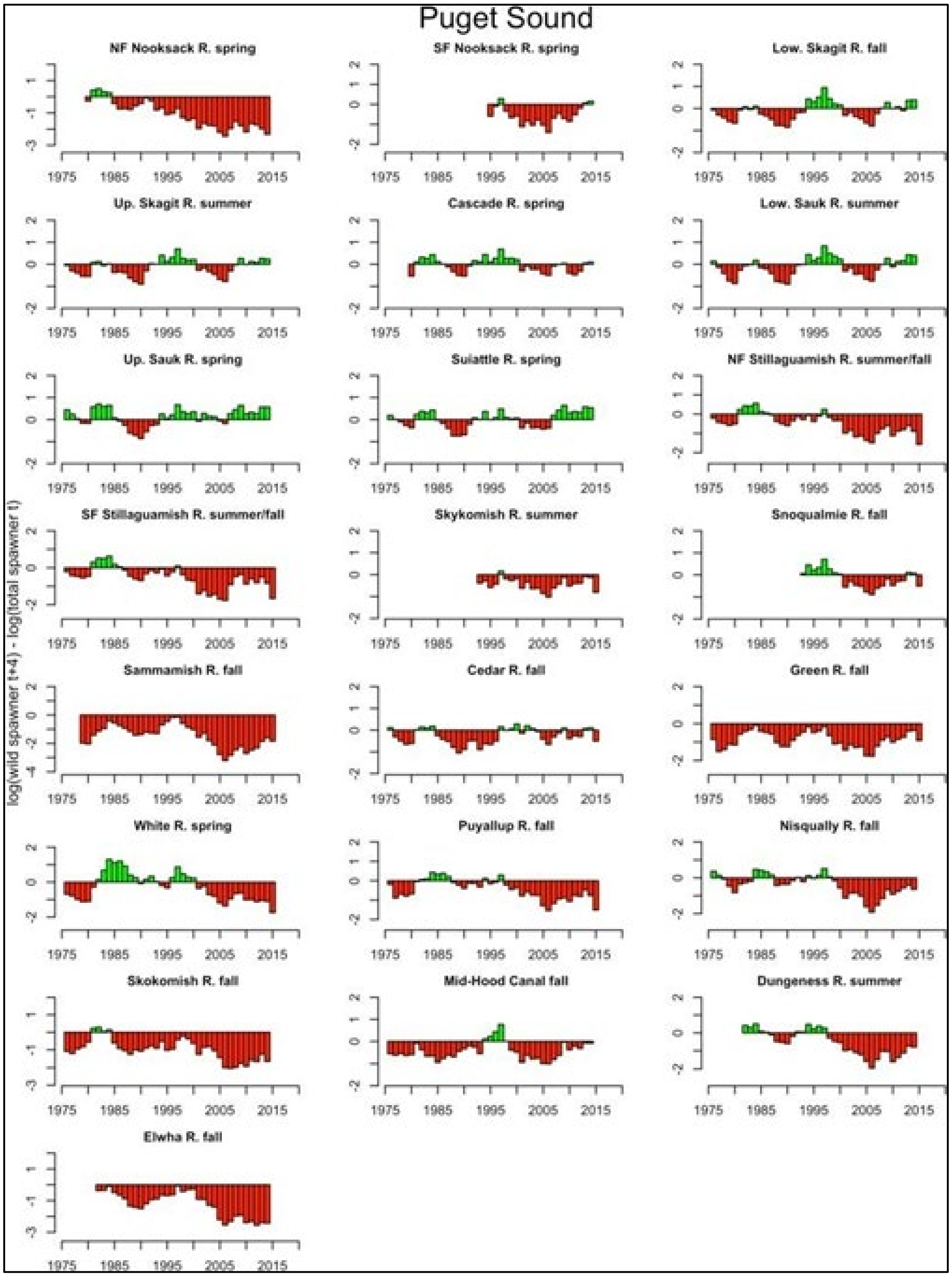


Figure 5. Trends in Chinook salmon population productivity, estimated as the log of the smoothed natural-origin spawning abundance in year t – smoothed natural-origin spawning abundance in year (t – 4) (Ford, 2022).

Limiting Factors: Limiting factors for this species include:

- Degraded floodplain and in-river channel structure
- Degraded estuarine conditions and loss of estuarine habitat
- Riparian area degradation and loss of in-river large woody debris
- Excessive fine-grained sediment in spawning gravel
- Degraded water quality and temperature
- Degraded nearshore conditions
- Impaired passage for migrating fish
- Altered flow regime

PS Chinook Salmon Recovery Plan: Nearshore areas serve as the nursery for juvenile PS Chinook salmon. Riparian vegetation, shade and insect production, and forage fish eggs along marine shorelines and river deltas help to provide food, cover and thermoregulation in shallow water habitats. Forage fish spawn in large aggregations along shorelines with suitable habitat, which produce prey for juvenile PS Chinook salmon. Juvenile salmon commonly occupy "pocket estuaries" where freshwater inputs provide salinity gradients that make adjusting to the marine environment less physiologically demanding. Pocket estuaries also provide refugia from predators. As the juvenile salmon grow and adjust, they move out to more exposed shorelines such as eelgrass, kelp beds and rocky shorelines where they continue to grow and migrate into the ocean environment. Productive shoreline habitats of Puget Sound are necessary for the recovery of Puget Sound salmon (SSPS 2007).

The Puget Sound Recovery Plan (Volumes 1 and 2) includes specific recovery actions for each of the 22 extant populations of PS Chinook salmon. General protection and restoration actions summarized from the plan include:

- Aggressively protect functioning drift cells and feeder bluffs that support eelgrass bands and depositional features;
- Counties should pass strong regulations and policies limiting increased armoring of these shorelines and offering incentives for protection;
- Aggressively protect areas, especially shallow water/low gradient habitats and pocket estuaries, within 5 miles of river deltas;
- Protect the forage fish spawning areas;
- Conduct limited beach nourishment on a periodic basis to mimic the natural sediment transport processes in select sections where corridor functions may be impaired by extensive armoring;
- Maintain the functioning of shallow, fine substrate features in and near 11 natal estuaries for Chinook salmon (to support rearing of fry);
- Maintain migratory corridors along the shores of Puget Sound;
- Maintain the production of food resources for salmon;
- Maintain functioning nearshore ecosystem processes (i.e., sediment delivery and transport; tidal circulation) that create and support the above habitat features and functions;

- Increase the function and capacity of nearshore and marine habitats to support key needs of salmon;
- Protect and restore shallow, low velocity, fine substrate habitats along marine shorelines, including eelgrass beds and pocket estuaries, especially adjacent to major river deltas;
- Protect and restore riparian areas;
- Protect and restore estuarine habitats of major river mouths;
- Protect and restore spawning areas and critical rearing and migration habitats for forage fish;
- Protect and restore drift cell processes (including sediment supply, e.g., from feeder bluffs, transport, and deposition) that create and maintain nearshore habitat features such as spits, lagoons, bays, beaches.

Development of shoreline and estuary areas of Puget Sound is expected to continue to adversely impact the quality of marine habitat for PS Chinook salmon. Projected changes in nearshore and estuary development based on documented rates of developed land cover change in Bartz et al. (2015) show that between 2008 and 2060, an additional 14.7 hectares of development of shoreline areas and 204 hectares of estuary development can be expected.

Status of Puget Sound Steelhead

The PS steelhead DPS was listed as a threatened species under the ESA on May 11, 2007 (72 FR 26722). Subsequent status assessments of the DPS after the ESA-listing decision have found that the status of PS steelhead regarding risk of extinction has not changed substantially (Ford et al. 2011a; NMFS 2016a) (81 FR 33468, May 26, 2016) (Ford, 2022). On October 4, 2019 NMFS published a Federal Register notice (84 FR 53117), announcing NMFS' intent to initiate a new 5-year status review for 28 listed species of Pacific salmon and steelhead and requesting updated information from the public to inform the most recent five-year status review. On March 24, 2020, NMFS extended the public comment period, from the original March 27, 2020, through May 26, 2020 (85 FR 16619). The NWFSC and the NMFS' WCR are currently preparing the final five-year status review documents, with anticipated completion in spring of 2022.

The PS Steelhead TRT produced viability criteria, including population viability analyses (PVAs), for 20 of 32 demographically independent populations (DIPs) and three major population groups (MPGs) in the DPS (Hard et al. 2015). It also completed a report identifying historical populations of the DPS (Myers et al. 2015). The DIPs are based on genetic, environmental, and life history characteristics. Populations display winter, summer, or summer/winter run timing (Myers et al. 2015). The TRT concludes that the DPS is currently at "very low" viability, with most of the 32 DIPs and all three MPGs at "low" viability.
The designation of the DPS as "threatened" is based upon the extinction risk of the component populations. For a DIP to be considered viable, it must have at least an 85 percent probability of meeting the viability criteria, as calculated by Hard et al. (2015).

At the time of listing the Puget Sound steelhead Biological Review Team (BRT) considered the major risk factors associated with spatial structure and diversity of PS steelhead to be: (1) the low abundance of several summer run populations; (2) the sharply diminishing abundance of some winter steelhead populations, especially in south Puget Sound, Hood Canal, and the Strait of Juan de Fuca; and (3) continued releases of out-of-ESU hatchery fish from Skamania-derived summer run and Chambers Creek-derived winter run stocks (Hard et al. 2007; Hard et al. 2015). Loss of diversity and spatial structure were judged to be "moderate" risk factors (Hard et al. 2007). In 2011 the BRT identified degradation and fragmentation of freshwater habitat, with consequential effects on connectivity, as the primary limiting factors and threats facing the PS steelhead DPS (Ford et al. 2011a). The BRT also determined that most of the steelhead populations within the DPS continued to show downward trends in estimated abundance, with a few sharp declines (Ford et al. 2011a). The 2015 status review concurred that harvest and hatchery production of steelhead in Puget Sound were at low levels and not likely to increase substantially in the foreseeable future, thus these risks have been reduced since the time of listing. However, unfavorable environmental trends previously identified (Ford et al. 2011a) were expected to continue (Hard et al. 2015).

In this Opinion, where possible, the 2015 status review information is supplemented with information and other population specific data available considered during the drafting of the 2020 five-year status review for PS steelhead.

On December 27, 2019, we published a recovery plan for PS steelhead (84 FR 71379) (NMFS 2019a). The Puget Sound steelhead Recovery Plan (Plan) (NMFS 2019a) provides guidance to recover the species to the point that it can be naturally self-sustaining over the long term. To achieve full recovery, steelhead populations in Puget Sound need to be robust enough to withstand natural environmental variation and some catastrophic events, and they should be resilient enough to support harvest and habitat loss due to human population growth. The Plan aims to improve steelhead viability by addressing the pressures that contribute to the current condition: habitat loss/degradation, water withdrawals, declining water quality, fish passage barriers, dam operations, harvest, hatcheries, climate change effects, and reduced early marine survival. NMFS is using the recovery plan to organize and coordinate recovery of the species in partnership with state, local, tribal, and federal resource managers, and the many watershed restoration partners in the Puget Sound. Consultations, including this one, will incorporate information from the Plan (NMFS 2019a).

In the Plan, NMFS and the PSSTRT modified the 2013 and 2015 PSSTRT viability criteria to produce the viability criteria for PS steelhead, as described below:

- All three MPGs (North Cascade, Central-South Puget Sound, and Hood Canal-Strait of Juan de Fuca) (Figure 5) must be viable (Hard et al. 2015). The three MPGs differ substantially in key biological and habitat characteristics that contribute in distinct ways to the overall viability, diversity, and spatial structure of the DPS.
- There must be sufficient data available for NMFS to determine that each MPG is viable.

The Plan (NMFS 2019h) also established MPG-level viability criteria. The following are specific criteria are required for MPG viability:

- At least 50 percent of steelhead populations in the MPG achieve viability.

- Natural production of steelhead from tributaries to Puget Sound that are not identified in any of the 32 identified populations provides sufficient ecological diversity and productivity to support DPS-wide recovery.
- In addition to the minimum number of viable DIPs (50 percent) required above, all DIPs in the MPG must achieve an average MPG-level viability that is equivalent to or greater than the geometric mean (averaged over all the DIPs in the MPG) viability score of at least 2.2 using the 1–3 scale for individual DIPs described under the DIP viability discussion in the PSSTRT Viability Criteria document (Hard et al. 2015). This criterion is intended to ensure that MPG viability is not measured (and achieved) solely by the strongest DIPs, but also by other populations that are sufficiently healthy to achieve MPG-wide resilience. The Plan allows for an alternative evaluation method to that in Hard et al. (2015) may be developed and used to assess MPG viability.

The Plan (NMFS 2019h) also identified specific DIPs in each of the three MPGs which must attain viability. These DIPs, by MPG, are described as follows:

For the **North Cascades MPG** eight of the sixteen DIPs in the North Cascades MPG must be viable. The eight (five winter-run and three summer-run) DIPs described below must be viable to meet this criterion:

- Of the eleven DIPs with winter or winter/summer runs, five must be viable:
- Nooksack River Winter-Run;
- Stillaguamish River Winter-Run;
- One from the Skagit River (either the Skagit River Summer-Run and Winter-Run or the Sauk River Summer-Run and Winter-Run);
- One from the Snohomish River watershed (Pilchuck, Snoqualmie, or Snohomish/Skykomish River Winter-Run); and
- One other winter or summer/winter run from the MPG at large.

The rationale for this is that there are four major watersheds in this MPG, and one viable population from each will help attain geographic spread and habitat diversity within core extant steelhead habitat (NMFS 2019h). Of the five summer-run DIPs in this MPG, three must be viable, representing each of the three major watersheds containing summer-run populations (Nooksack, Stillaguamish, Snohomish rivers). Therefore, the priority summer-run populations are as follows:

- South Fork Nooksack River Summer-Run;
- One DIP from the Stillaguamish River (Deer Creek Summer-Run or Canyon Creek Summer-Run); and
- One DIP from the Snohomish River (Tolt River Summer-Run or North Fork Skykomish River Summer-Run).

As described, these priority populations in the North Cascades MPG include specific, winter or winter/summer-run populations from the Nooksack, Stillaguamish, Skagit or Sauk, and Snohomish River basins and three summer-run populations from the Nooksack, Stillaguamish, and Snohomish basins. These populations are targeted to achieve viable status to support MPG viability. Having viable populations in these basins assures geographic spread, provides habitat diversity, reduces catastrophic risk, and increases life-history diversity (NMFS 2019h).

For the **Central and South Puget Sound MPG** four of the eight DIPs in the Central and South Puget Sound MPG must be viable. The four DIPs described below must be viable to meet this criterion:

- Green River Winter-Run;
- Nisqually River Winter-Run;
- Puyallup/Carbon rivers Winter-Run, or the White River Winter-Run; and
- At least one additional DIP from this MPG: Cedar River, North Lake Washington/Sammamish Tributaries, South Puget Sound Tributaries, or East Kitsap Peninsula Tributaries.

The rationale for this prioritization is that steelhead inhabiting the Green, Puyallup, and Nisqually River watersheds currently represent the core extant steelhead populations and these watersheds contain important diversity of stream habitats in the MPG.

For the **Hood Canal and Strait of Juan de Fuca MPG** four of the eight DIPs in the Hood Canal and Strait of Juan de Fuca MPG must be viable. The four DIPs described below must be viable to meet this criterion:

- Elwha River Winter/Summer-Run (see rationale below);
- Skokomish River Winter-Run;
- One from the remaining Hood Canal populations: West Hood Canal Tributaries Winter-Run, East Hood Canal Tributaries Winter-Run, or South Hood Canal Tributaries Winter-Run; and
- One from the remaining Strait of Juan de Fuca populations: Dungeness Winter-Run, Strait of Juan de Fuca Tributaries Winter-Run, or Sequim/Discovery Bay Tributaries Winter-Run.

The rationale for this prioritization is that the Elwha and Skokomish rivers are the two largest single watersheds in the MPG and bracket the geographic extent of the MPG. Furthermore, both Elwha and Skokomish populations have recently exhibited summer-run life histories, although the Dungeness River population was the only summer/winter run in this MPG recognized by the PSSTRT in Hard et al. (2015). Two additional populations, one population from the Strait of Juan de Fuca area and one population from the Hood Canal area, are needed for a viable MPG to maximize geographic spread and habitat diversity.

Lastly, the Plan (NMFS 2019h) also identified additional attributes, or characteristics which should be associated with a viable MPG:

- All major diversity and spatial structure conditions are represented, based on the following considerations:
- Populations are distributed geographically throughout each MPG to reduce risk of catastrophic extirpation; and

- Diverse habitat types are present within each MPG (one example is lower elevation/gradient watersheds characterized by a rain-dominated hydrograph and higher elevation/gradient watersheds characterized by a snow-influenced hydrograph).

Federal and state steelhead recovery and management efforts will provide new tools and data and technical analyses to further refine PS steelhead population structure and viability, if needed, and better define the role of individual populations at the watershed level and in the DPS. Future consultations will incorporate information from the Plan (NMFS 2019h).

Spatial Structure and Diversity: The PS steelhead DPS is the anadromous form of O. mykiss that occur in rivers, below natural barriers to migration, in northwestern Washington State that drain to Puget Sound, Hood Canal, and the Strait of Juan de Fuca between the U.S./Canada border and the Elwha River, inclusive. Non-anadromous ‘‘resident’’ *O. mykiss* occur within the range of PS steelhead but are not part of the DPS due to marked differences in physical, physiological, ecological, and behavioral characteristics (Hard et al. 2007). In October of 2016, NMFS proposed revisions to the hatchery programs included as part of Pacific salmon ESUs and steelhead DPSs listed under the ESA (81 FR 72759). NMFS issued its final rule in December of 2020 (85 FR 81822). This final rule includes steelhead from five artificial propagation programs in the PS steelhead DPS: the Green River Natural Program; White River Winter Steelhead Supplementation Program; Hood Canal Steelhead Supplementation Program; the Lower Elwha Fish Hatchery Wild Steelhead Recovery Program; and the Fish Restoration Facility Program. (85 FR 81822, December 17, 2020).

In 2013, the PSSTRT completed its evaluation of factors that influence the diversity and spatial structure VSP criteria for steelhead in the DPS. For spatial structure, this included the fraction of available intrinsic potential rearing and spawning habitat that is occupied compared to what is needed for viability[9]. For diversity, these factors included hatchery fish production, contribution of resident fish to anadromous fish production, and run timing of adult steelhead. Quantitative information on spatial structure and connectivity was not available for most PS steelhead populations, so a Bayesian Network framework was used to assess the influence of these factors on steelhead viability at the population, MPG, and DPS scales. The PSSTRT concluded that low population viability was widespread throughout the DPS and populations showed evidence of diminished spatial structure and diversity. Specifically, population viability associated with spatial structure and diversity was highest in the Northern Cascades MPG and lowest in the Central and South Puget Sound MPG (Puget Sound Steelhead Technical Recovery Team 2011). Diversity was generally higher for populations within the Northern Cascades MPG, where more variability in viability was expressed and diversity generally higher, compared to populations in both the Central and South Puget Sound and Hood Canal and Strait of Juan de Fuca MPG, where diversity was depressed and viabilities were generally lower (NWFSC 2015). Most PS steelhead populations were given intermediate scores for spatial structure and low scores for diversity because of extensive hatchery influence, low breeding population sizes, and freshwater habitat fragmentation or loss (NWFSC 2015). The PSSTRT concluded that the Puget Sound DPS was at very low viability, considering the status of all three of its constituent MPGs, and many of its 32 DIPs (Hard et al. 2015). For spatial structure there were a number of events that occurred in

[9] Where intrinsic potential is the area of habitat suitable for steelhead rearing and spawning, at least under historical conditions (Puget Sound Steelhead Technical Recovery Team 2011; PSSTRT 2013).

Puget Sound during the last review period (2015-2019) that are anticipated to improve status populations within several of the MPGs within the DPS.

Since the PSSTRT completed its 2013 review, the only additional spatial structure and diversity data that have become available have been estimates of the fraction of hatchery fish on the spawning grounds (NWFSC 2015). Since publication of the NWFSC report in 2015, reductions in hatchery programs founded from non-listed and out of DPS stocks (i.e., Skamania) have occurred. In addition, the fraction of out of DPS hatchery steelhead spawning naturally are low for many rivers (NWFSC 2015; NMFS 2016i; 2016h). The fraction of natural-origin steelhead spawners was 0.9 or greater for the 2005-2009 and 2010-2014 time periods for all populations where data was available, but the Snoqualmie and Stillaguamish Rivers. For 17 of 22 DIPs across the DPS, the five-year average for the fraction of natural-origin steelhead spawners exceeded 0.75 from 2005 to 2009; this average was near 1.0 for 8 populations, where data were available, from 2010 to 2014 (NWFSC 2015). However, the fraction of natural-origin steelhead spawners could not be estimated for a substantial number of DIPs during the 2010 to 2014 period, or for the most recent 2015 – 2019 timeframe (NWFSC 2015; 2020). In some river systems, such as the Green River, Snohomish/Skykomish Rivers, and the Stillaguamish Rivers these estimates were higher than some guidelines recommend (e.g., no more than 5percent hatchery-origin spawners on spawning grounds for isolated hatchery programs (HSRG 2009) over the 2005-2009 and 2010-2014 timeframes. The draft NWFSC viability risk assessment (Ford, 2022) states that a third of the 32 PS steelhead populations continue to lack monitoring and abundance data, and in most cases, it is likely that abundances are very low.

Early winter-run fish produced in isolated hatchery programs are derived from Chambers Creek stock in southern Puget Sound, which has been selected for early spawn timing, a trait known to be inheritable in salmonids.[10] Summer-run fish produced in isolated hatchery programs were historically derived from the Skamania River summer stock in the lower Columbia River Basin (i.e., from outside the DPS). The production and release of hatchery fish of both run types (winter and summer) may continue to pose risk to diversity in natural-origin steelhead in the DPS, as described in Hard et al. (2007) and Hard et al. (2015). However, the draft NWFSC viability risk assessment (Ford, 2022) states that risks to natural-origin PS steelhead that may be attributable to hatchery-related effects has decreased since the 2015 status review due to reductions in production of non-listed stocks, and the replacement with localized stocks. The three summer steelhead programs continuing to propagate Skamania derived stocks from outside of Puget Sound should be phased out completely by 2031 (NMFS 2019c; Ford, 2022). Lastly, annual reporting from the operators and current science suggest that risks remain at the same low to negligible levels as evaluated in 2016 and 2019 (NMFS 2016b; 2019c; 2019g; 2019h).

More information on PS steelhead spatial structure and diversity can be found in NMFS's PSSTRT viability report and NMFS's status review update on salmon and steelhead (NWFSC 2015) and recent viability risk assessment (Ford, 2022).

Abundance and Productivity: The viability of the PS steelhead DPS has improved somewhat since the Puget Sound Steelhead TRT concluded that the DPS was at very low viability, as were all three of its constituent MPGs, and many of its 32 DIPs (Hard et al. 2015). Increases in

[10] The native-origin Chambers Creek steelhead stock is now extinct.

spawner abundance have been observed in a number of populations over the last five years; however, these improvements were disproportionately found within the South and Central Puget Sound and Strait of Juan de Fuca and Hood Canal MPGs, and primarily among smaller populations. The recent positive trends among winter-run populations in the White, Nisqually, and Skokomish rivers improve the demographic risks facing those populations. The abundance, productivity, spatial structure, and diversity of Elwha River steelhead winter and summer-runs has dramatically improved following the removal of the Elwha River dams improved. Improvements in abundance have not been as widely observed in the Northern Puget Sound MPG. The declines of summer and winter-run populations in the Snohomish Basin are especially concerning. These populations figure prominently as sources of abundance for the MPG and DPS (NMFS 2019a). Additionally, the decline in the Tolt River summer-run steelhead population was especially alarming given that it is the only summer-run population for which we have abundance estimates. The demographic and diversity risks to the Tolt River summer-run DIP are very high. In fact, all summer-run steelhead populations in the North Cascades MPG are likely at a very high demographic risk. In spite of improvements in some areas, most populations are still at relatively low abundance levels, with about a third of the DIPs unmonitored and presumably at very low levels (Ford, 2022).

As described in the recovery plan, recovery targets were calculated using a two-tiered approach adjusting for years of low and high productivity (NMFS 2019a). Abundance information is unavailable for approximately one-third of the DIPs, disproportionately so for summer-run populations. In most cases where no information is available it is assumed that abundances are very low. Some population abundance estimates are only representative of part of the population (index reaches, etc.). Where recent five-year abundance information is available, 30 percent (6 of 20 populations) are less than 10 percent of their high productivity recovery targets (lower abundance target), 65 percent (13 of 20) are between 10 and 50 percent, and 5 percent (1 of 20) are greater than 50 percent of their low abundance targets (Table 6). A key element to achieving recovery is recovering a representative number of both winter- and summer-run steelhead populations, and the restoration of viable summer-run DIPs is a long-term endeavor (NMFS 2019a). Fortunately, the relatively rapid reestablishment of summer-run steelhead in the Elwha River does provide a model for potentially re-anadromizing summer-run steelhead sequestered behind impassable dams.

Table 6. Recent (2015-2019) 5-year geometric mean of raw wild spawner counts for Puget Sound steelhead populations and population groups compared with Puget Sound Steelhead Recovery Plan high and low productivity recovery targets (NMFS 2019). (SR) – Summer-run. Abundance is compared to the high productivity individual DIP targets. Colors indicate the relative proportion of the recovery target currently obtained: red (<10%), orange (10%>x<50%), yellow (50%>x<100%), green (>100%). "*" denotes an interim recovery target.

Major Population Group	Demographically Independent Population	Abundance (2015-2019)	Recovery Target	
			High Productivity	Low Productivity
Northern Cascades	Drayton Harbor Tributaries	N/A	1,100	3,700
	Nooksack River	1,906	6,500	21,700
	South Fork Nooksack River (SR)	N/A	400	1,300
	Samish River & Independent Tributaries	1,305	1,800	6,100
	Skagit River	7,181	15,000 *	
	Sauk River	N/A		
	Nookachamps River	N/A		
	Baker River	N/A		
	Stillaguamish River	487	7,000	23,400
	Canyon Creek (SR)	N/A	100	400
	Deer Creek (SR)	N/A	700	2,300
	Snohomish/Skykomish River	690	6,100	20,600
	Pilchuck River	638	2,500	8,200
	Snoqualmie River	500	3,400	11,400
	Tolt River (SR)	40	300	1,200
	North Fork Skykomish River (SR)	N/A	200	500
Central and South Sound	Cedar River	N/A	1,200	4,000
	North Lake Washington Tributaries	N/A	4,800	16,000
	Green River	1,282	5,600	18,700
	Puyallup/Carbon River	136	4,500	15,100
	White River	130	3,600	12,000
	Nisqually River	1,368	6,100	20,500
	East Kitsap Tributaries	N/A	2,600	8,700
	South Sound Tributaries	N/A	6,300	21,200
Strait of Juan de Fuca	Elwha River	1,241	2,619	
	Dungeness River	408	1,200	4,100
	Strait of Juan de Fuca Independent Tributaries	95	1,000	3,300
	Sequim and Discovery Bay Tributaries	N/A	500	1,700
	Skokomish River	958	2,200	7,300
	West Hood Canal Tributaries	150	2,500	8,400
	East Hood Canal Tributaries	93	1,800	6,200
	South Hook Canal Tributaries	91	2,100	7,100

There are a number of planned, ongoing, and completed actions that will likely benefit steelhead populations in the near term, but have not yet influenced adult abundance. Among these, the removal of the diversion dam on the Middle Fork Nooksack River, the Pilchuck Dam removal, passage improvements at Mud Mountain Dam, the ongoing passage program in the North Fork Skokomish River, and the planned passage program at Howard Hanson Dam. Dam removal in the Elwha River, and the resurgence of the endemic winter and summer-run steelhead populations have underscored the benefits of restoring fish passage. The Elwha River scenario is somewhat unique in that upstream habitat is in pristine condition and smolts emigrate into the Strait of Juan de Fuca and not Puget Sound or Hood Canal.

Improvements in spatial structure can only be effective if done in concert with necessary improvements in habitat. Habitat restoration efforts are ongoing, but land development and habitat degradation concurrent with increasing human population in the Puget Sound corridor may results in a continuing net loss of habitat. Recovery efforts in conjunction with improved ocean and climatic conditions have resulted in improved viability status for the majority of populations in this DPS; however, absolute abundances are still low, especially summer-run populations, and the DPS remains at high to moderate risk of extinction. However, since 2015, fifteen of the 21 populations indicate small to substantive increases in abundance.[11] Nevertheless, most steelhead populations remain small. From 2015 to 2019, nine of the 21 steelhead populations had fewer than 250 natural spawners annually, and 12 of the 21 steelhead populations had 500 or fewer natural spawners (Table 7).

[11] Nooksack River, Samish River/Bellingham Bays Tributaries, Skagit River, Stillaguamish River, Pilchuck River, Cedar River, Green River, Puyallup River, Nisqually River, White River, S. Hood Canal, Eastside Hood Canal Tributaries, Westside Hood Canal Tributaries, Skokomish River and Elwha River winter-run populations. The Skagit River and Elwha River summer-run steelhead are also showing increasing trends (Ford 2022).

Table 7. Five-year geometric mean of raw natural spawner counts for Puget Sound steelhead. This is the raw total spawner count times the fraction natural estimate, if available. Percent change between the most recent two 5-year periods is shown on the far right. (W=winter run; S=summer run).

Biogeographic Region	Population	2010-2014	2015-2019	Population trend (% Change)
North Cascades	Samish R./ Bellingham Bay Tribs. (W)	748	1305	Positive (74)
	Nooksack R. (W)	1745	1906	Positive (9)
	Skagit R. (S and W)	6391	7181	Positive (12)
	Stillaguamish R. (W)	386	487	Positive (26)
	Snohomish/ Skykomish R. (W)	975	690	Negative (-29)
	Pilchuck R. (W)	626	638	Positive (2)
	Snoqualmie R. (W)	706	500	Negative (-29)
	Tolt R. (S)	108	40	Negative (-63)
Central/South Puget Sound Basin	N. Lake WA Tribs. (W)	-	-	-
	Cedar R. (W)	4	6	Positive (50)
	Green R. (W)	662	1289	Positive (95)
	White R. (W)	514	451	Negative (-12)
	Puyallup R. (W)	85	201	Positive (136)
	Carbon R. (W)	(290)	(735)	Positive (153)
	Nisqually R. (W)	477	1368	Positive (187)
Hood Canal/Strait of Juan de Fuca	S. Hood Canal (W)	69	91	Positive (32)
	Eastside Hood Canal Tribs (W)	60	93	Positive (55)
	Skokomish R. (W)	533	958	Positive (80)
	Westside Hood Canal Tribs (W)	138	150	Positive (9)
	Dungeness R. (S and W)	517	448	Negative (-13)
	Strait of Juan de Fuca Independents (W)	151	95	Negative (-37)
	Elwha R. (W)	680	1241	Positive (82)

Limiting factors. In our 2013 proposed rule designating critical habitat for this species (USDC

- The continued destruction and modification of steelhead habitat
- Widespread declines in adult abundance (total run size), despite significant reductions in harvest in recent years

- Threats to diversity posed by use of two hatchery steelhead stocks (Chambers Creek and Skamania)
- Declining diversity in the DPS, including the uncertain but weak status of summer run fish
- A reduction in spatial structure
- Reduced habitat quality through changes in river hydrology, temperature profile, downstream gravel recruitment, and reduced movement of large woody debris
- In the lower reaches of many rivers and their tributaries in Puget Sound where urban development has occurred, increased flood frequency and peak flows during storms and reduced groundwater-driven summer flows, with resultant gravel scour, bank erosion, and sediment deposition
- Dikes, hardening of banks with riprap, and channelization, which have reduced river braiding and sinuosity, increasing the likelihood of gravel scour and dislocation of rearing juveniles

PS steelhead Recovery Plan: Juvenile Puget Sound steelhead are less dependent on nearshore habitats for early marine rearing than Chinook or Chum salmon; nevertheless, nearshore, estuarine, and shoreline habitats provide important features necessary for the recovery of steelhead. Puget Sound steelhead spend only a few days to a few weeks migrating through the large fjord, but mortality rates during this life stage are critically high (Moore et al. 2010; Moore and Berejikian 2017). Early marine mortality of Puget Sound steelhead is recognized as a primary limitation to the species' survival and recovery (NMFS 2019a). Factors in the marine environment influencing steelhead survival include predation, access to prey (primarily forage fish), contaminants (toxics), disease and parasites, migration obstructions (e.g., the Hood Canal bridge), and degraded habitat conditions which exacerbate these factors.

The PS steelhead recovery plan identifies ten ecological concerns that directly impact salmon and steelhead:

- Habitat quantity (anthropogenic barriers, natural barriers, competition);
- Injury and mortality (predation, pathogens, mechanical injury, contaminated food);
- Food (altered primary productivity, food-competition, altered prey species composition and diversity);
- Riparian condition (riparian condition, large wood recruitment);
- Peripheral and transitional habitats (side channel and wetland condition, estuary conditions, nearshore conditions);
- Channel structure and form (bed and channel form, instream structural complexity);
- Sediment conditions (decreased sediment quantity, increased sediment quantity);
- Water quality (temperature, oxygen, gas saturation, turbidity, pH, salinity, toxic contaminants);
- Water quantity (increased water quality, decreased water quality, altered flow timing); and
- Population-level effects (reduced genetic adaptiveness, small population effects, demographic changes, life history changes).

The Puget Sound steelhead recovery plan and its associated appendix 3 includes specific recovery actions for the marine environment. General protection and restoration actions summarized from the plan include:

- Continue to improve the assessments of harbor seal predation rates on juvenile steelhead;
- Remove docks and floats which act as artificial haul-out sites for seals and sea lions;
- Consistent with the MMPA, test acoustic deterrents and other hazing techniques to reduce steelhead predation from harbor seals;
- Develop non-lethal actions for "problem animals and locations" to deter predation;
- Increase forage fish habitat to increase abundance of steelhead prey;
- Remove bulkheads and other shoreline armoring to increase forage fish;
- Acquire important forage fish habitat to protect high forage fish production areas;
- Add beach wrack to increase forage fish egg survival;
- Protect and restore aquatic vegetation (e.g., eelgrass and kelp);
- Remove creosote pilings to reduce mortality of herring eggs;
- Increase the assessment of migratory blockages, especially the Hood Canal bridge, where differential mortality has been documented;
- Identify and remedy sources of watershed chemical contaminants (e.g., PBDEs and PCBs).

2.2.2. Status of Critical Habitat

This section examines the status of designated critical habitat affected by the proposed action by examining the condition and trends of essential physical and biological features throughout the designated areas. These features are essential to the conservation of the listed species because they support one or more of the species' life stages (*e.g*., sites with conditions that support spawning, rearing, migration and foraging).

For salmon and steelhead, NMFS ranked watersheds within designated critical habitat at the scale of the fifth-field hydrologic unit code (HUC5) in terms of the conservation value they provide to each listed species they support. The conservation rankings are high, medium, or low. To determine the conservation value of each watershed to species viability, NMFS's critical habitat analytical review teams (CHARTs) evaluated the quantity and quality of habitat features (for example, spawning gravels, wood and water condition, side channels), the relationship of the area compared to other areas within the species' range, and the significance to the species of the population occupying that area (NOAA Fisheries 2005). Thus, even a location that has poor quality of habitat could be ranked with a high conservation value if it were essential due to factors such as limited availability (e.g., one of a very few spawning areas), a unique contribution of the population it served (e.g., a population at the extreme end of geographic distribution), or if it serves another important role (e.g., obligate area for migration to upstream spawning areas).

The physical or biological features of nearshore marine areas that would be affected by the proposed action include, ample forage, areas free of artificial obstructions, sufficient natural cover, and adequate water quality and quantity to support adult growth, sexual maturation, and migration as well as nearshore juvenile rearing. These features are essential to conservation because they allow adult fish to swim upstream to reach spawning areas and they allow juvenile fish to grow and mature before migrating to the ocean.

CHART Salmon and Steelhead Critical Habitat Assessments: The CHART for each recovery domain assessed biological information pertaining to occupied habitat by listed salmon and steelhead, determine whether those areas contained PCEs essential for the conservation of those species and whether unoccupied areas existed within the historical range of the listed salmon and steelhead that are also essential for conservation. The CHARTs assigned a 0- to 3-point score for the PCEs in each HUC5 watershed for:

- Factor 1: Quantity,
- Factor 2: Quality—Current Condition,
- Factor 3: Quality—Potential Condition,
- Factor 4: Support of Rarity Importance,
- Factor 5: Support of Abundant Populations, and
- Factor 6: Support of Spawning/Rearing.

Thus, the quality of habitat in a given watershed was characterized by the scores for Factor 2 (quality—current condition), which considers the existing condition of the quality of PCEs in the HUC5 watershed; and Factor 3 (quality—potential condition), which considers the likelihood of achieving PCE potential in the HUC5 watershed, either naturally or through active conservation/restoration, given known limiting factors, likely biophysical responses, and feasibility.

Puget Sound Recovery Domain: Critical habitat has been designated in Puget Sound for PS Chinook salmon, PS steelhead, and HCSR chum salmon (HCSRC). Major tributary river basins in the Puget Sound basin include the Nooksack, Samish, Skagit, Sauk, Stillaguamish, Snohomish, Lake Washington, Cedar, Sammamish, Green, Duwamish, Puyallup, White, Carbon, Nisqually, Deschutes, Skokomish, Duckabush, Dosewallips, Big Quilcene, Elwha, and Dungeness rivers and Soos Creek.

Critical habitat for PS Chinook salmon was designated on September 2, 2005 (70 FR 52630). Critical habitat includes 1,683 miles of streams, 41 square mile of lakes, and 2,182 miles of nearshore marine habitat in Puget Sounds. The Puget Sound Chinook salmon ESU has 61 freshwater and 19 marine areas within its range. Of the freshwater watersheds, 41 are rated high conservation value, 12 low conservation value, and eight received a medium rating. Of the marine areas, all 19 are ranked with high conservation value.

Critical habitat for PS steelhead was designated on February 24, 2016 (81 FR 9252). Critical habitat includes 2,031 stream miles. Nearshore and offshore marine waters were not designated for this species. There are 66 watersheds within the range of this DPS. Nine watersheds received a low conservation value rating, 16 received a medium rating, and 41 received a high rating to the DPS. Critical habitat for PS steelhead includes freshwater spawning sites, freshwater rearing sites, and freshwater migration corridors.

Critical habitat is designated for PS Chinook salmon in estuarine and nearshore areas. Designated critical habitat for PS steelhead does not include nearshore areas, as this species does not make extensive use of these areas during juvenile life stage.

The following discussion is general to salmon and steelhead critical habitat in the Puget Sound basin. More specific information for each individual species' critical habitat is presented after the general discussion.

Landslides can occur naturally in steep, forested lands, but inappropriate land use practices likely have accelerated their frequency and the amount of sediment delivered to streams. Fine sediment from unpaved roads has also contributed to stream sedimentation. Unpaved roads are widespread on forested lands in the Puget Sound basin, and to a lesser extent, in rural residential areas. Historical logging removed most of the riparian trees near stream channels. Subsequent agricultural and urban conversion permanently altered riparian vegetation in the river valleys, leaving either no trees, or a thin band of trees. The riparian zones along many agricultural areas are now dominated by alder, invasive canary grass and blackberries, and provide substantially reduced stream shade and large wood recruitment (SSPS 2007).

Diking, agriculture, revetments, railroads and roads in lower stream reaches have caused significant loss of secondary channels in major valley floodplains in this region. Confined main channels create high-energy peak flows that remove smaller substrate particles and large wood. The loss of side-channels, oxbow lakes, and backwater habitats has resulted in a significant loss of juvenile salmonid rearing and refuge habitat. When the water level of Lake Washington was lowered 9 feet in the 1910s, thousands of acres of wetlands along the shoreline of Lake Washington, Lake Sammamish and the Sammamish River corridor were drained and converted to agricultural and urban uses. Wetlands play an important role in hydrologic processes, as they store water that ameliorates high and low flows. The interchange of surface and groundwater in complex stream and wetland systems helps to moderate stream temperatures. Forest wetlands are estimated to have diminished by one-third in Washington State (FEMAT 1993; Spence et al. 1996; SSPS 2007).

Loss of riparian habitat, elevated water temperatures, elevated levels of nutrients, increased nitrogen and phosphorus, and higher levels of turbidity, presumably from urban and highway runoff, wastewater treatment, failing septic systems, and agriculture or livestock impacts, have been documented in many Puget Sound tributaries (SSPS 2007).

Peak stream flows have increased over time due to paving (roads and parking areas), reduced percolation through surface soils on residential and agricultural lands, simplified and extended drainage networks, loss of wetlands, and rain-on-snow events in higher elevation clear cuts (SSPS 2007). In urbanized Puget Sound, there is a strong association between land use and land cover attributes and rates of coho spawner mortality likely due to runoff containing contaminants emitted from motor vehicles (Feist et al. 1996)., Recent studies have shown that coho salmon show high rates of pre-spawning mortality when exposed to chemicals that leach from tires (McIntyre et al. 2015). Researchers have recently identified a tire rubber antioxidant as the cause (Tian et al. 2020). Although Chinook salmon did not experience the same level of mortality, tire leachate is still a concern for all salmonids. Traffic residue also contains many unregulated toxic chemicals such as pharmaceuticals, polycyclic aromatic hydrocarbons (PAHs), fire retardants, and emissions that have been linked to deformities, injury and/or death of salmonids and other fish (Trudeau 2017; Young et al. 2018).

Urban stormwater is commonly a major contributing factor to water quality impairments throughout Washington (EPA 2020). Urban development alters the natural infiltration of vegetation and soil, and generates or collects many diverse pollutants that accumulate on impervious surfaces and compacted and poor soils. Precipitation runs off these surfaces and is quickly drained through a system of conveyances into streams, rivers, and lakes. The hydrologic effects of these alterations and climate change increase erosion and streambank scouring, downstream sedimentation and flooding, and channel simplifications, which can affect aquatic life (Jorgensen et al. 2013; Jonsson et al. 2017).

Dams constructed for hydropower generation, irrigation, or flood control have substantially affected PS salmon and steelhead populations in a number of river systems. The construction and operation of dams have blocked access to spawning and rearing habitat (e.g., Elwha River dams block anadromous fish access to 70 miles of potential habitat) changed flow patterns, resulted in elevated temperatures and stranding of juvenile migrants, and degraded downstream spawning and rearing habitat by reducing recruitment of spawning gravel and large wood to downstream areas (SSPS 2007). These actions tend to promote downstream channel incision and simplification (Kondolf 1997), limiting fish habitat. Water withdrawals reduce available fish habitat and alter sediment transport. Hydropower projects often change flow rates, stranding and killing fish, and reducing aquatic invertebrate (food source) productivity (Hunter 1992).

Juvenile mortality occurs in unscreened or inadequately screened diversions. Water diversion ditches resemble side channels in which juvenile salmonids normally find refuge. When diversion head gates are shut, access back to the main channel is cut off and the channel goes dry. Mortality can also occur with inadequately screened diversions from impingement on the screen, or mutilation in pumps where gaps or oversized screen openings allow juveniles to get into the system (WDFW 2009). Blockages by dams, water diversions, and shifts in flow regime due to hydroelectric development and flood control projects are major habitat problems in many Puget Sound tributary basins (SSPS 2007).

The nearshore marine habitat has been extensively altered and armored by industrial and residential development near the mouths of many of Puget Sound's tributaries. A railroad runs along large portions of the eastern shoreline of Puget Sound, eliminating natural cover along the shore and natural recruitment of beach sand (SSPS 2007).

Degradation of the near-shore environment has occurred in the southeastern areas of Hood Canal in recent years, resulting in late summer marine oxygen depletion and significant fish kills. Circulation of marine waters is naturally limited, and partially driven by freshwater runoff, which is often low in the late summer. However, human development has increased nutrient loads from failing septic systems along the shoreline, and from use of nitrate and phosphate fertilizers on lawns and farms. Shoreline residential development is widespread and dense in many places. The combination of highways and dense residential development has degraded certain physical and chemical characteristics of the near-shore environment (HCCC 2005; SSPS 2007).

In summary, critical habitat for salmon and steelhead throughout the Puget Sound basin has been degraded by numerous management activities, including hydropower development, loss of mature riparian forests, increased sediment inputs, removal of large wood, intense urbanization, agriculture, alteration of floodplain and stream morphology (i.e., channel modifications and diking), riparian vegetation disturbance, wetland draining and conversion, dredging, armoring of shorelines, marina and port development, road and railroad construction and maintenance, logging, and mining. Changes in habitat quantity, availability, and diversity, and flow, temperature, sediment load and channel instability are common limiting factors in areas of critical habitat. As mentioned above, development of shoreline and estuary areas of Puget Sound is expected to continue to adversely impact the quality of marine habitat for PS salmonids. Projected changes in nearshore and estuary development based on documented rates of developed land cover change in Bartz et al. (2015) show that between 2008 and 2060, an additional 14.7 hectares of development of shoreline areas and 204 hectares of estuary development can be expected.

The PS recovery domain CHART for PS Chinook salmon (NOAA Fisheries 2005) determined that only a few watersheds with PCEs for Chinook salmon in the Whidbey Basin (Skagit River/Gorge Lake, Cascade River, Upper Sauk River, and the Tye and Beckler rivers) are in good-to-excellent condition with no potential for improvement. Most HUC5 watersheds are in fair-to-poor or fair-to-good condition. However, many of these watersheds have some or a high potential for improvement.

As discussed in the Section 2.2.1, the abundance of Chinook salmon in recent years is significantly less than historic abundance due to a number of human activities. The most notable human activities that cause adverse effects on ESA-listed and non-ESA-listed salmon include: land use activities that result in habitat loss and degradation, hatchery practices, harvest and hydropower systems.

As mentioned previously, numerous factors have led to the decline of PS Chinook salmon including overharvest, freshwater and marine habitat loss, hydropower development, and hatchery practices, as mentioned in Section 2.2.1, above. Adjustments can, and have been made in the short term to ameliorate some of the factors for decline. Harvest can be adjusted on yearly or even in-season basis. Since PS Chinook salmon were listed, harvest in state and federal fisheries has been reduced in an effort to increase the number of adults returning to spawning grounds. Likewise, hatchery management can, and has been adjusted relatively quickly when practices are detrimental to listed species. To address needed improvements in hydropower, NMFS has issued biological opinions with reasonable and prudent alternatives to improve fish passage at existing hydropower facilities. Unlike the other factors, however, loss of critical habitat quality is much more difficult to address in the short term. Once human development causes loss of critical habitat quality, that loss tends to persist for decades or longer. The condition of critical habitat will improve only through active restoration or natural recovery following the removal of human infrastructure. As noted throughout this Opinion, future effects of climate change on habitat quality throughout Puget Sound are expected to be negative.

Habitat utilization by Chinook salmon and steelhead in the Puget Sound area has been historically limited by large dams and other manmade barriers in a number of drainages, including the Nooksack, Skagit, White, Nisqually, Skokomish, and Elwha river basins (Appendix B in NMFS (2015a)). In addition to limiting habitat accessibility, dams affect habitat quality through changes in river hydrology, altered temperature profile, reduced downstream gravel recruitment, and the reduced recruitment of large woody debris. Such changes can have significant negative impacts on salmonids (e.g., increased water temperatures resulting in decreased disease resistance) (Spence et al. 1996; McCullough 1999). However, over the past several years modifications have occurred to existing barriers, which have reduced the number of basins with limited anadromous access to historical habitat. The completion of the Elwha and Glines Canyon Dam removals occurred in 2014. The response of fish populations to this action is still being evaluated. It is clear; however, that Chinook salmon and steelhead are accessing much of this newly available habitat. Passage operations have begun on the North Fork Skokomish River to reintroduce steelhead above Cushman Dam, although juvenile collection efficiency is still relatively low, and further improvements are anticipated. Similarly, improvements in the adult fish collection facility at Mud Mountain Dam (White River basin) are near completion, with the expectation that improvements in adult survival will facilitate better utilization of habitat above the dam (NMFS 2014b). The recent removal of the diversion dam on the Middle Fork Nooksack Dam (16 July 2020) and the Pilchuck River Dam (late 2020) will provide access to important headwater salmonid spawning and rearing habitats. Similarly, the proposed modification of Howard Hanson Dam for upstream fish passage and downstream juvenile collection in the longer term (NMFS 2019f) will allow winter steelhead to return to historical habitat (Ford, 2022).

2.3. Environmental Baseline

The "environmental baseline" refers to the condition of the listed species or its designated critical habitat in the action area, without the consequences to the listed species or designated critical habitat caused by the proposed action. The environmental baseline includes the past and present impacts of all Federal, State, or private actions and other human activities in the action area, the anticipated impacts of all proposed Federal projects in the action area that have already undergone formal or early section 7 consultations, and the impact of State or private actions which are contemporaneous with the consultation in process. The consequences to listed species or designated critical habitat from ongoing agency activities or existing agency facilities that are not within the agency's discretion to modify are part of the environmental baseline (50 CFR 402.02).

The action area includes areas downstream of the proposed action based on the effects associated with stormwater discharge. The action area is located in the Lower Green River subbasin (WRIA 9) and the environmental baseline is influenced by upriver and upland activities. The Green River originates at Howard Hanson Dam and flows approximately 65 river miles before draining into Elliot Bay in the Puget Sound. The upper and middle Green River subbasins flow primarily through commercial forest land and several state parks. The lower Green River subbasin consists of agriculture, industrial, commercial, and residential land. The Green River eventually turns into the industrialized Duwamish Waterway before entering Elliot Bay. Auburn Drain is a small tributary joining the Green River between river mile 25 and 26 in the lower subbasin. The area surrounding Auburn Drain is dominated by agricultural fields, undeveloped land, and mixed commercial and residential land. The project site is almost entirely graded gravel and compacted rock that was historically used as a parking lot. Very little native vegetation exists in project footprint and the general condition is heavily degraded.

Watercourse K is primarily a linear farm ditch with very little riparian vegetation or suitable substrate for rearing juvenile salmonids. Watercourse K is considered fish-bearing by Washington Department of Fish and Wildlife because of it is connected to Auburn Drain. A flap gate exists upstream of where Auburn Drain flows into the Green River that the Corps acknowledges acts as a hindrance to fish passage. King County (2019) describes the gate as setback from the confluence and is perched above the stream channel except during high flows when water from the Green River backs up into Auburn Drain. Further, King County (2019) found that non-natal juvenile Chinook salmon rearing habitat exists in relatively high density despite turbid and degraded water quality conditions. The data and information included in the King County (2019) report provides evidence that Auburn Drain is utilized by juvenile salmonids. Therefore, when flow conditions are conducive fish are able to access Watercourse K.

Based on the information included in the initiation package, very little suitable freshwater habitat exists in Watercourse K to support juvenile rearing and migration or adult spawning and migration. Rearing juveniles require cold clean water and cover and forage opportunities to grow and mature. Sufficient riparian vegetation, gravel, cobble, and boulder substrate is necessary for fish to avoid predators and feed. Currently, the Watercourse K lacks most of these features. Spawning has not been documented anywhere in Auburn Drain or in the project area.

Currently, stormwater is managed through a series of catch basins, pipes, culverts, and drainage ditches. Most of the stormwater drainage system is a remnant of farming infrastructure developed more than 50 years ago and has largely fell into disrepair over the years. Due to the low gradient of the site, most stormwater is collected in roadside ditches and carried to two culverts under 277th Street. Infiltration is also low at the site due to a restrictive layer of alluvial silt and sand situated above the groundwater table determined by a recent geotechnical survey conducted by the applicant. In other words, infiltration rates were determined not to meet long-term design guidelines suggesting that stormwater treatment through infiltration is unfeasible across the site.

Contaminants become entrained in stormwater from a variety of sources in the urban landscape. Roads generate a broad range and large load of pollutants that accumulate and run off impervious surfaces into stormwater drains and into streams, rivers, and lakes. Vehicle wear and emissions are primary sources of tire tread particles, metallic particles (particularly copper and chromium); persistent bio-accumulating toxicants (PBTs) from upholstery, plastic, and carpet; and polycyclic aromatic hydrocarbons (PAHs), nickel, and zinc from exhaust and leakage. Stormwater conveyances are also likely to include: common-use herbicides and pesticides, nutrients (nitrogen, phosphorus), silt and sediment, chlorides, metals, petroleum hydrocarbons, livestock fecal matter (bacteria), pharmaceuticals, surfactants (detergents, cleaners, pesticide adjuvants), along with several PBTs and their metabolites (**Table 3**). Other pollutants present in water and sediments throughout Washington state include mercury, copper, and other metals; chlorinated pesticides (DDT) and their degradates (DDD and DDE), polychlorinated dibenzo-p-dioxins and furans, polychlorinated biphenyls (PCBs), polybrominated diphenyl ethers (PBDEs), PAHs, and many others (Hinck et al. 2006; Seiders et al. 2007; Johnson et al. 2006; Johnson et al. 2013a; Alvarez et al. 2014; Counihan et al. 2014; WDOE 2006). Persistent organochlorine pollutants (POPs), some of which were discontinued 15 to 30 years ago and still exceed benchmarks for human health, aquatic life, and fish-eating wildlife in water, bed-sediment, and fish tissue samples in areas such as the the Snake and Columbia rivers (Johnson and Norton 2005; Hinck et al. 2006; Seiders et al. 2011; Johnson et al. 2007; Johnson et al. 2013b; Nilsen et al. 2014; Alvarez et al. 2014; WDOE 2021). These common and legacy pollutants are often present regardless of land use within a drainage. Other parameters such as temperature, pH, hardness, and conductivity may also be pollutants or indicators that other pollutants are negatively impacting receiving waters.

Table 3. Pollutants commonly found in stormwater runoff in Washington State.

Pollutant Class	Examples	Urban Sources
PBT (persistent bio-accumulating toxicants)	POPs (persistent organochlorine pollutants) PCBs (polychlorinated biphenyls) PBDEs (polybrominated diphenyl ethers) PFCs (poly- and per-fluorinated compounds) Pharmaceuticals (estrogen, antidepressant)	Eroding soils, solids, development, redevelopment, vehicles, emissions, industrial, consumer products
Petroleum hydrocarbons	PAHs (poly aromatic hydrocarbons), microplastics	Roads (vehicles, tires), industrial, consumer products
Metals	Mercury, copper, chromium, nickel, titanium, zinc, arsenic, lead	Roads, electronics, pesticides, paint, waste treatment
Common use pesticides, surfactants	Herbicides (glyphosate, diquat), insecticides, fungicides, adjuvants, surfactants (detergents, soaps)	Roads, railways, lawns, levees, golf courses, parks
Nutrients and sediment	Nitrogen, phosphorus fertilizers, fine-grained inorganic sediment	Fertilizer, soil erosion
Temperature and dissolved oxygen	Warm water, un-vegetated exposed surfaces (soil, water, sediments)	Impervious surfaces, rock, soils (roads, parking lots, railways, roofs)
Bacteria	*Escherichia coli*	Livestock waste, organic solids, pet waste, septic tanks

Heavy Metals

Heavy metals, such as copper, zinc, cadmium, or mercury, can have a range of acute and chronic physiological and behavior effects on fish. Recent literature demonstrates that exposure to stormwater pollutants such as petroleum-based hydrocarbons and metals can affect salmonids, with effects ranging from avoidance to mortality depending on the pollutant and its concentration (Feist et al. 2011; Gobel et al. 2007; Mcintyre et al. 2012; Meadore et al. 2006; Sandahl et al. 2007; Spromberg et al. 2015). All stormwater discharge is expected to contain concentration levels of constituents and chemical mixtures that are toxic to fish and aquatic life (NMFS 2012, or "Oregon Toxics Opinion"). The Oregon Toxics Opinion concluded that for chronic saltwater criteria for metal compounds, fish exposed to multiple compounds, versus a single compound exposure, are likely to suffer toxicity greater than the assessment effects (e.g., 50 percent mortality) such as mortality, reduced growth, impairment of essential behaviors related to successful rearing and migration, cellular trauma, physiological trauma, and reproductive failure.

Mercury

Sources of mercury are diverse and include natural emissions and weathering of metallic ores, human activities (mining, emissions from the burning and refining of coal and petroleum fuels, paper mills, cement production), and consumer products (thermostats, automotive switches, fluorescent lights, and dental fillings (WDOE 2021). Air emissions from industrial activities are by far the major source of mercury in most locations (Fitzgerald et al. 1998; Obrist et al. 2018). Mercury is a common stormwater contaminant (Fleck et al. 2016; EPA 2020). Mercury contaminates aquatic habitats and food webs, including rearing and migrating salmonids in the action area. Mercury concentrations in resident fish exceed Washington's water quality criteria for human health concentrations in the action area (WDOE 2021). All forms of mercury are toxic to fish, invertebrates, other animals, and humans (Eisler 1987; Broussard et al. 2002). Mercury ions produce toxic effects by protein precipitation, enzyme inhibition, and generalized corrosive action (Broussard et al. 2002).

Mercury is a mutagen, teratogen, and carcinogen, and causes embryocidal, cytochemical, and histopathological effects (Eisler 1987). Significant adverse sub-lethal effects for sensitive aquatic species are observed at 0.03-0.1 µg/L and water quality criteria of 0.012 µg/L provide only limited protection (Eisler 1987; NMFS 2014a). Mercury species are transformed by organic and inorganic processes to methylmercury (MeHg), which bio-accumulates throughout aquatic food webs and biomagnifies through trophic levels. Bettaso and Goodman (2010) found that lamprey ammocetes, which filter-feed from burrows in contact with sediments and ingest more benthos-dependent prey, bio-accumulated 12-25 times greater concentrations of mercury in their bodies than did mussels, which feed from water columns. In reservoir habitats of the action area, juvenile salmonids ingest large numbers of benthic invertebrates. Smaller fish tend to ingest smaller invertebrates, which may accumulate higher concentrations of metals (Farag et al. 1998). Daily feeding on potentially contaminated invertebrates, long migrations, depleted lipid stores, and bursts of energy to escape predators, increase ventilation and growth. Together, these factors increase bioaccumulation rates and adverse effects to juvenile salmonids.

Copper

Copper from automobiles is one of the most common heavy metals contaminating stormwater, especially stormwater originating from parking lots. Copper is highly toxic to aquatic biota and ESA-listed salmon and steelhead can experience a variety of acute and chronic lethal and sub-lethal effects (NMFS 2014a). Copper bio-accumulates in invertebrates and fish (Feist et al. 2005; Layshock et al. 2021), is redox-active, and interacts with or alters many compounds in mixtures (Gauthier et al. 2015). Copper-PAH mixtures, which synergistically interact are highly toxic through several exacerbating mechanisms: copper weakens cell membranes increasing absorption of PAHs, copper chelates or hastens and preserves the bio-accumulative toxicity of PAHs; and PAHs in turn increase the bio-accumulative and redox properties of Copper (Gauthier et al. 2015). Sub-lethal effects of copper include avoidance at very low concentrations (Hecht et al. 2007) and reduced chemosensory function at slightly higher concentrations, which in turn causes maladaptive behaviors, including inability to avoid copper or to detect chemical alarm signals (McIntyre et al. 2012). Sandahl et al. (2007) demonstrated that copper concentration as low as 2 micrograms/liter can significantly impair the olfactory system of salmonids and hinder their predator avoidance behavior. Thus any fish that are exposed to stormwater containing high concentrations of copper may experience diminishment of predator avoidance ability and would be at greater risk of predation. Appreciable adverse effects can be expected with increases as small as 0.6 µg/L above background concentrations (NMFS 2014a).

Copper concentrations typically increase during spring-summer high flows when migrating juvenile salmonids are most actively feeding and growing at greatest rates (NMFS 2014a). Copper toxicity increases significantly during conditions of low calcium carbonate (CaCO3), low pH, and low DOC (NMFS 2014a). Survival of juvenile salmon and steelhead, particularly during migration, is strongly size and season dependent (Mebane and Arthaud 2010). Small reductions in size and slower growth may slow or delay migration and would result in disproportionately larger reductions in survival during migration and entry into saltwater (Tattam et al. 2013, Thompson and Beauchamp 2014).

Chromium

Sources of chromium include phosphate fertilizers, chrome plating, paper mills, sewage, and solid wastes from the disposal of consumer products and chromium is a common pollutant found in stormwater UAs and along roadways (Eisler 1986a). While the pure metallic form is absent naturally, it is commonly found in three oxidation states: Cr II, Cr III, and Cr VI (Bakshi and Panigrahi 2018). Chromium is a redox-active metal, causing oxidative stress and oxidative-induced alterations of DNA in fish and other aquatic organisms (Eisler 1986a; Sevcikova et al. 2011). Hook et al. (2006) found that Cr VI caused oxidative stress in rainbow trout. Toxicity and uptake of Cr VI increases when pH is 7.8 or lower, low DOC, and low hardness (Vanderputte et al. 1981; Eisler 1986a). Comprehensive reviews show that chromium is taken up by fish and aquatic organisms through the gastrointestinal tract, respiratory tract, and skin (Eisler 1986a; Farag et al. 2006; Sevcikova et al. 2011; Bakshi and Panigrahi 2018). Dietary uptake of Cr VI may cause chronic sub-lethal toxicity in juvenile salmonids and is likely to increase the toxic and absorptive properties of PBTs and other metals.

Zinc

Major sources of zinc include electroplaters, smelting and ore processors, mine drainage, domestic and industrial sewage, combustion of solid wastes and fossil fuels, road surface runoff (vehicle emissions, motor oils, lubricants, tires, and fuel oils), corrosion of zinc alloys and galvanized surfaces, and erosion of agricultural soils (Eisler 1993). Several species of zinc are highly mobile in aquatic environments, are often transported many miles downstream, and eventually load to sediments. Zinc interacts with many chemicals and aquatic conditions of reduced pH and dissolved oxygen, low DOC, and elevated temperatures increase zinc toxicity, causing altered patterns of accumulation, metabolism, and toxicity (Eisler 1993; Farag et al. 1998). Many aquatic invertebrates and some fish may be adversely affected from ingesting zinc-contaminated particulates (Farag et al. 1998). In freshwater fish, excess zinc affects the gill epithelium, which leads to internal tissue hypoxia, reduced immunity, and may acutely include osmoregulatory failure, acidosis, and low oxygen tensions in arterial blood (Eisler 1993). Toxicity of zinc mixtures with other metals is mostly additive; however, toxicity of zinc-copper mixtures is more than additive (or synergistic) for freshwater fish and amphipods (Skidmore 1964; de March 1988).

Titanium

Consumer products using bulk and nanoparticles of titanium dioxide (TiO2) are increasing worldwide in paints, pigments, varnishes, plastics, sewage treatment, among others (Sharma and Agrawal 2005; Nunes et al. 2018). Recent research finds that nanoparticles in freshwater and saltwater continually aggregate into larger micro-particles and bind with high affinity to mixtures of metals and other contaminants (Nunes et al. 2018). Titanium dioxide nanoparticles physically cling to fish gills, causing some physical injuries (oedema and thickening of lamellae) that may reduce efficiency of gas exchange and significantly decrease the proportion of time rainbow trout spent swimming at high speed (Boyle et al. 2013). When rainbow trout were exposed to high concentrations, titanium oxide caused oxidative stress, disrupted signal transducing in gills and intestine, decreased intracellular calcium, altered homeostasis and resting potential, changed tissue copper and zinc levels, and may decrease enzyme activity in the brain (Federici et al. 2007). TiO2 nanoparticles physically fill or clog digestive tracts of some aquatic invertebrates causing increased feeding rates and reduced digestion, which increases oxidative stress and may lead to lethality (Das et al. 2013). Large loads of TiO2 at high concentrations are likely to kill and contaminate prey (e.g., amphipods), cause chronic sub-lethal toxicity in juvenile and adult salmonids, and increase toxic and absorptive properties of PBTs and other metals.

Nickel

Sources of nickel in urban areas and highways include metal emissions from tires, petroleum combustion, household waste, and fertilizers (Sharma and Agrawal 2005). Nickel is a redox-active metal (Gauthier et al 2015) that can interact with other metals and PBTs to increase toxicity, oxidative stress, and immune defense depletion in fish and invertebrate prey (Eisler 1985, 1998; Stohs and Bagchi 1995; Sevicikova et al. 2011; Palermo et al. 2015). Stormwater discharges of nickel degrade water and sediment quality and can reduce and contaminate prey and cause sub-lethal toxicity in juvenile salmonids and increase toxic and absorptive properties of PBTs and other metals in the aquatic environment.

Persistent Bioaccumulative Toxicants (PBTs)

Lipophilic chemicals such as PCB’s, PBDE’s, or PAH’s tend to bioaccumulate in the tissues of organisms, particularly those at the top of trophic food chains such as salmonids. Increased levels of PAHs, oils, and other contaminants would be widely dispersed, and can have detrimental effects at very low levels of exposure either directly or indirectly through the consumption of contaminated prey or exposure to contaminants in the water column. This would impair the value of critical habitat for growth and maturation of each of the listed species. As the concentration of these constituents increases in the environment the likelihood that organisms are harboring dangerous chemical loads also increases. Environmental and biological accumulation of these chemicals can result in adverse long-term ecosystem impacts including altering species behavior, reproduction, and growth.

PBTs are an expansive grouping (WAC 2021) of chemical compounds (and some metals) that may persist several years while maintaining high toxicity, often move readily among air, water, sediment, and food webs, and may bioaccumulate in listed salmonids and other fish from exposure to water, sediments, and from their diet of zooplankton, invertebrates, and other fish. PBTs often bind to sediments and are typically found in diverse mixtures in aquatic environments along with a broad range of pesticides, nutrients, metals, and PAHs (Johnson et al.

2006; Laetz et al. 2009; Baldwin et al. 2009; Johnson et al. 2013a). PBTs include POPs (persistent organochlorine pollutants) as described by Sloan et al. (2010), which include PCB congeners, PBDE congeners, DDT and metabolites, dioxins and furans, other organochlorinated compounds, and pesticides (hexachlorocyclohexane, hexachlorobenzene, chlordanes, aldrin, dieldrin, mirex, and endosulfan I).

PBTs typically include similar modes of toxicity and are often carcinogens, endocrine and reproductive disruptors, and transgenerational disruptors. PBTs may cause neurological and developmental disorders, oxidative stress, weakened immune systems, and may cause mortality of invertebrates and fish in aquatic ecosystems (Soto et al. 1994; Major et al. 2020; WDOE 2021). PBTs are often found in mixtures together with a broad range of PAHs and metals, to which PBTs readily bind and interact; often-increasing toxicity and mobility. The following PBTs are expected to have these generally similar effects and are likely to be present in the state of Washington depending on current and legacy land use.

Persistent Organochlorine Pollutants (POPs)
POPs include organochlorinated pesticides and metabolites (DDT, DDE), toxaphene, dieldrin, and other DDT-like compounds, and polychlorinated dibenzo-p-dioxins and furans. Some POPs that were discontinued 15 to 30 years ago continue to be reported at toxic concentrations in fish (Johnson et al. 2013a and 2013b). DDT, toxaphene, and dieldrin are major agricultural insecticides that were often used on cereal grains and fruit orchards, in mosquito abatement programs, and to kill fish in ponds (Eisler 1970; WDOE 2021). Most POPs are likely to enter stormwater from wind and water erosion or construction disturbance of legacy-contaminated soils. Some POPs are volatile and often deposit in the atmosphere where they are highly mobile and are likely to settle on impervious surfaces and enter stormwater drainage systems. Dioxins and furans are most likely to be absorbed to particulate matter when entering stormwater. Common sources are air emissions from regional forest fires and from trash burning and stack emissions from industries in and around the Lewiston UA. Construction activities or erosion of soils may disturb recent or legacy deposits of POPs that become entrained in stormwater runoff and drain into receiving waters and sediments.

Polychlorinated Biphenyls (PCBs)
PCBs are very persistent and are found in over 209 synthetic compounds, typically occurring in complex mixtures. Sources include food packaging, electronic transformers and capacitors, plasticizers, wax and pesticide extenders, lubricants, inks and dyes, and legacy sealants (WDOE 2021) and are likely to occur in stormwater runoff that is discharged into receiving waters. PCB concentrations in resident fish often exceed Washington's water quality criteria for human health concentrations (WDOE 2021).

Polybrominated Diphenyl Ethers (PBDEs)
PBDEs are flame retardants added to foam, plastics, and textiles, and are often found in car seats, electronics, building insulation, and older upholstered furniture and mattresses (WDOE 2021; Eisler 1986b). Studies show PBDEs have been spreading from these common items in UAs and roadways and entering stormwater that partitions to biota and sediments in receiving waters (Hites 2004; WDOE 2021; Stone 2006). PBDEs are rapidly increasing in the environment, doubling every 2-5 years (WDOE 2021) and other pollutants (nutrients and other wastewater

contents; O'Neill et al. 2020) increase their toxicity. Salmon ingest contaminated terrestrial and aquatic prey in the action area and assimilate some PBDE congeners throughout life (Stone 2006; Arkoosh et al. 2017). Even low concentrations of some PBDEs cause sub-lethal effects in salmonids such as alteration of thyroid hormone levels or thyroid function and neurological disorders (Sloan et al. 2010). Arkoosh et al. (2017) found thyroid hormone concentrations were altered in juvenile Chinook salmon when fed environmentally relevant concentrations of some PBDE congeners for 5-40 days. Most migrating Chinook salmon smolts spend at least five days and as long as several weeks or months rearing in freshwater before migrating to the marine waters of the Puget Sound or the ocean. This exposure is likely to cause sub-lethal disruption of thyroid hormones that impact critical functions salmonids require for growth, smolting, and migration (Iwata 1995).

Polycyclic Aromatic Hydrocarbons (PAHs)
Petroleum-based contaminants are usually in the form of two or more condensed aromatic carbon rings, include more than 100 different chemicals, and usually occur as complex mixtures in the environment. Major human-related sources released to the environment are from wood stoves, creosote treated wood, and vehicle emissions, plastics including tire wear particles, improper motor oil disposal, leaks, and asphalt sealants (WDOE 2021). PAHs are lipophilic, persistent, interact synergistically with bio-accumulative and redox-active metals and other contaminants, and may disperse long-distances in water (Gauthier et al. 2014, 2015; Arkoosh et al. 2011; WDOE 2021). Metabolites are commonly more toxic than the parent, some are carcinogenic, neurotoxic, and cause genetic damage. Although biotransformation of PAHs causes oxidative stress with subsequent cellular damage and increased energy is required at the cost of growth, many organisms (including salmon) can eliminate at least the lower density PAHs from their bodies as part of metabolism and excretion (Arkoosh et al. 2011). However, plants and some aquatic organisms, such as mussels and lamprey, have limited ability to metabolize or degrade PAHs, which may bioaccumulate over several years (Tian et al. 2019; Nilsen et al. 2015). PAHs and metabolites are acutely toxic to salmonids and may cause narcosis at low levels of exposure, can in some cases bioaccumulate through food webs (water, groundwater, soil, and plants; Bravo et al. 2011; Zhang et al. 2017), and can also cause chronic sub-lethal effects to aquatic organisms at very low levels (Neff 1985; Varanasi et al. 1985; Meador et al. 1995). PAHs can affect DNA within the nucleus of cells, cause genetic damage, and are classified as carcinogens (Collier et al. 2014).

Microplastics and Transformation Products
Microplastics (MPs) are generally found in higher numbers near urbanized areas. Campanale et al. (2020) detailed sources of MPs were mostly from electrical and electronics, building and construction, transport, and textiles. Brahney et al. (2021) found that stormwater runoff from roads in urbanized areas in the western U.S. produced 84 percent of MPs compared to the remainder of urbanized areas, which produced only 0.4 percent. Agricultural runoff produced five percent of MPs and 11 percent were legacy MPs from the ocean. City roads produced fewer MPs in stormwater because surrounding buildings and trees reduced wind and dust and because vehicles emit fewer microplastics (tire tread particles) at slow speeds. Highways and roads with higher speed limits and increased exposure produced vastly more MPs, because vehicles produce their own buffeting winds and tire tread wears at much greater rates (Brahney et al. 2021). Ingested MPs can interfere with food capture and digestion, particularly for benthic filter feeders,

leading to decreased feeding, oxidative stress, or mortality of sensitive aquatic invertebrates and fish (Kapp and Yeatman 2018). MPs are infused with PBT additives and when released to aquatic environments strongly attract other PBTs, PAHs, and metals (especially copper and zinc). Some MPs sink to sediments and others are transported long distances downstream, including through and over dams (Rochman et al. 2013; Wang et al. 2018; Campanale et al. 2020). MPs are also transported into the ocean and can carry PBTs and several metals (Rochman et al. 2014). Many MPs eventually enter the hydrologic cycle to be re-deposited throughout the western U.S. (Brahney et al. 2021). Mounting evidence shows MPs bioaccumulate in benthic invertebrates (e.g., amphipods, prawns) (Campanale et al. 2020), which are primary food sources for juvenile salmonids. Some MPs in fish, breakdown into smaller particles that can enter the circulatory system and bioaccumulate to higher trophic predators (Wang et al. 2018). PBTs and other contaminants leach from the MPs and bioaccumulate in tissues (Rochman et al. 2013; Campanale et al. 2020).

One of most common microplastics entering aquatic habitats from proximate roadways and stormwater discharges are tire tread wear particles (Tian et al. 2020; Brahney et al. 2021). The ubiquitous antioxidant 6PPD or [(N-(1, 3-dimethylbutyl)-N'-phenyl-p-phenylenediamine] is used to preserve elasticity of tires. 6PPD may transform in the presence of ozone (O3) from automotive and other urbanized area emissions to 6PPD-quinone. 6PPD-quinone is acutely toxic to juvenile and adult salmonids and is identified by Tian et al. (2020) as the primary cause of urban runoff mortality syndrome described by Scholz et al. (2011). Acute toxicity ending in mortality of juveniles and adult salmonids is caused by relatively low concentrations and short duration exposures (24 hr., LC50 = 0.79 µg/L) of 6PPD-quinone. All 6PPD added to tires is designed to react with atmospheric ozone to form a protective film on tires. The transformation product found to be toxic to salmonids is 6PPD-quinone found in tire tread particles ubiquitous to both rural and urban roadways (Sutton et al. 2019; Feist et al. 2018). Subsequent laboratory studies demonstrated that juvenile coho salmon (Chow et al. 2019) as well as juvenile steelhead and Chinook salmon (J. McIntyre and N. Scholz, unpublished results, 2020) were also susceptible to varying degrees of mortality when exposed to stormwater containing 6PPD-quinone. Fortunately, other recent literature has shown that the mortality can be prevented by infiltrating the road runoff through soil media containing organic matter, which results in removal of this (and other) contaminant(s) (Fardel et al. 2020; Spromberg et al. 2016; McIntrye et al. 2015). These types of green infrastructure or low impact development practices are commonly included in new construction projects but are often lacking in existing infrastructure and many redevelopment or routine maintenance projects. Stormwater discharges of MPs (especially tire tread particles) contribute to the degraded water and sediment quality in Washington. Pulses and cumulative loads of tire tread particles and MPs may cause acute lethal toxicity of adult and juvenile steelhead in Washington State.

Pesticides and Nutrients

Pesticides and fertilizers are ubiquitous in urbanized areas and are applied annually on lawns, pastures, orchards, and other interspersed agricultural lands (Gilliom et al. 2006; Gilliom 2007). Terrestrial pesticides, adjuvants, and fertilizers can be highly persistent and toxic upon entering aquatic environments, causing acute and chronic effects to salmonids and their invertebrate prey (Scholtz et al. 2012). Glyphosate-based-herbicides (e.g., Roundup) are mostly likely to runoff of roads and railways (Botta et al. 2009), riprap and levees, and areas of limited and poor soil with intensive vegetation control (Kjaer et al. 2011). Highest concentrations (75-90 μg/L) of glyphosate in streams are commonly from urban sewers during storms (Botta et al. 2009) and were concentrated in soil, sediments, and solid matter (Primost et al. 2017), even as water levels remained low. Effective vegetation removal by herbicides increases erosion of soil that may contain legacy POPs and mercury (Jonsson et al. 2017). Glyphosate and other contaminants in biofilms of wetlands can be 2-3 orders of magnitude higher than surrounding water and represent concentrated exposures to higher trophic levels (Beecraft and Rooney 2021). Commonly used terrestrial herbicide formulations and adjuvants may include bio-accumulating metals and PAHs, which are added to enhance performance and increase toxicity of active ingredients (Defarge et al. 2018). Additives are often labeled as proprietary "inert" ingredients but consist primarily of petroleum-based oxidized molecules and trace metals (arsenic, chromium, cobalt, lead, nickel, and others), which accumulate in soils, organic solids, sediments, and biofilms. Glyphosate significantly increases the bio-accumulation of mercury in zooplankton (Tsui et al. 2005). Mammals, mussels, amphibians, several insects, and many aquatic invertebrates are sensitive to sub-lethal and lethal toxicity of several pesticides, including glyphosate-based herbicides and their surfactants (Bringolf et al. 2007; Relyea and Diecks 2008; Janssens and Stoks 2017; Motta et al. 2018; Scully-Engelmeyer et al. 2021). Some pesticides are endocrine disruptors and may include transgenerational effects (Kubsad et al. 2019; Major et al. 2020). Pulses and cumulative loads of common-use herbicides and other biocides are likely to reduce and contaminate prey, cause acute and chronic sub-lethal toxicity in juvenile and adult salmonids, and increase toxic and absorptive properties of PBTs and metals.

Stormwater discharges of nutrients (nitrogen, nitrite, nitrate, phosphorus) and sediment contribute to the impairment of aquatic ecosystems throughout Washington. Water and sediment quality impairments from siltation and excessive nutrients degrade spawning and rearing habitat by clogging substrates, reducing interstitial oxygen required by incubating eggs, and altering and reducing cover. Nitrite and nitrate can also be toxic to fish. Davidson et al. (2014) found nitrate concentrations of 80-100 mg/L were related to increased mortality and other chronic health impacts (abnormal swimming behavior) in juvenile rainbow trout. Nutrients from agriculture and wastewater may increase toxicity of PBTs to juvenile Chinook salmon (O'Neill et al. 2020). Chronic exposure by fathead minnows to environmentally relevant nitrate levels may cause endocrine disruption, alter steroid hormone synthesis and metabolism in male and female fish, and may include transgenerational effects (Kellock et al. 2018). Sediment and nutrient loads are likely to reduce and contaminate prey and cause chronic lethal and sub-lethal toxicity in incubating eggs and juvenile steelhead.

Green Stormwater Infrastructure

Treatment of stormwater using biofiltration or bioremediation, also referred to as green stormwater infrastructure (GSI), to remove toxic pollutants has been shown to reduce harmful effects to fish (McIntyre et al. 2014) and prevent lethality in coho salmon (McIntyre et al. 2015; Spromberg et al. 2016). Research points to infiltration of polluted stormwater into soil as a highly effective method of removing toxic compounds before discharging into streams or rivers. McIntyre et al. (2015) observed that untreated urban stormwater was acutely lethal to salmon and invertebrates, but stormwater filtered through soil media in biorention columns eliminated acute mortality in both salmon and invertebrates. Previous scientific understanding relied on dilution as the primary method for evaluating risk of stormwater effects to listed species. Recent research in the Puget Sound has revealed that stormwater remains toxic to coho salmon even after dilution. GSI are commonly being installed as part of larger transportation and infrastructure projects to limit the delivery of toxic stormwater to the aquatic environment. While infiltration of stormwater into soil may be the best method for removing pollutants and preventing lethal effects, full infiltration may not always be possible due to constraining site factors such as soil types or existing infrastructure. In those cases alternative methods are available such as modular wetland systems.

2.3.1. Salmonid Populations in the Action Area

Green River Chinook Salmon

Viable Salmon Population (VSP) as described above provides the basis for recovery for Green River Chinook salmon populations. The 2007 recovery plan uses abundance, productivity, spatial structure and diversity to determine viability and extinction risk. The primary metric to assess abundance goals is natural origin spawners. Since the 1980's natural origin spawner abundance has fluctuated around 2,000 fish annually and has been in decline since 2009 (**Figure 5**, red line). Abundance has been below recovery goals frequently since the early 2000's (WRIA 9 2021). Natural origin productivity has also been well below recovery goals since before the 2007 Recovery plan was finalized. Chinook salmon productivity has been negative since 1975 indicating that natural origin spawners are not replacing themselves and hatchery supplementation has been a key factor in sustaining population abundance (**Figure 6**).

Spawners typically utilize Newaukum Creek and the mainstem Green River below Howard Hanson Dam (WRIA 9 2021), which are located well upstream of the project site. Chinook salmon are not currently passed above the dam because downstream fish passage facilities do not exist. Downstream fish passage facilities are planned to be installed following a deadline set by NMFS as part of a 2019 Biological Opinion. Spatial structure would be improved once habitat above the dam is accessible to natural origin spawners. King County has documented salmonids utilizing Auburn Drain up to an artificial barrier (Figure A - 1).

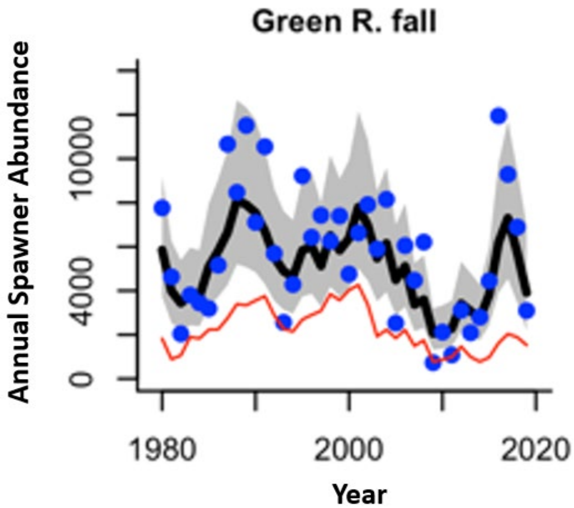


Figure 4. Smoothed trends in estimated total (thick black line, with 95% confidence interval in grey) and natural (thin red line) spawner abundance of Green River fall Chinook salmon (Adapted from Ford, 2022).

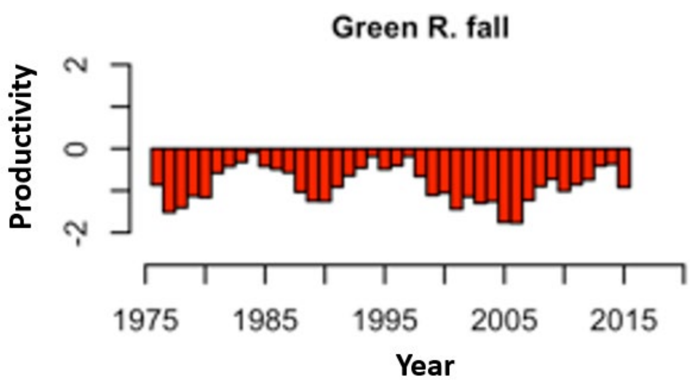


Figure 5. Annual trends in Green River fall Chinook salmon productivity calculated as the difference of the log of the smoothed natural origin spawning abundance in year *t* and the smoothed natural origin spawning abundance in year *t* – 4 (Adapted from Ford, 2022).

Green River Steelhead

Green River steelhead abundance has declined since the late 90's and remains below recovery goals (**Figure 7**). Productivity, while improving over recent years, has varied widely since the 80's (**Figure 8**). Meyers et al. (2015) estimate historic population intrinsic potential to be between 19,800 and 39,000 adult steelhead spawners in the Green River basin. Green River steelhead are supported by three hatchery programs including Chambers Creek early winter stock and Skamania early summer stock (Cram et al. 2018). Dams, fish passage, hatcheries, and disease/parasites were identified by WDFW as key factors threatening the viability of steelhead in the Green River basin (Cram et al. 2018). Nearly half of historical habitat exists above

Howard Hanson Dam and is a critical component inhibiting recovery of the population. Steelhead utilize the mainstem Green River and tributaries such as Newaukum and Soos Creek for spawning and rearing. Addressing smaller fish passage projects would help move the population towards recovery. King County has documented salmonids utilizing Auburn Drain up to an artificial barrier (Figure A - 2).

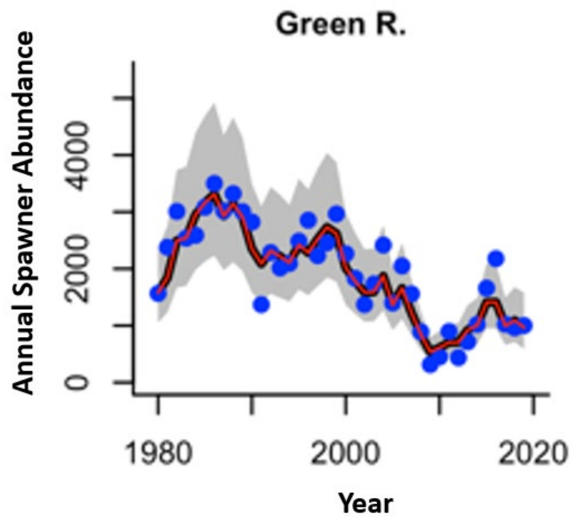


Figure 6. Smoothed trends in estimated total (thick black line, with 95% confidence interval in grey) and natural (thin red line) population abundance of Green River steelhead (Adapted from Ford 2022).

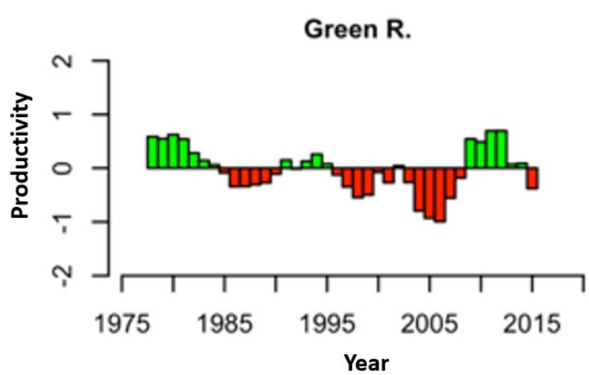


Figure 7. Annual trends in Green River steelhead population productivity calculated as the difference of the log of the smoothed natural origin spawning abundance in year *t* and the smoothed natural origin spawning abundance in year *t* – 4 (Adapted from Ford, 2022).

2.3.2. Critical Habitat in the Action Area

Within the action area critical habitat is designated for both Chinook salmon and steelhead along the mainstem Green River (**Figure 9**). In addition, steelhead critical habitat is designated approximately 600 feet upstream into the Auburn Drain. Critical habitat for both species would be impacted by the project both in Auburn Drain and the Green River. Specific PBFs that would be affected by the proposed action include water quality.

The action area is considered migration habitat for PS Chinook salmon; for PS steelhead the action area is both rearing and migration habitat. The features of CH for rearing and migration area:

1. Freshwater rearing sites with water quantity and floodplain connectivity to form and maintain physical habitat conditions and support juvenile growth and mobility; water quality and forage supporting juvenile development; and natural cover such as shade, submerged and overhanging large wood, log jams and beaver dams, aquatic vegetation, large rocks and boulders, side channels, and undercut banks. These features are essential to conservation because without them juveniles cannot access and use the areas needed to forage, grow, and develop behaviors (*e.g.*, predator avoidance, competition) that help ensure their survival.
2. Freshwater migration corridors free of obstruction with water quantity and quality conditions and natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, side channels, and undercut banks supporting juvenile and adult mobility and survival. These features are essential to conservation because without them juveniles cannot use the variety of habitats that allow them to avoid high flows, avoid predators, successfully compete, begin the behavioral and physiological changes needed for life in the ocean, and reach the ocean in a timely manner. Similarly, these features are essential for adults because they allow fish in a non-feeding condition to successfully swim upstream, avoid predators, and reach spawning areas on limited energy stores.

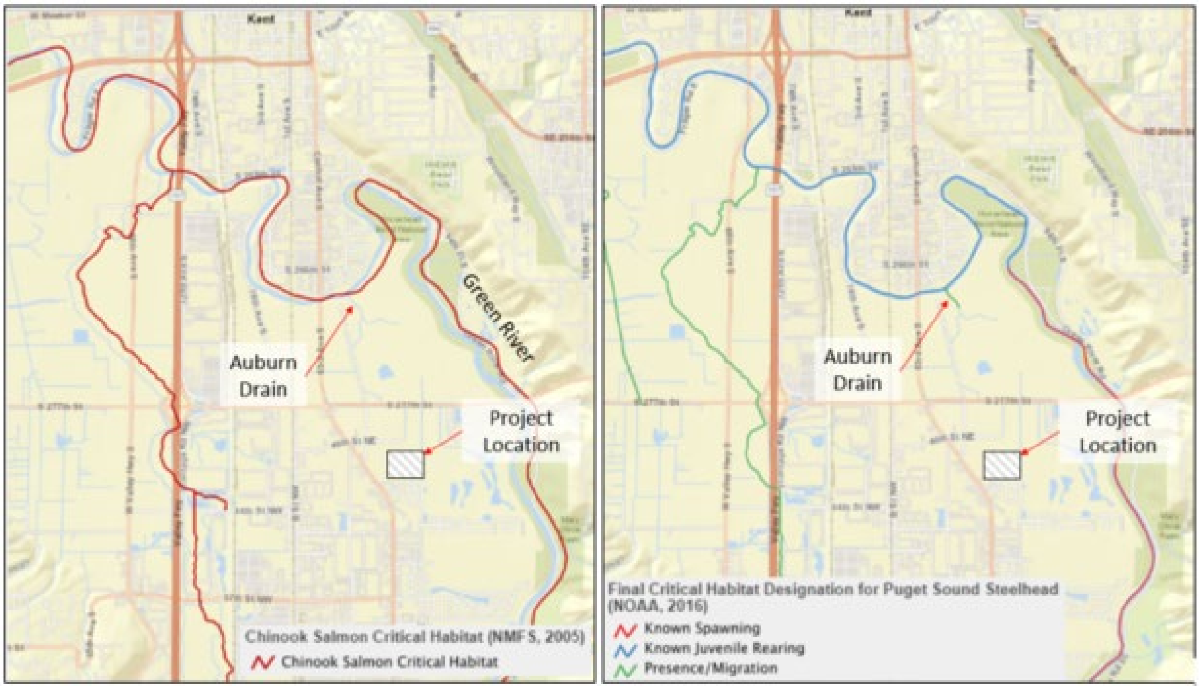


Figure 9. Critical habitat designations for Puget Sound Chinook salmon (left) and Puget Sound steelhead (right) in relation to the project location.

2.4. Effects of the Action

Under the ESA, "effects of the action" are all consequences to listed species or critical habitat that are caused by the proposed action, including the consequences of other activities that are caused by the proposed action. A consequence is caused by the proposed action if it would not occur but for the proposed action and it is reasonably certain to occur. Effects of the action may occur later in time and may include consequences occurring outside the immediate area involved in the action (see 50 CFR 402.17). In our analysis, which describes the effects of the proposed action, we considered 50 CFR 402.17(a) and (b).

After the application of all minimization and conservation measures described in Section 1.3 the proposed action would still result in adverse effects that cannot be avoided. Likely effects include short-term construction impacts, and long-term impacts of the proposed structural changes.

Temporary effects associated with construction that are reasonably certain to occur include: fish handling/exclusion prior to construction, turbid conditions, and modifications to the channel and riparian zone.

The long-term effects of the project that are reasonably certain to occur include degraded water quality from the increase in impervious surface and the associated stormwater and improved fish passage and riparian habitat resulting from culvert replacement and riparian planting.

2.4.1. Effects of the Action on Habitat

Channel Fill and Relocation/Turbidity

The proposed action would result in temporary negative effects on water quality by increasing suspended sediments and turbidity. The degree to which this effect would occur is dependent on the quantity of water in Watercourse K at the time of construction. Watercourse K frequently dries up during the summer and it is possible water would be absent during construction. However, if water is present, prior to construction sandbag dams would be installed up and downstream of the project site ensure water and potentially fish cannot enter the project site. Once fish are confirmed to be absent from the existing channel would be filled. Once the new channel is completed it is likely that sediment levels would increase briefly immediately following removal of the sandbag dams and during and following the first large storm event. However, based state on water quality criteria for turbidity in streams of this size, it is unlikely that sediments would be transported downstream to Auburn Drain or the mainstem Green River and degrade critical habitat.

Stormwater Discharges/Water Quality

Auburn Drain and the Green River would receive stormwater runoff from the additional impervious surfaces associated with the extension of I Street, culvert removal and replacement, and Watercourse K relocation and realignment. The proposed action would add approximately 19.5 acres of PGIS draining into Watercourse K. Due to the site characteristics appropriate stormwater management BMPs described in Ecology's 2014 SWMMWW were limited (described in detail in Section 1.3 Proposed Federal Action). The quantity of stormwater is expected to increase as a result of the proposed action because of the increase in impervious surfaces and create a mechanistic pathway for increases in higher rates of erosion, sedimentation, and transport of pollutants from the surrounding areas.

Traffic volume is expected to increase as a result of the project and would likely increase with population growth over time. Only full infiltration would completely remove all contaminants from road runoff, but this treatment method is not physically available at this location. Contaminants in road runoff are dominated by vehicle sources including brake friction materials, tire wear, and fuel and oil discharges.

Stormwater runoff occurs following heavy rainfall or snowmelt over impervious surfaces where post construction, vehicular, and industrial pollutants are picked up, carried, and deposited into aquatic environments (Dressing et al. 2016). Stormwater can discharge at any time of year, with the potential to expose individual salmon and steelhead in the action area. Concentration levels and toxicity of chemical mixtures are seasonally influenced. First- flush rain events after long periods without rain that most typically occur in September in western Washington are expected to have extremely high levels of toxic pollutants (Peter et al. 2020). Higher concentrations are also expected to occur between March and October in any given year—as there would be more dry periods during rain events. However, the occurrence of these events would occur with less frequency. In Western Washington, most discharge would occur between October and March, concurrent with when the region receives the most rain. Any action that is reasonably certain to result in increased urbanization and/or commercial development is expected to lead to a general increase in stormwater volume and a corollary decrease in water quality in the surrounding aquatic environments, unless stormwater management and treatment is adequately addressed in the proposed action. Effects caused by stormwater runoff are considered long term intermittent or episodic effects as they occur during and after rain events for the life of the impervious surface. Construction activities that include installing, replacing, or repairing pollution generating impervious surfaces (PGIS) provide a pathway for numerous pollutants from diffuse sources to be mobilized by stormwater runoff and transported to waterways.

Modified Fish Passage

Culvert removal and replacement would result in greater accommodation of high flow events, improvements to instream habitat conditions, and increase access to suitable upstream habitat. The 12-foot wide concrete box culvert is designed according to Stream Simulation criteria and to accommodate stormwater discharge during high flow events. Culvert replacement also includes placement of suitable streambed substrate according to Washington State Department of Transportation guidelines (WSDOT 2020), which would further enhance fish habitat conditions. Improved fish passage and substrate conditions at the project site would benefit fish habitat in the long-term with increased access to spawning areas, and improved substrate. These habitat benefits occur upstream of designated critical habitat.

Modified Rearing Habitat

Large woody debris would be placed in the new Watercourse K channel below the ordinary high water mark which would alter habitat and hydraulic conditions in the channel, adding instream complexity. Large wood slows down flow which can cause suspended sediments to settle out of the water column. Additionally, large wood creates habitat suitable for rearing juvenile fish to forage and avoid predators. Over the long-term, the addition of large wood would cause the complexity of the stream channel to increase and consequently improve fish habitat conditions. These habitat benefits occur upstream of designated critical habitat.

Modified Riparian Vegetation

Upon completion of the channel fill and relocation effort, noxious weeds would be removed from the riparian area surrounding the new channel and would be replanted with fast growing native trees and shrubs to stabilize the newly created stream bank. The new vegetation, once established, would provide shade for the new stream channel while improving longevity of the channel. Additionally, once mature, the riparian vegetation would create new habitat for juvenile fish along the stream margins as well as provide organic inputs to the stream, which would enhance forage opportunities for rearing juveniles. This habitat benefit occurs upstream of critical habitat.

2.4.2. Effects of the Action on Critical Habitat

Critical habitat for PS Chinook salmon and PS steelhead is designated in the mainstem Green River approximately 1 river mile downstream from the project site. Critical habitat for PS steelhead is also designated about 500 feet upstream in Auburn Drain (**Figure 9**). Critical habitat is not designated for either species directly within the project footprint. So impacts from the project that are likely to impact critical habitat would be limited to effects that are transported downstream. Specific effects include long-term degradation of water quality from an increase in impervious surfaces and stormwater volume.

Enduring Effects to Water Quality

Stormwater discharges are likely to transport contaminants to designated critical habitat for both species, and multiple pollutants found in stormwater (**Table 3**) would degrade water quality, a feature of designated critical habitat for both ESA listed salmonids in the freshwater environment[12]. Contaminants in stormwater can be transported far from the point of delivery either dissolved in solution, attached to suspended sediments, or through bioaccumulation. Water currents may transport contaminants that are in solution or bound to suspended sediment far downstream, to estuaries and the ocean. Contaminants bound to solids typically settle on substrates, where some are buried by sedimentation and sequestered to deep sediments away from most aquatic biota. Wind waves, water currents, and changing water levels erode substrates and resuspend contaminated sediments that are then transported farther downstream (Johnson et al. 2005). Sedimentation of contaminated material occurs in habitats with slower currents (wider or deeper sections of channel, reservoir backwaters, coves, and shorelines). In soil, sediments, and water, various metals and changes in oxygen, pH, and temperature can alter toxicity, binding properties, volatility, and degradation patterns and persistence of contaminants (Johnson et al. 2005). Metals especially serve as redox catalysts, chelating or binding other contaminants or eluting them from their bound state. Benthic prey communities can accumulate body load of contaminants from contaminated sediments.

This effect of stormwater discharge and the anticipated array of constituent pollutants, because it is a long term modification with multiple episodes of load each year, is likely to diminish the water quality and indirectly diminish the quantity and quality forage reducing the role of each in the action area for rearing or migration of either species (survival, growth, maturation, development, and downstream movement of juveniles).

2.4.3. Effects of the Action on Listed Species

Period of Exposure and Species Presence

Listed PS Chinook salmon and PS steelhead may not be exposed to all effects of the proposed action. Timing of work when some of the streams sections may be dry, (and if not dry, removal or exclusion of fish from the project site) reduces the likelihood of exposure to suspended sediment.

[12] Habitat area of particular concern (HAPC).

Table 4. Expected presence of listed species and lifestages in the action area relative to the in-water work window (IWWW).

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
In-water work												
F. Chinook							Adult Migration					
			Juvenile Migration									
W. Steelhead												
				Juvenile Migration								
S. Steelhead						Adult Migration						
				Juvenile Migration								

<u>Puget Sound Chinook Salmon – Green River Population</u>

Juvenile PS Chinook salmon generally emigrate from freshwater natal areas to estuarine and nearshore habitats from January to April as fry, and from April through early July as larger sub-yearlings. The proposed in-water work window is July 16 through September 30 when conditions are expected to dry and avoids peak juvenile Chinook salmon outmigration timing. However, we cannot rule out that juvenile Chinook may be residing in Watercourse K if flow is maintained through the summer at the start of construction.

Adult Chinook salmon typically enter the Duwamish River from mid-June through October. Many adults hold in the lower river until early fall when river conditions are more favorable; adults typically move upstream to spawning grounds in the Upper Green River basin following autumn rains. Given the timing of adult migration, it is possible that adult Chinook salmon may be present in the Green River downstream of the Auburn Drain confluence during the work window.

<u>Puget Sound Steelhead – Green River Population</u>

Washington Department of Fish and Wildlife (WDFW) data indicates occurrences of both summer and winter-run steelhead stocks in the Green/Duwamish Rivers. Green/Duwamish River adult summer steelhead enter the river from the Puget Sound from April to October and migrate to the upper Green River to spawn. Winter steelhead migrate upstream between November and May. Summer steelhead typically spawn from the end of January through March while winter fish spawn from late February through June. Similar to Chinook salmon, the action area does not currently provide any spawning habitat for steelhead. Puget Sound steelhead typically emigrate from natal streams in April and May, and appear to move directly out into the ocean to rear, spending little time in the nearshore or estuarine zones (Goetz et al. 2015). Juvenile and adult steelhead are unlikely to be in the action area during the work window and are thus unlikely to be exposed to the short-term construction impacts. While it is unlikely, we cannot rule out the possibility that juvenile steelhead may be rearing in immediate construction area if flow conditions are adequate.

Short-term effects associated with fish handling and exclusion are expected to occur at the beginning of the work window prior to construction commencing. Long-term effects associated with stormwater runoff are expected to occur episodically on an annual basis.

Fish Handling and Exclusion Activities

Prior to filling the current Watercourse K channel, a biologist would survey the area and determine if fish are present. If present, fish would be removed and relocated downstream to a more suitable location. Capture and handling induced stress can increase plasma levels of cortisol and glucose, decrease growth, decrease reproductive capabilities, increase vulnerability to predation, and increase the likelihood of mortality. Electrofishing significantly increases the chance of harm, injury, or mortality. Given that the likelihood of Watercourse K having very little flow is high, any fish that are residing in the channel would likely be experiencing high levels of stress from low water levels, poor dissolved oxygen, and high temperatures. This would amplify the negative effects of capturing, handling, and transporting fish. We advise the Corps and the applicant to utilize non-invasive capture techniques such as dip netting or seining and transport fish using tanks equipped with oxygen regulation technology. It is highly likely that if fish are handled, injury and/or mortality would occur among a portion of the individuals captured. While we acknowledge and agree with the Corps that the likelihood of encountering PS Chinook salmon or PS steelhead during exclusion and relocation efforts is low, we cannot, based on the best available science and data rule out the possibility that listed fish would be captured and handled; handling even a small number of handled PS Chinook salmon or PS steelhead would constitute an adverse effect, even with the handling is intended to reduce exposure to other adverse exposures. If the stream is wet and juvenile fish are present at the time of work, any juvenile fish that cannot be successfully captured and removed because they are undetected (i.e. juveniles may burrow to avoid capture) would be killed when dewatering and filling of the channel occurs.

Response to Water Quality Impacts

Listed fish species are unlikely to be adversely affected in the short-term by the proposed construction effects to water quality because of the construction BMPs, work-site isolation, and fish exclusion components included in the proposed action. Prior to construction, if fish are observed in the channel of Watercourse K then they would be captured and relocated downstream. The channel would then be isolated using sandbag dams at the up and downstream ends to prevent sediment from being transported downstream during channel fill and relocation. These measures would prevent exposing listed PS Chinook salmon and PS steelhead to temporary effects of the construction.

Conversely, we do expect degraded water quality stemming from stormwater runoff generated by the PGIS installed as part of the project to adversely affect listed fish species. Specifically, the project would increase PGIS and upgrade stormwater treatment facilities. However, given recent scientific findings, despite the proposed stormwater treatment plan (described in section 1.3 Proposed Federal Action) fish would still be exposed to harmful pollutants such as PAHs, heavy metals such as copper, zinc, or cadmium, and other vehicle related toxins (e.g., 6PPD-quinone), following storm events. Furthermore, we cannot predict the number of fish that would be exposed to these chemicals annually as the numbers of each species within the action area (Watercourse K, Auburn Drain, and Green River) would vary year to year. Because the site characteristics preclude infiltrating 100% of PGIS stormwater runoff (see section 1.3 Proposed Federal Action), we expect fish to be exposed to toxic contaminants for the life of the project.

In turn, aquatic organisms including ESA-listed fish and marine mammals may accumulate contaminants by direct contact in water and sediments, ventilation in water, or ingestion of contaminated plankton, invertebrates, detritus, or sediment. The intensity of effects largely depends on the pollutant, its concentration, and the duration of exposure. Pollutants can have individual as well as synergistic and additive effects on exposed species. Responses can range from behavioral changes, to injury or to death, depending on the contaminant and concentration.

Stormwater runoff is certain to continue to deliver toxic and potentially lethal contaminants from urban and rural areas if left untreated, degrading water quality, a feature of designated critical habitat all ESA listed species, serving multiple conservation values depending on location (e.g., for salmonids - spawning in upstream reaches; rearing and migration lower in the riverine system; growth and maturation in estuarine and nearshore areas). Exposure to untreated, and to insufficiently treated, stormwater causes adverse effects to ESA-listed salmonids. Similarly, prey communities in fresh and estuarine waters are an additional feature of designated critical habitat that can be impaired by stormwater; prey communities exposed to the various contaminants in stormwater may be reduced in quantity, composition, and in quality if they accumulate toxins. This creates a second, indirect pathway of exposure among ESA-listed species.

The incremental addition of small amounts of these pollutants over time are a source of adverse effects to salmon and steelhead, even when the source load cannot be distinguished from ambient levels; many pollutants common in stormwater bioaccumulate in the tissues of aquatic organisms and in benthic sediments and over time can cause a variety of lethal and sublethal effects (Hecht et al. 2007). Repeated and chronic exposures, even at very low levels, are likely to injure or kill individual fish, by themselves and through synergistic interactions with other contaminants already present in the water (Baldwin et al. 2009; Feist et al. 2011; Hicken et al. 2011; Spromberg and Meador 2006; Spromberg and Scholz 2011).

In an examination of effect on juvenile salmon, McIntyre et al (2015) exposed sub yearling coho salmon to urban stormwater. One hundred percent of the juveniles exposed to untreated highway runoff died within 12 hours of exposure. McIntyre et al (2018) later examined the prespawn mortality rate of adult coho salmon exposed to urban stormwater runoff. In their experiments one hundred percent of coho salmon exposed to stormwater mixtures expressed abnormal behavior (lethargy, surface respiration, loss of equilibrium, and immobility) within 2 to 6 hours after exposure. Recent studies have shown that coho salmon show high rates of pre-spawning mortality when exposed to chemicals that leach from tires (McIntyre et al. 2015). Researchers have recently identified a tire rubber antioxidant (6 ppd quinone) as the cause (Tian et al. 2020), and dilution does not appear to reduce toxicity. Although Chinook salmon and steelhead did not experience the same level of mortality, tire leachate is still a health concern for all salmonids and more research is needed to determine toxicity across Pacific salmon species. Vehicle residue also contains many unregulated toxic chemicals such as pharmaceuticals, PAHs, fire retardants, and emissions that have been linked to deformities, injury and/or death of salmonids and other fish (Trudeau 2017; Young et al. 2018).

Several large classes of nearly ubiquitous environmental pollutants, including certain polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and dioxins are known to be cardiotoxic to fish early life stages. Tricyclic PAHs derived from a wide variety of environmental sources can initiate several cardiotoxicity-based adverse outcome pathways (AOPs), and these have been characterized in a variety of laboratory and wild fish species. These effects range from outright embryonic heart failure and mortality at relative high PAH exposures (Adams et al., 2014a,b; Esbaugh et al., 2016; Incardona et al., 2014, 2013; Jung et al., 2013, 2015; Madison et al., 2015; Martin et al., 2014; McIntyre et al., 2016a,b; Sørhus et al., 2015), to more subtle effects on heart shape and delayed impacts on cardiovascular performance at lower concentrations (Hicken et al., 2011; Incardona et al., 2015). These latter, protracted physiological impacts likely contributed to the delayed mortality and poor population recruitment previously observed both in (1) mark-recapture studies with pink salmon (Oncorhynchus gorbuscha) exposed to crude oil during embryogenesis (Heintz, 2007; Heintz et al., 2000) and (2) the losses of wild pink salmon spawned in shoreline habitats that were oiled in the aftermath of the 1989 Exxon Valdez disaster (Rice et al., 2001; Incardona, and Scholz 2016)

PCB's, PBDE's, and PAH's tare lipophilic and bioaccumulate in the tissues of organisms, particularly those at the top of trophic food chains such as salmonids or marine mammals. Increased levels of PAHs, oils, and other contaminants are widely dispersed in stormwater originating from roads and other impervious surfaces associated with high vehicle use. PAHs can have detrimental effects at very low levels of exposure either directly or indirectly through the consumption of contaminated prey or exposure to contaminants in the water column. This would impair the value of critical habitat for growth and maturation of PS Chinook salmon and PS steelhead. Environmental and biological accumulation of these chemicals can result in adverse long-term ecosystem impacts including altering species behavior, reproduction, and growth.

There are two pathways for PAH exposure to listed fish species in the action area, direct uptake through the gills and dietary exposure (Lee and Dobbs 1972; Neff et al. 1976; Karrow et al. 1999; Varanasi et al. 1993; Meador et al. 2006; McCain et al. 1990; Roubal et al. 1977). Fish rapidly uptake PAHs through their gills and food but also efficiently remove them from their body tissues (Lee and Dobbs 1972; Neff et al. 1976). Juvenile Chinook salmon prey, including amphipods and copepods, uptake PAHs from contaminated sediments (Landrum and Scavia 1983; Landrum et al. 1984; Neff 1982). Varanasi et al. (1993) found high levels of PAHs in the stomach contents of juvenile Chinook salmon in the Duwamish estuary. The primary response of exposed salmonids, from both uptake through their gills and dietary exposure, are immunosuppression and reduced growth. Karrow et al. (1999) characterized the immunotoxicity of creosote to rainbow trout (O. mykiss) and reported a lowest observable effect concentration for total PAHs of 17 µg/l. Varanasi et al. (1993) found greater immune dysfunction, reduced growth, and increased mortality compared to control fish. In order to isolate the effects of dietary exposure of PAHs on juvenile Chinook salmon, Meador et al. (2006) fed a mixture of PAHs intended to mimic those found by Varanasi et al. (1993) in the stomach contents of field-collected fish. These fish showed reduced growth compared to the control fish. Of the listed fish exposed to PAHs and other contaminants, all are likely to have some degree of immunosuppression and reduced growth, which, generally, increases the risk of death.

Heavy metals can have a range of acute and chronic physiological and behavior effects on fish. Recent literature demonstrates that exposure to stormwater pollutants such as petroleum-based hydrocarbons and metals can affects salmonids, with effects ranging from avoidance to mortality depending on the pollutant and its concentrations (Feist et al. 2011; Gobel et al. 2007; Mcintyre et al. 2012; Meadore et al. 2006; Sandahl et al. 2007; Spromberg et al. 2015) Copper from automobiles is one of the most common heavy metals contaminating stormwater. Sandhal et al. (2007) showed that copper concentration as low as 2 micrograms per liter can significantly impair the olfactory system of salmonids and hinder their predator avoidance behavior. Predator avoidance impairment is likely to increase the rate of predation. Thus any fish that occupy or attempt to occupy the action area during times when rainfall is significant would likely experience diminishment of predator avoidance ability and would be at greater risk of predation.

We cannot estimate the number of individuals that would experience adverse effects from exposure to stormwater with any meaningful level of accuracy. We cannot predict the number or duration of each pulse of discharge events, nor the number of individual fish that would be exposed during those events. Furthermore, not all exposed individuals would experience immediate adverse effects. We expect that every year some individuals PS Chinook (juvenile and adult) and PS steelhead (juvenile and adult) would experience sublethal effects such as stress and reduced prey consumption, some may respond with avoidance behaviors that disrupt feeding and migratory behavior, and some experience reduced growth, impairment of essential behaviors related to successful rearing and migration, cellular trauma, physiological trauma, reproductive failure, and mortality. As described in section 2.4.2 *Effects of the Action on Critical Habitat* stormwater would be treated using a modular wetland system, which, depending on influent concentration, would not remove all pollutants or reduce loads to zero. Since we do not know pollutant concentrations in stormwater originating from the project and we cannot estimate the reduction in pollutant load following treatment, we expect, even after treatment that individual fish would be exposed to toxic stormwater, within Watercourse K, Auburn Drain, and the Green River.

Response to Improved Passage, Rearing Habitat, and Riparian Conditions

The proposed action would improve fish passage, and instream complexity with the addition of large wood, and riparian vegetation, relative to current conditions. The two removed culverts would be replaced with a concrete stream simulation compliant box culvert, which would benefit fish by allowing for upstream movement and allowing fish to utilize any additional habitat that exists upstream. Additionally, the new culvert would more effectively convey water and debris during high events. Further, the addition of suitable stream substrate and large wood would limit the amount of erosion and channelization while creating high quality habitat for juvenile salmon and steelhead to avoid predation and take refuge during high flow events.

These actions, along with planting the riparian and upland areas of the new channel with native trees and shrubs, would benefit PS Chinook salmon and PS steelhead utilizing Watercourse K in several ways including stabilizing the stream banks, adding organic material, cooling the water by providing shade, and creating cover for juvenile fish along the stream margins. Upland and riparian trees may also, over time deliver large wood to the stream channel creating additional habitat for juvenile salmonids. These elements of the proposed action would improve habitat conditions over the long term and provide an overall net benefit to listed fish species by improving growth and fitness of juvenile fish, and potentially increasing access to additional spawning areas among adult fish.

Summary of Effects to Species

Listed species would be affected by the proposed action in the short and long-term. If fish are present in the channel prior to construction they would be captured and transported downstream resulting in adverse effects to individual fish in one cohort. Adverse effects of stormwater though minimized via extensive stormwater treatment, would not be completely eliminated, therefore water quality would be adversely affected by stormwater runoff and would in turn adversely affect many individual listed fish species from many cohorts over time, through exposure to toxic pollutants. Culvert removal and replacement and riparian planting would improve habitat conditions benefit juvenile fish utilizing Watercourse K, and this benefit would accrue to many individual fish of many cohorts over time.

Effects to Population Viability

We assess the importance of habitat effects in the action area to the species by examining the relevance of those effects to the characteristics of VSP. The characteristics of VSPs are sufficient abundance, population growth rate (productivity), spatial structure, and diversity. While these characteristics are described as unique components of population dynamics, each characteristic exerts significant influence on the others. For example, declining abundance can reduce spatial structure of a population; and when habitats are less varied, then diversity among the population declines. We expect a temporary negative effect from the proposed action on the survival of juvenile PS Chinook salmon and juvenile PS steelhead. We expect populations from the Green/Duwamish River basin to be present in the action area and impacted by the proposed action.

Abundance: The specific amount of death, injury, or reduction in fitness of individual fish cannot be estimated, from either temporary or long term adverse effects, with the exception of fish handling. The long term adverse effects are contemporaneous with beneficial effects, so over the long term effects to individual fishes from the proposed action would not appreciably alter population level characteristics of Green River Chinook salmon or steelhead populations in the action area.

Productivity: Productivity could increase over the long-term once construction is complete due to a slight increase in accessible habitat upstream of the new culvert, however this could be nullified by reductions in fitness of fish when they are downstream of the culvert, exposed to the contaminants in stormwater. The resulting slight increase in habitat area is could slightly increase PS Chinook salmon and PS steelhead productivity and carrying capacity by creating more rearing habitat.

Spatial Structure: Despite the access to additional upstream areas, we do not expect the proposed project to significantly alter the spatial structure of the PS Chinook salmon ESU or PS steelhead DPS.

Diversity: We do not expect the proposed project to impact the diversity of the PS Chinook salmon ESU or PS steelhead DPS.

2.5. Cumulative Effects

"Cumulative effects" are those effects of future state or private activities, not involving federal activities, that are reasonably certain to occur within the action area of the federal action subject to consultation (50 CFR 402.02 and 402.17(a)). Future federal actions that are unrelated to the proposed action are not considered in this section because they require separate consultation pursuant to section 7 of the ESA.

Some continuing non-federal activities are reasonably certain to contribute to climate effects within the action area. However, it is difficult if not impossible to distinguish between the action area's future environmental conditions caused by global climate change that are properly part of the environmental baseline *vs.* cumulative effects. The project is an infrastructure project that is expected to last for several decades. Climate change effects described as a baseline condition in section 2.3 are expected to increase over that time. Anticipated climate effects on abundance and distribution of PS Chinook salmon and PS steelhead include a wide variety of climate impacts. The greatest risks would likely occur during incubation, when eggs are vulnerable to high mortality due to increased flooding and variability in seasonal flow (Ward et al. 2015). Crozier et al. (2019) identified early life stages such as incubating eggs as highly sensitive when exposed to more variable hydrologic regimes. Crozier et al (2019) also predicted that 8% of spawning habitat would change from snow-dominated to transitional, and 16% would change from transitional to rain-dominated. These projections suggest that winter flooding would become more common, directly affecting incubating eggs. Stream temperature ranks high in the extent of change expected, which could increase pre-spawn mortality in low-elevation tributaries (Cristea and Burges 2010). Rising temperatures during late spring and summer may also impact Chinook salmon juveniles in estuary and riverine habitats. Most Puget Sound estuaries already surpass optimal summer rearing temperatures, and the expectation of additional warming would further degrade already degraded habitat (Crozier et al 2019, Appendix S3).

The current condition of ESA-listed species and designated critical habitat within the action area are described in the Status of the Species and Critical Habitat (2.2) and the Environmental Baseline (2.3) sections above. The contribution of non-federal activities to those conditions include past and on-going forest management, agriculture, urbanization, road construction, water development, and restoration activities in the action area. Those actions are driven by a combination of economic conditions that characterized traditional natural resource-based industries, general resource demands associated with settlement of local and regional population centers, and the efforts of conservation groups dedicated to restoration and use of natural amenities, such as cultural inspiration and recreational experiences.

NMFS is unaware of any specific future non-federal activities that are reasonably certain to affect the action area. However, NMFS is reasonably certain that future non-federal actions such as those previously mentioned are all likely to continue and increase in the future as the human population continues to grow across the region. Continued habitat loss and degradation of water quality from development and chronic low-level inputs of non-point source pollutants will likely continue into the future as population projections suggest that human numbers in the greater Puget Sound region will increase by two million in the next 30 years (Levin 2020; PSRC 2018). The effects of climate change may also intensify the consequences of water quality effects associated with human population growth, as shifting acidity, salinity, and water temperatures modify food both bioaccumulation and food webs (Alava et al. 2018).

As mentioned above, human populations are expected to increase within the Puget Sound region, and if population growth trends remain relatively consistent with recent trends, we can anticipate future growth at approximately 1.5 percent per year. The human population in the PS region increased from about 1.29 million people in 1950 to about 3.84 million in 2014, and is expected to reach nearly 5 million by 2040 (Puget Sound Regional Council 2020). As of the date of this Opinion, the human population in the Puget Sound Region is roughly 4.2 million, slightly exceeding projections. Thus, future private and public development actions are reasonably certain to continue in and around Puget Sound. As the human population continues to grow, demand for agricultural, commercial, and residential development and supporting public infrastructure is also reasonably certain to grow. We believe the majority of environmental effects related to future growth will be linked to these activities, in particular land clearing, associated land-use changes (i.e., from forest to impervious, lawn or pasture), increased impervious surface, and related contributions of contaminants to area waters. Land use changes and development of the built environment that are detrimental to salmonid habitats are reasonably certain to continue under existing regulations. Though the existing regulations minimize future potential adverse effects on salmon habitat, as currently constructed and implemented, they still allow systemic, incremental, additive degradation to occur.

The intensity of these influences depends on many social and economic factors, and therefore is difficult to predict. Further, the adoption of more environmentally acceptable practices and standards may gradually reduce some negative environmental impacts over time. Interest in restoration activities has increased as environmental awareness rises among the public. State, tribal, and local governments have developed plans and initiatives to benefit ESA-listed PS Chinook salmon and PS steelhead within many Puget Sound watersheds. However, the implementation of plans, initiatives, and specific restoration projects are often subject to political, legislative, and fiscal challenges that increase the uncertainty of their success.

The cumulative effects associated with continued development in the action area are reasonably certain to have ongoing adverse effects on the populations of listed species addressed in this Opinion. Only improved, low-impact development actions together with increased numbers of restoration actions, watershed planning, and recovery plan implementation would be able to address growth related impacts into the future. To the extent that non-federal recovery actions are implemented and offset ongoing development actions, adverse cumulative effects may be minimized, but will probably not be completely avoided.

2.6. Integration and Synthesis

The Integration and Synthesis section is the final step in our assessment of the risk posed to species and critical habitat as a result of implementing the proposed action. In this section, we add the effects of the action (Section 2.5) to the environmental baseline (Section 2.4) and the cumulative effects (Section 2.6), taking into account the status of the species and critical habitat (Section 2.2), to formulate the agency's biological opinion as to whether the proposed action is likely to: (1) Reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing its numbers, reproduction, or distribution; or (2) appreciably diminish the value of designated or proposed critical habitat as a whole for the conservation of the species.

Status: The two species of ESA-listed fish addressed in this Opinion that are likely to be adversely affected by this proposed action are listed as threatened, based on low abundance and productivity, and reductions in spatial structure and diversity. Many of the same listing factors and limiting factors affect both salmon and steelhead, including loss and degradation of important habitats (e.g., spawning areas, off channel and side channel rearing areas). Many of the limiting factors are systemic, affecting critical habitat negatively, even in areas with high conservation value.

Baseline: Similar to areas designated as critical habitat, the environmental baseline within the action area has been degraded by the multiple effects of urbanization, agriculture, forestry, water diversion, and road building and maintenance.

Cumulative effects: The most significant cumulative effects are from the continued conversion of land and intensifying development is stormwater-associated pollutant load, and climate change. Given that state and federal laws regulate point and nonpoint discharges, we anticipate that much of the new stormwater would be captured and treated, limiting the amount of pollutants intermittently entering the stream to low levels; however the additive nature of this perturbation, even in small amounts, is expected to be negative over time. Climate change is also expected to have a negative effect over time on habitat values.

Project effects: The effect of the proposed action, when added to the environmental baseline, includes both positive and negative, permanent and temporary effects, as described above. The timing of work overlaps with the migration of adult and juvenile PS Chinook salmon and PS steelhead lifestages in the Green River, but it is unlikely that either lifestage would be in the direct footprint of the project during construction. However, given the implications of stormwater discharge and delivery of pollutants to the Green River, PS Chinook salmon and PS steelhead would be exposed to potentially toxic compounds for the life of the structures. We evaluate the addition of the project effects to this baseline, factoring status and these cumulative effects, by species and critical habitat, below.

2.6.1. PS Chinook Salmon

PS Chinook salmon are currently listed as threatened with generally negative recent trends in status. Widespread negative trends in natural-origin spawner abundance across the ESU have been observed since 1980. Productivity remains low in most populations, and hatchery-origin spawners are present in high fractions in most populations outside of the Skagit watershed. Available data now shows that most populations have increased in abundance over the last evaluation period (NWFSC 2015; Ford, 2022)(see section 2.2.1 *Status of ESA-Listed Fish Species*). However, most populations are consistently below the spawner-recruit levels identified by the recovery plan for this ESU. The population that would be affected by the proposed action is Green River fall Chinook salmon.

As described in Sections 2.2 and 2.3 Green River fall Chinook salmon abundance have been well below recovery goals for the last 20 year and productivity has been negative since the 1970's. PS Chinook salmon were recently evaluated by Ford, 2022) to be at moderate risk of extinction. Stormwater impacts to Duwamish/Green River Basin Chinook are likely to negatively affect recovery efforts and VSP characteristics of the PS ESU because of the chronic nature of exposure to many individuals of this population over time, with the response to the exposure generally being latent health effects (reduced fitness). Based on the best available information, the scale of the direct and indirect negative effects of the proposed action, when considered in combination with the degraded baseline, cumulative effects, and the impacts of climate change, would be too diffuse and latent to cause discernible effects on any of the characteristics of a viable salmon population (abundance, productivity, distribution, or genetic diversity) Green River Fall Chinook salmon.

Conversely, the number of Chinook salmon currently utilizing Auburn Drain and the surrounding tributaries is low due to fish passage issues and low flow conditions and the improvements to habitat conditions through riparian planting, culvert replacement, and channel restoration are likely to benefit PS Chinook salmon utilizing Auburn Drain. The improvements may even increase use by the species in the future, though these effects also are likely to be too small to cause detectable change in the abundance, productivity, or other characteristics of a viable salmon population. The proposed action would not improve overall flow conditions, but it may improve access to areas upstream of the I street road crossing. In summary, when the positive and negative effects of the proposed action are considered together, the proposed action would not appreciably reduce the numbers, distribution, or reproduction at the population level.

2.6.2. PS Steelhead

The long-term abundance trend of the PS steelhead DPS is negative, especially for native-origin spawners. The extinction risk for most DIPs is estimated to be moderate to high, and the DPS is currently considered "not viable." Reduced or eliminated accessibility to historically important habitat, combined with degraded conditions in available habitat due to land use activities appear to be the greatest threats to the recovery of PS steelhead. Fisheries activities also continue to impact this species.

The PS steelhead populations most likely to occur in the project area would be winter and summer-run fish from the Duwamish/Green River basin. Adults are typically present in the Green River during the winter of their upstream migration and juveniles during the spring and early summer of their outmigration. It is possible that some juveniles may utilize Auburn Drain and its tributaries to rear. No known spawning habitat exists in or upstream of Auburn Drain. When PS steelhead were recently evaluated by Ford (2022) the species was considered to be at moderate risk of extinction. The Green, Puyallup, Carbon, and White River winter steelhead populations are an integral component to the core MPG of the southern Puget Sound DPS (NMFS 2019). The Green, Puyallup, and Nisqually River basins contain important diverse stream habitats to support core populations. Current abundance of Green River winter steelhead remain well below recovery goals and significant recovery efforts would be needed to attain recovery of these populations. Specific measures include reconnecting side channels, wetlands, and floodplains, removing bank armoring and reducing confinement throughout the basin.

When the project effects are evaluated, similar to Green River Chinook salmon, the proposed action does not result in effects that are likely to significantly reduce population's abundance, distribution or reproduction, because negative effects of stormwater and positive effects of improved passage and rearing conditions are contemporaneous.

Species conclusions: Based on the best available information, the scale of the direct and indirect effects of the proposed action, when considered in combination with the degraded baseline, cumulative effects, and the impacts of climate change, would be too diffuse to cause detectable effects on any of the characteristics of a viable salmon population (abundance, productivity, distribution, or genetic diversity) for the affected PS steelhead and PS Chinook salmon populations, nor the overall DPS or ESU. Therefore, the proposed action would not appreciably reduce the likelihood of survival and recovery of this listed species and may in fact benefit survival and recovery of the species over the long term.

2.6.3. Salmon and Steelhead Critical Habitat

PS Chinook salmon and PS steelhead critical habitat exists approximately 1.25 miles downstream of the project site, but is within the action area based on the downstream effects of stormwater. At the designation scale, the quality of PS Chinook salmon and PS steelhead critical habitat is generally poor with only a small amount of freshwater habitat remaining in good condition. Most freshwater critical habitat for these species is degraded but nonetheless maintains a high importance for conservation of the species, based largely on its restoration potential, and the essential life history purpose it supports. Degradation of freshwater critical habitat quality is a limiting factor for these species. Development of Puget Sound watersheds are expected to continue to adversely impact the quality of critical habitat PBFs for PS Chinook salmon and PS steelhead, designation wide.

Thus, the effects of the proposed action, considered with cumulative effects and added to the baseline, are likely to be incrementally negative with negative effects accruing in designated critical habitat, and positive habitat effects accruing well upstream of critical habitat. In summary, the status of critical habitat for PS Chinook salmon and steelhead is poor, the baseline conditions are poor, and the project benefits occur upstream of critical habitat designations for both species, with negative effects occurring to the water quality PBF through contaminated annual episodic stormwater discharge originating from the project's new impervious surfaces. While these effects are both negative, and chronic, the slight reduction in water quality and prey conditions for juvenile salmonid growth, maturation, and fitness are latent and diffuse, and does not appreciably reduce the conservation role of the critical habitat at the ESU or DPS scale.

2.7. Conclusion

After reviewing and analyzing the current status of the listed species, the environmental baseline within the action area, the effects of the proposed action, any effects of actions caused by the proposed action, and cumulative effects, it is NMFS' opinion that the proposed action is not likely to jeopardize the continued existence of PS Chinook salmon or PS steelhead nor is it likely to destroy or adversely modify designated critical habitat for PS Chinook salmon or PS steelhead.

2.8. Incidental Take Statement

Section 9 of the ESA and Federal regulations pursuant to section 4(d) of the ESA prohibit the take of endangered and threatened species, respectively, without a special exemption. "Take" is defined as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in any such conduct. "Harm" is further defined by regulation to include significant habitat modification or degradation that actually kills or injures fish or wildlife by significantly impairing essential behavioral patterns, including breeding, spawning, rearing, migrating, feeding, or sheltering (50 CFR 222.102). "Incidental take" is defined by regulation as takings that result from, but are not the purpose of, carrying out an otherwise lawful activity conducted by the Federal agency or applicant (50 CFR 402.02). Section 7(b)(4) and section 7(o)(2) provide that taking that is incidental to an otherwise lawful agency action is not considered to be prohibited taking under the ESA if that action is performed in compliance with the terms and conditions of this incidental take statement (ITS).

2.8.1. Amount or Extent of Take

In the biological opinion, NMFS determined that incidental take is reasonably certain to occur as follows:

- Harm of juvenile PS Chinook salmon and PS steelhead from exposure to polluted stormwater discharge.

- Capture, including injury or death from handling for exclusion from the work site.

With the exception of fish exclusion and relocation, NMFS cannot predict with meaningful accuracy the number of fishes that are reasonably certain to be injured or killed by exposure to any of these stressors. The distribution and abundance of the fish that occur within an action area are affected by spawning success in upstream and adjacent areas, habitat quality, competition, predation, and the interaction of processes that influence population, and environmental characteristics. These biotic and environmental processes interact in ways that may be random or directional, and may operate across far broader temporal and spatial scales than are affected by the proposed action. Not only is presence (exposure) over time highly variable, but because responses are to stormwater are largely chronic and sublethal, we cannot estimate how many fish are harmed. NMFS knows of no device or practicable technique that would yield reliable counts of individuals that may experience responses.

In such circumstances NMFS uses the casual link established between the activity and the likely extent and duration of changes in habitat conditions to describe the extent of take as a numerical level of habitat disturbance. The most appropriate surrogates for take are action-related parameters that are directly related to the magnitude of the expected take.

- The extent of take in the form of harm of juvenile and adult Green River Chinook salmon and Green River steelhead from exposure to water quality impairments and consumption of contaminated prey exposure is measured as the amount of PGIS at the project site (20 acres) and the treated discharge from this site. This is a causal measurement, because, if the footprint of impervious surfaces increases at the site, or if the capture of stormwater is from less than this area, then load of contaminants will increase, the intensity of exposure will increase, and the extent of harm will be exceeded.

Work area isolation is a conservation measure intended to reduce adverse effects from in-water work activities. However, capture is a form of take, and the exclusion and relocation efforts can cause injury or death. Due to the uncertainty in potential abundance and density we relied on a maximum possible density within the project location, estimating no more than 25 juvenile (including smolts) PS Chinook and 25 juvenile (including smolts) PS steelhead that would be captured and handled during the isolation and relocation efforts. However, due to the intermittenet nature of flow in Watercourse K we expect the likely number of fish handled would be much lower. If the number of PS Chinook salmon or PS steelhead captured and handled exceeds the above numbers then the amount of take would be exceeded, and the reinitiation provisions of this opinion would be triggered and the Corps must notify NMFS within 24 hours if work area isolation take is exceeded.

2.8.2. Effect of the Take

In the biological opinion, NMFS determined that the amount or extent of anticipated take, coupled with other effects of the proposed action, is not likely to result in jeopardy to the species or destruction or adverse modification of critical habitat.

2.8.3. Reasonable and Prudent Measures

"Reasonable and prudent measures" are measures that are necessary or appropriate to minimize the impact of the amount or extent of incidental take (50 CFR 402.02).

1. The Corps shall instruct the applicant to minimize incidental take of listed species resulting from handling, capture, and electrofishing.

2. The Corps shall instruct the applicant to minimize incidental take associated with long-term habitat degradation due to stormwater.

3. The Corps shall instruct the applicant to implement a monitoring and reporting plan to confirm that RPM's are implemented as required and take exemption for the proposed action is not exceeded, and that the terms and conditions are effective at minimizing incidental take.

2.8.4. Terms and Conditions

In order to be exempt from the prohibitions of section 9 of the ESA, the federal action agency must comply (or must ensure that any applicant complies) with the following terms and conditions. The Corps or any applicant has a continuing duty to monitor the impacts of incidental take and must report the progress of the action and its impact on the species as specified in this ITS (50 CFR 402.14). If the entity to whom a term and condition is directed does not comply with the following terms and conditions, protective coverage for the proposed action would likely lapse.

1. The following terms and conditions implement RPM 1 (electrofishing, capture and handling):
   a. Take all appropriate steps to minimize the amount and duration of handling during capture and release operations, including the following:
      i. Corps or applicant fish biologists, their subordinate staff, or certified contractors must conduct all fish capture, handling, and electrofishing operations, unless otherwise approved in writing by NMFS.
      ii. Conduct a spawner/redd survey prior to starting work to ensure spawning adults or redds are not present in the action area.
      iii. Utilize less invasive capture methods before using electrofishing equipment. Herding fish using kick nets is a less invasive technique that keeps fish in the water.
      iv. If electrofishing is used to capture fish for relocation, NMFS's electrofishing guidelines will be followed (NMFS 2000). Those guidelines are available from the NMFS West Coast Region, Protected Resources Division, Portland, Oregon.[13]
      v. Do not use seining or electrofishing equipment if water temperatures exceed 18ºC, or are expected to rise above 18ºC.
      vi. ESA-listed fish must be handled with extreme care, keeping fish in water to the maximum extent possible during seining and transfer procedures to prevent the added stress of out-of-water handling.
      vii. Water quality conditions must be adequate in tanks, buckets, or in sanctuary nets that hold water to transport fish by providing circulation of clean, cold water, using aerators to provide DO, and minimizing holding times. DO and temperature should be periodically monitored in transport containers.
      viii. Fish must be released into a safe location as quickly as possible, and as near as possible to capture sites.

2. The following terms and conditions implement RPM 2 (stormwater):
   a. Confirm that stormwater treatment measures comport with the 2019 SWMMWW(Ecology 2019). If updates are needed, provide those in writing to NMFS.
   b. Monitor pollutant loads of water discharging from stormwater treatment facilities during 1 major storm events before and after project completion. By monitoring stormwater prior to treatment and following treatment effectiveness of BMPs can be evaluated. Include the following contaminants: Copper (solid and dissolved), zinc (solid and dissolved), PCB, PBDE, PAH, TSS, and nitrogen. See more details in term and condition 3, below.
   c. Comply with the conditions of use described in Ecology's General Use Designation for Basic (TSS), Enhanced, and Phosphorous treatment for MWS-

[13] https://media.fisheries.noaa.gov/dam-migration/electro2000.pdf

Linear Modular Wetland[14] which includes installing, maintaining, and monitoring per the Ecology guidance.

   d. Provide copies of the projects NPDES permit, SWPPP, and TESCP referenced in the proposed action description.

3. The following terms and conditions implement RPM 3 (monitoring and reporting):
   a. Before work begins, all contractors working on site must receive a complete list of Corps permit special conditions, this Biological Opinion's ITS, including the RPMs and terms and conditions intended to minimize the amount and extent of take resulting from in-water work.
   b. On the start date of the construction, the Corps shall notify NMFS that construction has commenced: This notification should be sent to projectreports.wcr@noaa.gov and include:
      i. Email subject line: "NOTIFICATION OF START DATE **WCRO-2020-02915**"
      ii. Date project construction began
   c. Report to NMFS the total number of PS Chinook salmon and PS steelhead encountered, captured, killed, and relocated within 30 days of completing fish exclusion and relocation work. This notification should be sent to projectreports.wcr@noaa.gov and include:
      i. Email subject line: "NOTIFICATION OF FISH EXCLUSION WORK COMPLETED **WCRO-2020-02915**"
      ii. Date fish exclusion work completed.
   d. Report to NMFS the total pre- and post-project amount of PGIS in acres and the net increase in PGIS upon completion of the project. This notification should be sent to projectreports.wcr@noaa.gov and include:
      i. Email subject line: "NOTIFICATION OF CONSTRUCTION COMPLETION: TOTAL PGIS **WCRO-2020-02915"**
      ii. Total amount of PGIS prior to construction (acres)
      iii. Total amount of PGIS after construction (acres)
      iv. Total net increase (acres)
   e. Report to NMFS findings from stormwater monitoring described in bullet 2 above within 60 days of completing monitoring requirements. Report should include contaminant loads and details pertaining to the size and intensity of the storm including but not limited to total rainfall and duration. This notification should be sent to projectreports.wcr@noaa.gov and include:
      i. Email subject line: "NOTIFICATION OF STORM EVENT **WCRO-2020-02915**"
      ii. Date of start and end of storm event.
      iii. Total rainfall.
      iv. Contaminant load in stormwater prior to and following treatment.

[14] https://fortress.wa.gov/ecy/ezshare/wq/tape/use_designations/MWSlinearMODULARwetlandGULD.pdf

2.9. Conservation Recommendations

Section 7(a)(1) of the ESA directs federal agencies to use their authorities to further the purposes of the ESA by carrying out conservation programs for the benefit of the threatened and endangered species. Specifically, conservation recommendations are suggestions regarding discretionary measures to minimize or avoid adverse effects of a proposed action on listed species or critical habitat or regarding the development of information (50 CFR 402.02).

1. The Corps should evaluate appropriate applications for pervious pavement and develop guidance for use of pervious pavement, such as adding bicycle lanes and road shoulders.

2. Design all road crossings for ecological connectivity and ensure culvert designs are sized, constructed, and maintained to match the gradient, flow characteristics, and width of the stream so as to accommodate flood events at the 100 year flood level.

3. All new road crossing structures (culverts) should accommodate future increased flows (addressing build-out and climate projections).

2.10. Reinitiation of Consultation

This concludes formal consultation for the Inland Group culvert replacement, I street extension, and Watercourse K realignment and replacement project.

As 50 CFR 402.16 states, reinitiation of consultation is required and shall be requested by the Federal agency or by the Service where discretionary Federal agency involvement or control over the action has been retained or is authorized by law and if: (1) The amount or extent of incidental taking specified in the ITS is exceeded, (2) new information reveals effects of the agency action that may affect listed species or critical habitat in a manner or to an extent not considered in this opinion, (3) the identified action is subsequently modified in a manner that causes an effect to the listed species or critical habitat that was not considered in the biological opinion, or (4) a new species is listed or critical habitat designated that may be affected by the action.

3. MAGNUSON–STEVENS FISHERY CONSERVATION AND MANAGEMENT ACT ESSENTIAL FISH HABITAT RESPONSE

Section 305(b) of the MSA directs Federal agencies to consult with NMFS on all actions or proposed actions that may adversely affect EFH. Under the MSA, this consultation is intended to promote the conservation of EFH as necessary to support sustainable fisheries and the managed species' contribution to a healthy ecosystem. For the purposes of the MSA, EFH means "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity", and includes the physical, biological, and chemical properties that are used by fish (50 CFR 600.10). Adverse effect means any impact that reduces quality or quantity of EFH, and may include direct or indirect physical, chemical, or biological alteration of the waters or substrate and loss of (or injury to) benthic organisms, prey species and their habitat, and other ecosystem components, if such modifications reduce the quality or quantity of EFH. Adverse effects on EFH may result from actions occurring within EFH or outside of it and may include site-specific or EFH-wide impacts, including individual, cumulative, or synergistic consequences of actions (50 CFR 600.810). Section 305(b) of the MSA also requires NMFS to recommend measures that can be taken by the action agency to conserve EFH. Such recommendations may include measures to avoid, minimize, mitigate, or otherwise offset the adverse effects of the action on EFH (CFR 600.905(b)).

This analysis is based, in part, on the EFH assessment provided by the Corps and descriptions of EFH for Pacific Coast salmon (PFMC 2014) contained in the fishery management plans developed by the PFMC and approved by the Secretary of Commerce.

3.1. Essential Fish Habitat Affected by the Project

The Pacific Fishery Management Council (PFMC) described and identified EFH for groundfish (PFMC 2005), coastal pelagic species (PFMC 1998), and Chinook, coho, and PS pink salmon (PFMC 2014). The proposed action and action described in Section 1: Introduction of this document includes areas designated as EFH for various lifestages of Chinook and coho salmon. Based on the information provided by the Corps and the analysis of the effects included in the ESA portion of this document, NMFS concludes that the proposed action would degrade water quality conditions causing adverse effects on EFH for Pacific Coast salmon.

3.2. Adverse Effects on Essential Fish Habitat

As part of the information included in this consultation, NMFS determined that the action, as proposed, would adversely affect EFH designated Chinook and coho salmon. The project would discharge stormwater runoff containing PAHs, dissolved and suspended metals, and other persistent contaminants of concern into Auburn Drain which drains into the Green River and eventually Elliot Bay in the Puget Sound. Contaminants that are dissolved or in suspension, while still present in the water, would be indiscernible from background levels by the time the water reaches Elliot Bay. These contaminants would affect water, sediment, and prey base within freshwater habitat areas. Riverine habitat is also a habitat area of particular concern (HAPC) for Pacific salmonids. This HAPC would be adversely affected in the Green River.

3.3. Essential Fish Habitat Conservation Recommendations

NMFS determined that the following conservation recommendations are necessary to avoid, minimize, mitigate, or otherwise offset the impact of the proposed action on EFH.

1. Monitor water quality discharges following National Pollutant Discharge Elimination System requirements from all discharge points.

2. Manage stormwater to replicate the natural hydrologic cycle, maintaining natural infiltration and runoff rates to the maximum extent practicable.

3. Properly maintain roadway ditches and associated stormwater collection systems.

4. Conduct road maintenance using practices according to the requirements of existing NMFS rules, such as the July 2000 ESA 4(d) rule (Protective Regulations) for listed West Coast salmon and steelhead (65 FR 42422; July 10, 2000), Limit 10, covering road maintenance. Implementing maintenance under these programs avoids exacerbation of existing impacts, and protects EFH to the extent that it contributes to the conservation of the species.

5. The Corps and the applicant should provide annual photo documentation of plantings to meet term and condition 3, above, for a period of three years following completion of the project to show planting survival.

3.4. Statutory Response Requirement

As required by section 305(b)(4)(B) of the MSA, the Corps must provide a detailed response in writing to NMFS within 30 days after receiving an EFH Conservation Recommendation. Such a response must be provided at least 10 days prior to final approval of the action if the response is inconsistent with any of NMFS' EFH Conservation Recommendations unless NMFS and the Federal agency have agreed to use alternative time frames for the Federal agency response. The response must include a description of the measures proposed by the agency for avoiding, minimizing, mitigating, or otherwise offsetting the impact of the activity on EFH. In the case of a response that is inconsistent with the Conservation Recommendations, the Federal agency must explain its reasons for not following the recommendations, including the scientific justification for any disagreements with NMFS over the anticipated effects of the action and the measures needed to avoid, minimize, mitigate, or offset such effects (50 CFR 600.920(k)(1)).

In response to increased oversight of overall EFH program effectiveness by the Office of Management and Budget, NMFS established a quarterly reporting requirement to determine how many conservation recommendations are provided as part of each EFH consultation and how many are adopted by the action agency. Therefore, we ask that in your statutory reply to the EFH portion of this consultation, you clearly identify the number of conservation recommendations accepted.

3.5. Supplemental Consultation

The Corps must reinitiate EFH consultation with NMFS if the proposed action is substantially revised in a way that may adversely affect EFH, or if new information becomes available that affects the basis for NMFS' EFH Conservation Recommendations (50 CFR 600.920(l)).

4. DATA QUALITY ACT DOCUMENTATION AND PRE-DISSEMINATION REVIEW

The Data Quality Act (DQA) specifies three components contributing to the quality of a document. They are utility, integrity, and objectivity. This section of the opinion addresses these DQA components, documents compliance with the DQA, and certifies that this opinion has undergone pre-dissemination review.

Utility

Utility principally refers to ensuring that the information contained in this consultation is helpful, serviceable, and beneficial to the intended users. The intended users of this opinion are the Corps and the Inland Construction Group. Other interested users could include recreational fishing groups, conservation groups, and Treaty Tribes. Individual copies of this opinion were provided to the Corps. The document will be available within two weeks at the NOAA Library Institutional Repository [https://repository.library.noaa.gov/welcome]. The format and naming adheres to conventional standards for style.

Integrity

This consultation was completed on a computer system managed by NMFS in accordance with relevant information technology security policies and standards set out in Appendix III, 'Security of Automated Information Resources,' Office of Management and Budget Circular A-130; the Computer Security Act; and the Government Information Security Reform Act.

Objectivity

Information Product Category: Natural Resource Plan

Standards: This consultation and supporting documents are clear, concise, complete, and unbiased; and were developed using commonly accepted scientific research methods. They adhere to published standards including the NMFS ESA Consultation Handbook, ESA regulations, 50 CFR 402.01 et seq., and the MSA implementing regulations regarding EFH, 50 CFR 600.

Best Available Information: This consultation and supporting documents use the best available information, as referenced in the References section. The analyses in this opinion and EFH consultation, if applicable contain more background on information sources and quality.

Referencing: All supporting materials, information, data and analyses are properly referenced, consistent with standard scientific referencing style.

Review Process: This consultation was drafted by NMFS staff with training in ESA and MSA implementation, if applicable, and reviewed in accordance with West Coast Region ESA quality control and assurance processes.

5. REFERENCES

Abatzoglou, J. T., D. E. Rupp, and P. W. Mote. 2014. Seasonal climate variability and change in the Pacific Northwest of the United States. Journal of Climate 27(5): 2125-2142.

Adams, J., Bornstein, J.M., Munno, K., Hollebone, B., King, T., Brown, R.S., Hodson, P.V., 2014a. Identification of compounds in heavy fuel oil that are chronically toxic to rainbow trout embryos by effects-driven chemical fractionation. Environ. Toxicol. Chem. 33, 825–835.

Adams, J., Sweezey, M., Hodson, P.V., 2014b. Oil and oil dispersant do not cause synergistic toxicity to fish embryos. Environ. Toxicol. Chem. 33, 107–114.

Alpers, C.N., R.C. Antweiler, H.E. Taylor, P.D. Dileanis, and J.L. Domagalski (editors). 2000a. Volume 2: Interpretation of metal loads. In: Metals transport in the Sacramento River, California, 1996-1997, Water-Resources Investigations Report 00-4002. U.S. Geological Survey. Sacramento, California.

Alpers, C.N., R.C. Antweiler, H.E. Taylor, P.D. Dileanis, and J.L. Domagalski (editors). 2000b. Volume 1: Methods and Data.In: Metals transport in the Sacramento River, California,1996-1997, Water-Resources Investigations Report 99-4286. U.S. Geological Survey. Sacramento, California.

Alvarez, D., S. Perkins, E. Nilsen, and J. Morace. 2014. Spatial and temporal trends in occurrence of emerging and legacy contaminants in the Lower Columbia River 2008-2010. Science of the Total Environment 484: 322-330.

Anderson, C.W., F.A. Rinella, and S.A. Rounds. 1996. Occurrence of selected trace elements and organic compounds and their relation to land use in the Willamette River Basin, Oregon, 1992–94. U.S. Geological Survey. Water-Resources Investigations Report 96-4234. Portland, Oregon.

Arkoosh, M., A.L. Van Geist, S.A. Strickland, G.P. Hutchinson, A.B. Krupkin, and J.P. Dietrich. 2017. Alteration of thyroid hormone concentrations in juvenile Chinook salmon (Oncorhynchus tshawytscha) exposed to polybrominated diphenyl ethers, BDE-47 and BDE-99. Chemosphere 171: 1-8.

Arkoosh, M., S. Strickland, A. Gaest, G. Ylitalo, L. Johnson, G. Yanagida, T. Collier, J. Dietrich. 2011. Trends in organic pollutants and lipids in juvenile Snake River spring Chinook salmon with different out-migrating histories through the Lower Snake and Middle Columbia Rivers. Science of the Total Environment 409: 5086-5100.

Bakshi, A., and A. Panigrahi. 2018. A comprehensive review on chromium induced alterations in freshwater fishes. Toxicology Reports 5: 440-447.

Baldwin, D.H., J.A. Spromberg, T.K. Collier, and N.L. Scholz. 2009. A fish of many scales: extrapolating sub-lethal pesticide exposures to the productivity of wild salmon populations. Ecological Applications 19: 2004-2015.

Barton, A., B. Hales, G.G. Waldbuster, C. Langdon, and R. Feely. 2012. The Pacific Oyster, Crassostrea gigas, Shows Negative Correlation to Naturally Elevated Carbon Dioxide

Levels: Implications for Near-Term Ocean Acidification Effects. Limnology and Oceanography. 57:12.

Bartz KK, Ford MJ, Beechie TJ, Fresh KL, Pess GR, et al. (2015) Trends in Developed Land Cover Adjacent to Habitat for Threatened Salmon in Puget Sound, Washington, U.S.A.. PLOS ONE 10(4): e0124415. https://doi.org/10.1371/journal.pone.0124415

Beecraft, L., and R. Rooney. 2021. Bioconcentration of glyphosate in wetland biofilms. Science of the Total Environment 756: 143993. https://doi.org/10.1016/j.scitotenv.2020.143993

Bettaso, J. B., & Goodman, D. H. 2010. A comparison of mercury contamination in mussel and ammocoete filter feeders. *Journal of Fish and Wildlife Management*, *1*(2), 142-145.

Botta, F., G. Lavison, G. Couturier, F. Alliot, E. Moreau-Guigon, N. Fauchon, B. Guery, M. Chevreuil, and H. Blanchoud. 2009. Transfer of glyphosate and its degradate AMPA to surface waters through urban sewerage systems. Chemosphere 77: 133-139.

Boyle, D., G.A. Al-Bairuty, C.S. Ramsden, K.A. Sloman, T.B. Henry, and R.D. Handy. 2013. Subtle alterations in swimming speed distributions of rainbow trout exposed to titanium dioxide nanoparticles are associated with gill rather than brain injury. Aquatic Toxicology 126: 116-127.

Brahney, J., N. Mahowald, M. Prank, G. Cornwell, Z. Klimont, H. Matsui, and K.A. Prather. 2021. Constraining the atmospheric limb of the plastic cycle. Proceedings of the National Academy of Sciences of the U.S.A. 118: e2020719118. https://doi.org/10.1073/pnas.2020719118

Bravo, C.F., L.R. Curtis, M.S. Myers, J.P. Meador, L.L. Johnson, J. Buzitis, T.K. Collier, J.D. Morrow, C.A. Laetz, F.J. Loge, and M.R. Arkoosh. 2011. Biomarker responses and disease susceptibility in juvenile rainbow trout Oncorhynchus mykiss fed a high molecular weight PAH mixture. Environmental Toxicology and Chemistry 30: 704-714.

Bringolf, R.B., W.G. Cope, S. Mosher, M.C. Barnhart, and D. Shea. 2007. Acute and chronic toxicity of glyphosate compounds to glochidia and juveniles of Lampsilis siliquoidea (Unionidae).

Broussard, L. A., Hammett-Stabler, C. A., Winecker, R. E., & Ropero-Miller, J. D. 2002. The toxicology of mercury. Laboratory medicine, 33(8), 614-625.

Burnett, K.M., G.H. Reeves, D.J. Miller, S. Clarke, K. Vance-Borland and K. Christiansen. 2007. Distribution of salmon-habitat potential relative to landscape characteristics and implications for conservation. Ecological Applications 17:66-80.

Campanale, C., C. Massarelli, I. Savino, V. Locaputo, and V.F. Uricchio. 2020. A detailed review study on potential effects of microplastics and additives of concern on human health. International Journal of Environmental Research and Public Health 17: 1212; doi:10.3390/ijerph17041212

Chow, M., et al., 2019. An urban stormwater runoff mortality syndrome in juvenile coho salmon. Aquatic Toxicology 214 (2019) 105231.

City of Auburn Department of Public Works. 2014. Surface water management manual November 2009; Revision #1 Effective June 6, 2014.

Collier, T.K., B.F. Anulacion, M.R. Arkoosh, J.P Dietrich, J.P. Incardona, L.L. Johnson, G.M Ylitalo, and M.S. Myers. 2014. Effects on fish of polycyclic aromatic hydrocarbons (PAHS) and naphthenic acid exposures. Organic Chemical Toxicology of Fishes 33: 195-255.

Counihan, T.D., I.R. Waite, E.B. Nilsen, J.M. Hardiman, E. Elias, G. Gelfenbaum and S.D. Zaugg. 2014. A survey of benthic sediment contaminants in reaches of the Columbia River estuary based on channel sedimentation characteristics. Science of the Total Environment 484: 331-343.

Cram, J., N. Kendall, A. Marshall, T. Buehrens, T. Seamons, B. Leland, K. Ryding, and R. Neatherlin. 2018. Steelhead at Risk Report: Assessment of Washington's Steelhead Populations. Washington Department of Fish and Wildlife Report, October 2018.

Crozier L.G., M.M. McClure, T. Beechie, S.J. Bograd, D.A. Boughton, M. Carr, et al. 2019. Climate vulnerability assessment for Pacific salmon and steelhead in the California Current Large Marine Ecosystem. PLoS ONE 14(7): e0217711.

Crozier, L. G., M. D. Scheuerell, and E. W. Zabel. 2011. Using Time Series Analysis to Characterize Evolutionary and Plastic Responses to Environmental Change: A Case Study of a Shift Toward Earlier Migration Date in Sockeye Salmon. The American Naturalist 178 (6): 755-773.

Crozier, L.G., Hendry, A.P., Lawson, P.W., Quinn, T.P., Mantua, N.J., Battin, J., Shaw, R.G., and Huey, R.B. 2008. Potential responses to climate change in organisms with complex life histories: evolution and plasticity in Pacific salmon. Evolutionary Applications 1(2): 252-270.

Das, P, M.A. Xenopoulos, and C.D. Metcalfe. 2013. Toxicity of silver and titanium dioxide nanoparticle suspensions to the aquatic invertebrate, Daphnia magna. Bulletin of Environmental Contamination and Toxicology 91: 76-82.

Davidson, J., C. Good, C. Welsh, and S.T. Summerfelt. 2014. Comparing the effects of high vs. low nitrate on the health, performance, and welfare of juvenile rainbow trout Oncorhynchus mykiss within water recirculating aquaculture systems. Aqua cultural Engineering 59: 30-40.

de March, B.G.E. 1988. Acute toxicity of binary mixtures of five cations (Cu2+, Cd2+, Zn2+, Mg2+, and K+) to the freshwater amphipod Gammarus lacustris (Sars): alternative descriptive models. Canadian Journal of Fisheries and Aquatic Sciences 45: 625-633.

Defarge, N., J. Spiroux de Vedomois, and G. Seralini. 2018. Toxicity of formulants and heavy metals in glyphosate-based herbicides and other pesticides. Toxicology Reports 5: 156-163. DOI: 10.1021/acs.est.0c00872

Dominguez, F., E. Rivera, D. P. Lettenmaier, and C. L. Castro. 2012. Changes in Winter Precipitation Extremes for the Western United States under a Warmer Climate as Simulated by Regional Climate Models. Geophysical Research Letters 39(5).

Doney, S. C., M. Ruckelshaus, J. E. Duffy, J. P. Barry, F. Chan, C. A. English, H. M. Galindo, J. M. Grebmeier, A. B. Hollowed, N. Knowlton, J. Polovina, N. N. Rabalais, W. J. Sydeman, and L. D. Talley. 2012. Climate Change Impacts on Marine Ecosystems. Annual Review of Marine Science, 4: 11-37.

Dressing, S. A., D. W. Meals, J.B. Harcum, and J. Spooner, J.B. Stribling, R.P. Richards, C.J. Millard, S.A. Lanberg, and J.G. O'Donnell. 2016. Monitoring and evaluating nonpoint source watershed projects. Prepared for the U.S. Environmental Protection Agency, Office of Water Nonpoint Source Control Branch, Washington, DC. EPA 841-R-16-010. May 2016. https://www.epa.gov/sites/production/files/2016-06/documents/nps_monitoring_guide_may_2016-combined_plain.pdf

Eisler, R. 1970. Acute toxicities of organochlorine and organophosphorus insecticides to estuarine fishes. U.S. Dept. Inter. Bur. Sport fish. Wildlife. Tech. Pap 46.

Eisler, R. 1985. Cadmium hazards to fish, wildlife, and invertebrates: a synoptic review. U.S. Fish and Wildlife Service Biological Report 85 (1.2). 30 pp.

Eisler, R. 1986a. Chromium hazards to fish, wildlife, and invertebrates: a synoptic review. U.S. Fish and Wildlife Service Biological Report 85 (1.6). 60 pp.

Eisler, R. 1986b. Polychlorinated biphenyl hazards to fish, wildlife, and invertebrates: A synoptic review. U. S. Geological Survey, Biological Science Report 85(1.7). Contaminant Hazard Reviews, April 1986. Report No. 7.

Eisler, R. 1987. Mercury hazards to fish, wildlife, and invertebrates: a synoptic review. U.S. Fish and Wildlife Service Biological Report 85 (1.10). 63 pp.

Eisler, R. 1993. Zinc hazards to fish, wildlife, and invertebrates: A synoptic review. U. S. Fish and Wildlife Service, Biological Report 10, Contaminant Hazard Reviews Report 26.

Eisler, R. 1998. Nickel hazards to fish, wildlife, and invertebrates: a synoptic review. U.S. Geological Survey, Biological Resources Division, Biological Science Report USGS/BRD/BSR—1998-0001. 76 pp.

Environmental Protection Agency. 2020. Biological Evaluation and Essential Fish Habitat Assessment for Endangered Species Act Section 7 Consultation on National Pollutant Discharge Elimination System (NPDES) Municipal Stormwater Permits Located in the Lewiston, Idaho Urbanized Area: City of Lewiston and Lewis-Clark State College (IDS028061) and Idaho Transportation Department District #2 (IDS028258). U.S. EPA Region 10. August 2020.

Esbaugh, A.J., Mager, E.M., Stieglitz, J.D., Hoenig, R., Linbo, T.L., Brown, T.L., French, B.L., Scholz, N.L., Incardona, J.P., Benetti, D.D., Grosell, M., 2016. The effects of weathering and chemical dispersion on Deepwater Horizon crude oil toxicity to mahi-mahi (Coryphaena hippurus) early life stages. Sci. Total Environ. 543, 644–651

Farag, A.M., D.F. Woodward, J.N. Goldstein, W. Brumbaugh, and J.S. Meyer. 1998.Concentrations of metals associated with mining waste in sediments, biofilm, benthic macroinvertebrates, and fish from the Coeur d'Alene River Basin, Idaho. Archives of Environmental Contamination and Toxicology 34: 119-127.

Farag, A.M., T. May, G.D. Marty, M. Easton, D.D. Harper, E.E. Little, et al. 2006. The effect of chronic chromium exposure on the health of Chinook salmon (Oncorhynchus tshawytscha). Aquatic Toxicology 76: 246-257.

Fardel. A., et al., 2020. Performance of two contrasting pilot swale designs for treating zinc, polycyclic aromatic hydrocarbons and glyphosate from stormwater runoff. Science Total Env. 743:140503

Federici, G., B.J. Shaw, and R.D. Handy. 2007. Toxicity of titanium dioxide nanoparticles to rainbow trout (Oncorhynchus mykiss): gill injury, oxidative stress, and other physiological effects. Aquatic Toxicology 84: 415-430.

Feely, R.A., T. Klinger, J.A. Newton, and M. Chadsey (editors). 2012. Scientific summary of ocean acidification in Washington state marine waters. NOAA Office of Oceanic and Atmospheric Research Special Report.

Feist, B. E., J. J. Anderson, and R. Miyamoto. 1996. Potential impacts of pile driving on juvenile pink (Oncorhynchus gorbuscha) and chum (O. keta) salmon behavior and distribution. Fisheries Research Institute Report No. FRI-UW-9603:66 pp.

Feist, B.E., E.R. Buhle, P. Arnold, J.W. Davis, and N.L. Scholz. 2011. Landscape ecotoxicology of coho salmon spawner mortality in urban streams. Plos One 6(8): e23424.

Feist, G.W., M.A.H. Webb, D.T. Gundersen, E.P. Foster, C.B. Schreck, A.G. Maule, and M.S. Fitzpatrick. 2005. Evidence of Detrimental Effects of Environmental Contaminants on Growth and Reproductive Physiology of White Sturgeon in Impounded Areas of the Columbia River. Environmental Health Perspectives 113: 1675-1682.

Fitzgerald, W. F., Engstrom, D. R., Mason, R. P., & Nater, E. A. (1998). The case for atmospheric mercury contamination in remote areas. Environmental science & technology, 32(1), 1-7.

Fleck, J.A., M. Marvin-DiPasquale, C.A. Eagles-Smith, J.T. Ackerman, M.A. Lutz, M. Tate, C.N. Alpers, B.D. Hall, D.P Krabbenhoft, and C.S. Eckley. 2016. Mercury and Methylmercury in Aquatic Sediment Across Western North America. Science of the Total Environment. 568 (2016) 727-738. http://dx.doi.org/10.1016/j.scitotenv.2016.03.0440048-9697

Ford, M. J., (editor) (2011). Status review update for Pacific salmon and steelhead listed under the Endangered Species Act: Pacific Northwest. U.S. Department of Commerce. NOAA Technical Memorandum NMFS-NWFSC-113: 281 p.

Ford, M. J., T. Cooney, P. McElhany, N. J. Sands, L. A. Weitkamp, J. J. Hard, M. M. McClure, R. G. Kope, J. M. Myers, A. Albaugh, K. Barnas, D. Teel, and J. Cowen. 2011a. Status Review Update for Pacific Salmon and Steelhead Listed Under the Endangered Species Act: Pacific Northwest. November 2011. U.S. Dept. Commer., NOAA Tech. Memo., NMFS-NWFSC-113. 307p.

Ford, M., editor. 2022. Biological Viability Assessment Update for Pacific Salmon and Steelhead Listed Under the Endangered Species Act: Pacific Northwest. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC.

Forest Ecosystem Management Assessment Team (FEMAT). 1993. Forest ecosystem management: An ecological, economic, and social assessment. Report of the Forest Ecosystem Management Assessment Team. 1993-793-071. U.S. Gov. Printing Office.

Gallagher, S.P., P.B. Adams, D.W. Wright, and B.W. Collins. 2010. Performance of Spawner Survey Techniques at Low Abundance Levels, N. Am. J. Fish. Manage, 30(5):1086-1097, DOI: 10.1577/M09-204.1

Gauthier, P.T., W.P. Norwood, E.E. Prepas, and G.G. Pyle. 2014. Metal–PAH mixtures in the aquatic environment: A review of co-toxic mechanisms leading to more-than-additive outcomes. Aquatic Toxicology 154: 253-269.

Gauthier, P.T., W.P. Norwood, E.E. Prepas, and G.G. Pyle. 2015. Metal−polycyclic aromatic hydrocarbon mixture toxicity in Hyalella azteca. 2. metal accumulation and oxidative stress as interactive co-toxic mechanisms. Environmental Science and

Gilliom, R. J., J. E. Barbash, C. G. Crawford, P. A. Hamilton, J. D. Martin, N. Nakagaki, L. H. Nowell, J. C. Scott, P. E. Stackelberg, G .P. Thelin, and D. M. Wolock. 2006. The Quality of Our Nation's Waters—Pesticides in the Nation's Streams and Ground Water, 1992–2001: U.S. Geological Survey Circular 1291,172 pp.

Gilliom, R.J. 2007. Pesticides in U.S. streams and groundwater. Environmental Science and Technology 41: 3408–3414.

Glick, P., J. Clough, and B. Nunley. 2007. Sea-level Rise and Coastal Habitats in the Pacific Northwest: An Analysis for Puget Sound, Southwestern Washington, and Northwestern Oregon. The National Wildlife Foundation.

Gobel, P., C. Dierkes, & W.C. Coldewey. 2007. Storm water runoff concentration matrix for urban areas. Journal of Contaminant Hydrology, 91, 26–42.

Goetz, F. A., Jeanes, E., Moore, M. E., and Quinn, T. P. (2015). Comparative migratory behavior and survival of wild and hatchery steelhead (Oncorhynchus mykiss) smolts in riverine, estuarine, and marine habitats of Puget Sound, Washington. Environmental Biology of Fishes, 98(1), 357-375. doi:http://dx.doi.org/10.1007/s10641-014-0266-3

Goode, J.R., Buffington, J.M., Tonina, D., Isaak, D.J., Thurow, R.F., Wenger, S., Nagel, D., Luce, C., Tetzlaff, D. and Soulsby, C., 2013. Potential effects of climate change on streambed scour and risks to salmonid survival in snow-dominated mountain basins. Hydrological Processes 27(5): 750-765

Hard, J. J., J. M. Myers, E. J. Connor, R. A. Hayman, R. G. Kope, G. Lucchetti, A. R. Marshall, G. R. Pess, and B. E. Thompson. *in press*. Viability criteria for Puget Sound steelhead. Page 373 p in U.S. Department of Commerce, editor.

Hard, J.J., J.M. Myers, E.J. Connor, R.A. Hayman, R.G. Kope, G. Lucchetti, A.R. Marshall, G.R. Pess, and B.E. Thompson. 2015. Viability criteria for steelhead within the Puget Sound distinct population segment. U.S. Dept. of Commerce, NOAA Tech. Memo. NMFS-NWFSC-129. May 2015. 367 pp

Hard, J.J., J.M. Myers, M.J. Ford, R G. Cope, G.R. Pess, R S. Waples, G.A. Winans, B.A. Berejikian, F.W. Waknitz, P.B. Adams, P.A. Bisson, D.E. Campton, and R.R. Reisenbichler. 2007. Status review of Puget Sound steelhead (Oncorhynchus mykiss). U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-81.

Hood Canal Coordinating Council (HCCC). 2005. Hood Canal and Eastern Strait of Juan de Fuca summer chum salmon recovery plan. Version November 15, 2005. 339 pp.

Hecht, S.A., Baldwin DH, Mebane CA, Hawkes T, Gross SJ, and Scholz NL. 2007. An overview of sensory effects on juvenile salmonids exposed to dissolved copper: Applying a benchmark concentration approach to evaluate sub-lethal neurobehavioral toxicity. National Marine Fisheries Service, NOAA Technical Memorandum NMFS-NWFSC-83, Seattle, WA.

Heintz, R.A., 2007. Chronic exposure to polynuclear aromatic hydrocarbons in natal habitats leads to decreased equilibrium size, growth, and stability of pink salmon populations. Integr. Environ. Assess. Manag. 3, 351–363.

Heintz, R.A., Rice, S.D., Wertheimer, A.C., Bradshaw, R.F., Thrower, F.P., Joyce, J.E., Short, J.W., 2000. Delayed effects on growth and marine survival of pink salmon Oncorhynchus gorbuscha after exposure to crude oil during embryonic development. Mar. Ecol. Prog. Ser. 208, 205–216.

Hicken, C.E., Linbo, T.L., Baldwin, D.H., Willis, M.L., Myers, M.S., Holland, L., Larsen, M., Stekoll, M.S., Rice, G.S., Collier, T.K., Scholz, N.L., Incardona, J.P., 2011. Sub-lethal exposure to crude oil during embryonic development alters cardiac morphology and reduces aerobic capacity in adult fish. Proc. Natl. Acad. Sci. U. S. A. 108, 7086–7090.

Hinck, J.E., C.J. Schmitt, V.S. Blazer, N.D. Denslow, T.M. Bartish, P.J. Anderson, J.J. Coyle, G.M. Dethloff, and D.E. Tillitt. 2006. Environmental contaminants and biomarker responses in fish from the Columbia River and its tributaries: spatial and temporal trends. Science of the Total Environment 366: 549-578.

Hites, R.A. 2004. Polybrominated diphenyl ethers in the environment and in people: a meta-analysis of concentrations. Environmental Science and Technology 38: 945-956.

Hook, S., A. Skillman, J. Small, and I. Schultz. 2006. Gene expression patterns in rainbow trout, Oncorhynchus mykiss, exposed to a suite of model toxicants. Aquatic Toxicology 77: 372-385

HSRG. 2009. Columbia River Hatchery Reform System-Wide Report. February 2009. Prepared by Hatchery Scientific Review Group. 278p.

Hunter, M.A. 1992. Hydropower flow fluctuations and salmonids: A review of the biological effects, mechanical causes, and options for mitigation. Washington Department of Fisheries. Technical Report No. 119. Olympia, Washington.

Incardona, J. P., & Scholz, N. L. 2016. The influence of heart developmental anatomy on cardiotoxicity-based adverse outcome pathways in fish. Aquatic Toxicology, 177, 515-525..

Incardona, J.P., Carls, M.G., Holland, L., Linbo, T.L., Baldwin, D.H., Myers, M.S., Peck, K.A., Rice, S.D., Scholz, N.L., 2015. Very low embryonic crude oil exposures cause lasting cardiac defects in salmon and herring. Sci. Rep. 5, 17326.

Incardona, J.P., Gardner, L.D., Linbo, T.L., Brown, T.L., Esbaugh, A.J., Mager, E.M., Stieglitz, J.D., French, B.L., Labenia, J.S., Laetz, C.A., Tagal, M., Sloan, C.A., Elizur, A., Benetti, D.D., Grosell, M., Block, B.A., Scholz, N.L., 2014. Deepwater horizon crude oil impacts the developing hearts of large predatory pelagic fish. Proc. Natl. Acad. Sci. U. S. A. 111.

Incardona, J.P., Swarts, T.L., Edmunds, R.C., Linbo, T.L., Edmunds, R.C., Aquilina-Beck, A., Sloan, C.A., Gardner, L.D., Block, B.A., Scholz, N.L., 2013. Exxon Valdez to Deepwater Horizon: comparable toxicity of both crude oils to fish early life stages. Aquat. Toxicol. 142–143, 303–316.

Independent Scientific Advisory Board (ISAB, editor). 2007. Climate change impacts on Columbia River Basin fish and wildlife. In: Climate Change Report, ISAB 2007-2. Independent Scientific Advisory Board, Northwest Power and Conservation Council. Portland, Oregon.

Intergovernmental Panel on Climate Change (IPCC). 2014. Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.

Isaak, D.J., Wollrab, S., Horan, D. and Chandler, G., 2012. Climate change effects on stream and river temperatures across the northwest US from 1980–2009 and implications for salmonid fishes. Climatic Change 113(2): 499-524.

Iwata, M. 1995. Downstream migratory behavior of salmonids and its relationship with cortisol and thyroid hormones: a review. Aquaculture 135: 131-139.

Janssens, L. and R. Stoks. 2017. Stronger effects of Roundup than its active ingredient glyphosate in damselfly larvae. Aquatic Toxicology 193: 210-216.

Johnson, A., and D. Norton. 2005. Concentrations of 303(d) Listed Pesticides, PCBs, and PAHs Measured with Passive Samplers Deployed in the Lower Columbia River. Washington State Department of Ecology, Olympia, WA. Publication No. 05-03-006.

Johnson, L.L., B. Anulacion, M. Arkoosh, O.P. Olson, C. Sloan, S.Y. Sol, J. Spromberg, D.J. Teel, G. Yanagida, and G. Ylitalo. 2013a. Persistent organic pollutants in juvenile Chinook salmon in the Columbia River Basin: implications for stock recovery. Transactions of the American Fisheries Society 142: 21-40. DOI: 10.1080/00028487.2012.720627

Johnson, L.L., B.F. Anulacion, M.R. Arkoosh, D.G. Burrows, D.A.M. da Silva, J.P. Dietrich, M.S. Myers, J. Spromberg, and G.M. Ylitalo. 2013b. Effects of legacy persistent organic pollutants (POPs) in fish—current and future challenges. Fish Physiology 33: 53-140.

Johnson, L.L., G.M. Ylitalo, C.A. Sloan, B.F. Anulacion, A.N. Kagley, M.R. Arkoosh, T.A. Lundrigan, K. Larson, M. Siipola, and T.K. Collier. 2007. Persistent organic pollutants in out-migrant juvenile Chinook salmon from the Lower Columbia Estuary, USA. Science of the Total Environment 374: 342–366.

Johnson, L.L., G.M. Ylitalo, M.R. Arkoosh, A.N. Kagley, C. Stafford, J.L. Bolton, J. Buzitis, B.F. Anulacion, and T.K. Collier. 2006. Contaminant exposure in out-migrant juvenile salmon from Pacific Northwest estuaries of the United States. Environmental Monitoring and Assessment 87: 1-28.

Johnson, V.G., R.E. Peterson, and K.B. Olsen. 2005. Heavy metal transport and behavior in the lower Columbia River, USA. Environmental Monitoring and Assessment 110: 271-289.

Jonsson, S., A. Andersson, M.B. Nilsson, U. Skyllberg, E. Lundberg, J.K. Schaefer, S. Akerblom, and E. Bjorn. 2017. Terrestrial discharges mediate trophic shifts and enhance methylmercury accumulation in estuarine biota. Science Advances 3: e1601239.

Jorgensen, J.C., M.M. McClure, M.B. Sheer, and N.L. Munn. 2013. Combined effects of climate change and bank stabilization on shallow water habitats of Chinook salmon. Conservation Biology 27: 1201-1211.

Jung, J.-H., Hicken, C.E., Boyd, D., Anulacion, B.F., Carls, M.G., Shim, W.J., Incardona, J.P., 2013. Geologically distinct crude oils cause a common cardiotoxicity syndrome in developing zebrafish. Chemosphere 91, 1146–1155.

Jung, J.-H., Kim, M., Yim, U.H., Ha, S.Y., Shim, W.J., Chae, Y.S., Kim, H., Incardona, J.P., Linbo, T.L., Kwon, J.H., 2015. Differential toxicokinetics determines the sensitivity of two marine embryonic fish exposed to Iranian heavy crude oil. Environ. Sci. Technol. 49, 13639–13648.

Kapp, K.J., and E. Yeatman. 2018. Microplastic hotspots in the Snake and lower Columbia rivers: a journey from the Greater Yellowstone Ecosystem to the Pacific Ocean. Environmental Pollution 241: 1082-1090.

Karrow, N., H.J. Boermans, D.G. Dixon, A. Hontella, K.R. Soloman, J.J. White, and N.C. Bols. 1999. Characterizing the immunotoxicity of creosote to rainbow trout (Oncorhynchus mykiss): a microcosm study. Aquatic Toxicology. 45 (1999) 223–239.

Kellock, K.A., A.P. Moore, and R.B. Bringolf. 2018. Chronic nitrate exposure alters reproductive physiology in fathead minnows. Environmental Pollution 232: 322-328.

King County. 2019. WRIA 9 Marine Shoreline Monitoring and Compliance Project Phase 2 Final Report. Prepared by Kollin Higgins, King County Water and Land Resources Division, Science and Technical Support Section. Seattle, Washington.

Kjaer, J., V. Ernstsen, O. Jacobsen, N. Hansen, L. Wollesen de Jonge, and P. Olsen. 2011. Transport modes and pathways of the strongly sorbing pesticides glyphosate and pendimethalin through structured drained soils. Chemosphere 84:471-479.

Kondolf, G.M. 1997. Hungry water: Effects of dams and gravel mining on river channels. Environmental Management 21(4):533-551.

Kubsad, D., E. Nilsson, S. King, I. Sadler-Riggleman, D. Beck and M. Skinner. 2019. Assessment of glyphosate induced epigenetic transgenerational inheritance of pathologies and sperm epimutations: Generational toxicology. Scientific Reports 9: 6372.

Kunkel, K. E., L. E. Stevens, S. E. Stevens, L. Sun, E. Janssen, D. Wuebbles, K. T. Redmond, and J. G. Dobson. 2013. Regional Climate Trends and Scenarios for the U.S. National Climate Assessment: Part 6. Climate of the Northwest U.S. NOAA Technical Report NESDIS 142-6. 83 pp. National Oceanic and Atmospheric Administration, National Environmental Satellite, Data, and Information Service, Washington, D.C.

Laetz, C.A., D.H. Baldwin, T.K. Collier, V. Hebert, J.D. Stark, and N.L. Scholz. 2009. The synergistic toxicity of pesticide mixtures: implications for risk assessment and the conservation of endangered Pacific salmon. Environmental Health Perspectives 117: 348-353.

Landrum, P.F., and D. Scavia. 1983. Influence of sediment on anthracene uptake, depuration, and biotransformation by the amphipod Hyalella azteca. Canada. J. Fish. Aquatic Sci. 40:298-305.

Landrum, P.F., B.J. Eadie, W.R. Faust, N.R. Morehead, and M.J. McCormick. 1984. Role of sediment in t e bioaccumulation of benzo(a)pyrene by the amphipod, Pontoporeia hoyi. Pages 799-812 in M. Cooke and A.J. Dennis (eds.). Polynuclear aromatic hydrocarbons: mechanisms, methods and metabolism. Battelle Press, Columbus, Ohio.

Lawson, P. W., Logerwell, E. A., Mantua, N. J., Francis, R. C., and V. N. Agostini. 2004. Environmental factors influencing freshwater survival and smolt production in Pacific Northwest coho salmon (Oncorhynchus kisutch). Canadian Journal of Fisheries and Aquatic Sciences 61(3): 360-373

Layshock, J., M. Webb, O. Langness, J.C. Garza, L. Heironimus, and D. Gundersen. 2021. Organochlorine and metal contaminants in the blood plasma of green sturgeon caught in Washington coastal estuaries. DOI: https://doi.org/10.21203/rs.3.rs-172046/v1

Lee, R. and G. Dobbs. 1972. Uptake, Metabolism and Discharge of Polycyclic Aromatic Hydrocarbons by Marine Fish. Marine Biology. 17, 201-208.

Levin P.S., E.R. Howe, and J.C. Robertson. 2020. Impacts of stormwater on coastal ecosystems: the need to match the scales of management objectives and solutions. Phil. Trans. R. Soc. B 375: 20190460 http://dx.doi.org/10.1098/rstb.2019.0460

Madison, B.N., Hodson, P.V., Langlois, V.S., 2015. Diluted bitumen causes deformities and molecular responses indicative of oxidative stress in Japanese medaka embryos. Aquat. Toxicol. 165, 222–230

Major K.M., B.M. DeCourten, J. Li, M. Britton, M.L. Settles, A.C. Mehinto, R.E. Connon, and S.M. Brander. 2020. Early Life Exposure to Environmentally Relevant Levels of Endocrine Disruptors Drive Multigenerational and Transgenerational Epigenetic Changes in a Fish Model. Frontiers in Marine Science 7: 471. doi: 10.3389/fmars.2020.00471

Mantua, N., I. Tohver, and A. Hamlet. 2010. Climate change impacts on streamflow extremes and summertime stream temperature and their possible consequences for freshwater salmon habitat in Washington State. Climatic Change 102(1): 187-223.

Martin, J.D., Adams, J., Hollebone, B., King, T., Brown, R.S., Hodson, P.V., 2014. Chronic toxicity of heavy fuel oils to fish embryos using multiple exposure scenarios. Environ. Toxicol. Chem. 33, 677–687

McCain, B., D.C. Malins, M.M. Krahn, D.W. Brown, W.D. Gronlund, L.K. Moore, and S-L. Chan. 1990. Uptake of Aromatic and Chlorinated Hydrocarbons by Juvenile Chinook Salmon (Oncorhynchus tshawytscha) in an Urban Estuary. Arch. Environ. Contam. Toxicol. 19, 10-16 (1990).

McCullough, D. A. 1999. A Review and Synthesis of Effects of Alterations to the Water Temperature Regime on Freshwater Life Stages of Salmonids, with Special Reference to Chinook Salmon. EPA 910-R-99-010, July 1999. CRITFC, Portland, Oregon. 291p.

McElhany, P., M.H. Ruckelshaus, M.J. Ford, T.C. Wainwright, and E.P. Bjorkstedt. 2000. Viable Salmonid Populations and the Recovery of Evolutionarily Significant Units. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-42. June 2000. 156 pp.

McIntyre, J. K., Davis, J. W., Hinman, C., Macneale, K. H., Anulacion, B. F., Scholz, N. L., & Stark, J. D. 2015. Soil bioretention protects juvenile salmon and their prey from the toxic impacts of urban stormwater runoff. Chemosphere, 132, 213-219.

Mcintyre, J.K, D.H. Baldwin, D.A. Beauchamp, and N.L. Scholz. 2012. Low-level copper exposures increase visibility and vulnerability of juvenile coho salmon to cutthroat trout predators. Ecological Applications, 22(5), 2012, pp. 1460–1471

McIntyre, J.K., Edmunds, R.C., Anulacion, B.F., Davis, J.W., Incardona, J.P., Stark, J.D., Scholz, N.L., 2016a. Severe coal tar sealcoat runoff toxicity to fish is prevented by bioretention filtration. Environ. Sci. Technol. 50, 1570–1578.

McIntyre, J.K., Edmunds, R.C., Redig, M.G., Mudrock, E.M., Davis, J.W., Incardona, J.P., Stark, J.D., Scholz, N.L., 2016b. Confirmation of stormwater bioretention treatment effectiveness using molecular indicators of cardiovascular toxicity in developing fish. Environ. Sci. Technol. 50, 1561–1569.

McIntyre, J.K., et al., 2018. Interspecies Variation in the Susceptibility of adult Pacific salmon to Toxic Urban Stormwater Runoff. Env. Pollution 238:196-203.

McMahon, T.E., and G.F. Hartman. 1989. Influence of cover complexity and current velocity on winter habitat use by juvenile coho salmon (Oncorhynchus kisutch). Canadian Journal of Fisheries and Aquatic Sciences 46: 1551–1557.

Meador, J.P., F.C. Sommers, G.M. Ylitalo and C.A. Sloan. 2006. Altered growth and related physiological responses in juvenile Chinook salmon (Oncorhynchus tshawytscha) from dietary exposure too polycyclic aromatic hydrocarbons (PAHs). Canadian Journal of Fisheries and Aquatic Sciences 63: 2364-2376.

Meador, J.P., J.E. Stein, W.L. Reichert, and U. Varanasi. 1995. Bioaccumulation of polycyclic aromatic hydrocarbons by marine organisms. Reviews of Environmental Contamination and Toxicology 143: 79-165.

Mebane, C., and D. Arthaud. 2010. Extrapolating growth reductions in fish to changes in population extinction risks: copper and Chinook salmon. Human and Ecological Risk Assessment 16: 1026-1065.

Meyer, J. L., M. J. Sale, P. J. Mulholland, and N. L. Poff. 1999. Impacts of climate change on aquatic ecosystem functioning and health. JAWRA Journal of the American Water Resources Association 35(6): 1373-1386

Moore, M. E., and B. A. Berejikian. 2017. Population, habitat, and marine location effects on early marine survival and behavior of Puget Sound steelhead smolts. Ecosphere 8(5):e01834. 10.1002/ecs2.1834

Moore, M. E., B. A. Berejikian, and E. P. Tezak. 2013. A Floating Bridge Disrupts Seaward Migration and Increases Mortality of Steelhead Smolts in Hood Canal, Washington State. PloS one. September 2013. Vol 8. Issue 9. E73427. 10 pp.

Moore, M. E., F. A. Goetz, D. M. Van Doornik, E. P. Tezak, T. P. Quinn, J. J. Reyes-Tomassini, and B. A. Berejikian. 2010. Early marine migration patterns of wild coastal cutthroat trout (Oncorhynchus clarki clarki), steelhead trout (Oncorhynchus mykiss), and their hybrids. PLoS ONE 5(9):e12881. Doi:10.1371/journal.pone.0012881. 10 pp.

Mote, P.W, A. K. Snover, S. Capalbo, S.D. Eigenbrode, P. Glick, J. Littell, R.R. Raymondi, and W.S. Reeder. 2014. Ch. 21: Northwest. In Climate Change Impacts in the United States: The Third National Climate Assessment, J. M. Melillo, T.C. Richmond, and G.W. Yohe, Eds., U.S. Global Change Research Program, 487-513.

Mote, P.W., D.E. Rupp, S. Li, D.J. Sharp, F. Otto, P.F. Uhe, M. Xiao, D.P. Lettenmaier, H. Cullen, and M. R. Allen. 2016. Perspectives on the cause of exceptionally low 2015 snowpack in the western United States, Geophysical Research Letters, 43, doi:10.1002/2016GLO69665.

Mote, P.W., J.T. Abatzoglou, and K.E. Kunkel. 2013. Climate: Variability and Change in the Past and the Future. In Climate Change in the Northwest: Implications for Our Landscapes, Waters, and Communities, edited by M.M. Dalton, P.W. Mote, and A.K. Snover, 41-58. Island Press, Washington, DC.

Motta, E., K. Raymann, and N. Moran. 2018. Glyphosate perturbs the gut microbiota of honey bees. Proceedings of the National Academy of Sciences USA 115: 10305-10310.

Myers, J. M., J. J. Hard, E. J. Connor, R. A. Hayman, R. G. Kope, G. Lucchetti, A. R. Marshall, G. R. Pess, and B. E. Thompson. in press. Identifying historical populations of steelhead within the Puget Sound distinct population segment Page 149 p. in U.S. Department of Commerce, editor.

Myers, J. M., J. J. Hard, E. J. Connor, R. A. Hayman, R. G. Kope, G. Lucchetti, A. R. Marshall, G. R. Pess, and B. E. Thompson. 2015. Identifying historical populations of steelhead within the Puget Sound distinct population segment. U.S. Dept. Commerce, NOAA Tech. Memo. NMFS-NWFSC 128.

Neff, J. 1985. Polycyclic aromatic hydrocarbons. Pages 416-454 in G.M. Rand and S.R. Petrocelli, editors. Fundamentals of aquatic toxicology. Hemisphere Publishing, Washington, D.C.

Neff, J. M., B. A. Cox, D. Dixit, and J. W. Anderson. 1976. Accumulation and release of petroleum-derived aromatic hydrocarbons by four species of marine animals. Marine Biology 38(3):279-289. https://setac.onlinelibrary.wiley.com/doi/abs/10.1002/etc.5620151218

Neff, J.M. 1982. Accumulation and release of polycyclic aromatic hydrocarbons from water, food, and sediment by marine animals. Pages 282-320 in N.L. Richards and B.L. Jackson (eds.). Symposium: carcinogenic polynuclear aromatic hydrocarbons n the marine environment. U.S. Environ. Protection Agency Rep. 600/9-82-013.

Nilsen, E., S. Zaugg, D. Alvarez, J. Morace, I. Waite, T. Counihan, J. Hardman, L. Torres, R. Patino, M. Mesa, and R. Grove. 2014. Contaminants of legacy and emerging concern in largescale suckers (Catastomus macrocheilus) and the food web in the lower Columbia River, Oregon and Washington, USA. Science of the Total Environment 484: 344-352.

Nilsen, E., W. Hapke, B. McIlraith and D. Markovchick. 2015. Reconnaissance of contaminants in larval Pacific lamprey (Entosphenus tridentatus) tissues and habitats in the Columbia River Basin, Oregon and Washington, USA. Environmental Pollution 201: 121-130.

NMFS (National Marine Fisheries Service). 2019. ESA Recovery Plan for the Puget Sound Steelhead Distinct Population Segment (Oncorhynchus mykiss). National Marine Fisheries Service. Seattle, WA.

NMFS. 2000. Guidelines for Electrofishing Waters Containing Salmonids Listed Under the Endangered Species Act. National Marine Fisheries Service Protected Resource Division, Portland, OR.

NMFS. 2005a. Appendix A CHART assessment for the Puget Sound salmon evolutionary significant unit from final assessment of NOAA Fisheries' Critical Habitat Analytical Review Teams for 12 ESUs of West Coast salmon and steelhead. August 2005. 55p.

NMFS. 2005b. Evaluation of and Recommended Determination on a Resource Management Plan (RMP), Pursuant to the Salmon and Steelhead 4(d) Rule. Puget Sound Comprehensive Chinook Management Plan: Harvest Management Component. NMFS, Northwest Region, Sustainable Fisheries Division. January 27, 2005. 2004/01962. 100p.

NMFS. 2005d. A Joint Tribal and State Puget Sound Chinook salmon harvest Resource Management Plan (RMP) submitted under Limit 6 of a section 4(d) Rule of the Endangered Species Act (ESA) - Decision Memorandum. Memo from S. Freese to D. Robert Lohn. NMFS NW Region. March 4, 2005.

NMFS. 2006. Final supplement to the Shared Strategy's Puget Sound salmon recovery plan.in National Marine Fisheries Service, Northwest Region, editor., Seattle.

NMFS. 2006b. Final supplement to the Shared Strategy's Puget Sound salmon recovery plan. National Marine Fisheries Service, Northwest Region. Seattle.

NMFS. 2008b. Endangered Species Act Section 7 Biological Opinion on the Effects of the Pacific Coast Salmon Plan and U.S. Fraser Panel Fisheries on the Lower Columbia River Coho and Lower Columbia River Chinook Evolutionarily Significant Units Listed under the Endangered Species Act and Magnuson-Stevens Act Essential Fish Habitat Consultation. April 28, 2008. NMFS, Portland, Oregon. Consultation No.: NWR-2008-02438. 124p.

NMFS. 2008c. Endangered Species Act Section 7 Consultation Biological Opinion and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Consultation on EPA's Proposed Approval of Revised Washington Water Quality Standards for Designated Uses, Temperature, Dissolved Oxygen, and Other Revisions. February 5, 2008. NMFS Consultation No.: NWR-2007-02301. 137p.

NMFS. 2008d. Endangered Species Act Section 7 Consultation Final Biological Opinion and Magnuson-Stevens Fishery Conservation and Managment Act Essential Fish Habitat Consultation. Implementation of the National Flood Insurance Program in the State of Washington Phase One Document-Puget Sound Region. NMFS Consultation No.: NWR-2006-00472. 226p.

NMFS. 2008e. Endangered Species Act Section 7(a)(2) Consultation Biological Opinion and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat

Consultation. Consultation on the Approval of Revised Regimes under the Pacific Salmon Treaty and the Deferral of Management to Alaska of Certain Fisheries Included in those Regimes. December 22, 2008. NMFS Consultation No.: NWR-2008-07706. 422p.

NMFS. 2008f. Endangered Species Act Section 7(a)(2) Consultation Biological Opinion and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Consultation. Consultation on Treaty Indian and Non-Indian Fisheries in the Columbia River Basin Subject to the 2008-2017 U.S. v. Oregon Management Agreement. May

NMFS. 2010. Draft Puget Sound Chinook Salmon Population Recovery Approach (PRA). NMFS Northwest Region Approach for Distinguishing Among Individual Puget Sound Chinook Salmon ESU Populations and Watersheds for ESA Consultation and Recovery Planning Purposes. November 30, 2010. Puget Sound Domain Team, NMFS, Seattle, Washington. 19p.

NMFS. 2010a. Biological Opinion on the Effects of the Pacific Coast Salmon Plan and U.S. Fraser Panel Fisheries in 2010 and 2011 on the Lower Columbia River Chinook Evolutionarily Significant Unit and Puget Sound/Georgia Basin Rockfish Distinct Populations Segments Listed Under the Endangered Species Act and Magnuson-Stevens Act Essential Fish Habitat Consultation. April 30, 2010. Consultation No.: NWR-2010-01714. 155p.

NMFS. 2011a. Evaluation of and recommended determination on a Resource Management Plan (RMP), pursuant to the salmon and steelhead 4(d) Rule comprehensive management plan for Puget Sound Chinook: Harvest management component. Salmon Management Division, Northwest Region, Seattle, Washington.

NMFS. 2012. Endangered Species Act Section 7(a)(2) Biological Opinion and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat (EFH) Consultation. EPA's Proposed Approval of Certain Oregon Administrative Rules Related to Revised Water Quality Criteria for Toxic Pollutants. August 14, 2012 NMFS Consultation No.: NWR-2008-00148. 784p.

NMFS. 2013b. ESA Recovery Plan for Lower Columbia River coho salmon, Lower Columbia River Chinook salmon, Columbia River chum salmon, and Lower Columbia River steelhead. June 2013. 503p.

NMFS. 2014a. Final Environmental Impact Statement to inform Columbia River Basin Hatchery Operations and the Funding of Mitchell Act Hatchery Programs. West Coast Region. National Marine Fisheries Service. Portland, Oregon.

NMFS. 2014b. Endangered Species Act Biological Opinion and Magnuson-Stevens Act Essential Fish Habitat Consultation. Impacts of Programs Administered by the Bureau of Indian Affairs that Support Puget Sound Tribal Salmon Fisheries, Salmon Fishing Activities Authorized by the U.S. Fish and Wildlife Service, and Fisheries. Authorized by the U.S. Fraser Panel in 2014. May 1, 2014. NMFS Consultation No.: WCR-2014-578. 156p.

NMFS. 2015a. Endangered Species Act Section 7(a)(2) Biological Opinion and Magnuson-Stevens Act Essential Fish Habitat Consultation and Fish and Wildlife Coordination Act

Recommendations for the Continued Use of Multi-User Dredged Material Disposal Sites in Puget Sound and Grays Harbor. NMFS, West Coast Region. December 17, 2015.

NMFS. 2015c. Endangered Species Act Section 7(a)(2) Biological Opinion and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Consultation. Impacts of Programs Administered by the Bureau of Indian Affairs that Support Puget Sound Tribal Salmon Fisheries, Salmon Fishing Activities Authorized by the U.S. Fish and Wildlife Service, and Fisheries. Authorized by the U.S. Fraser Panel in 2015. NMFS, Seattle, Washington. May 7, 2015. NMFS Consultation No.: WCR-2015-2433. 172p.

NMFS. 2016. Memorandum to the Record Re: WCR-2016-4769 Smith Pier Extension, 8341 Juanita Dr. NE, Kirkland, Washington – Acoustic Assessment for Planned Pile Driving. June 9, 2016. 7 pp.

NMFS. 2016a. Endangered Species Act Section 7(a)(2) Biological Opinion and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat (EFH) Consultation and Fish and Wildlife Coordination Act Recommendations. NOAA's National Marine Fisheries Service's Response for the Regional General Permit 6 (RGP6): Structures in Inland Marine Waters of Washington State. September 13, 2016. NMFS Consultation No.: WCR-2016-4361. 115p.

NMFS. 2016f. Endangered Species Act (ESA) Section 7(a)(2) Biological Opinion and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Consultation. Impacts of the Role of the BIA with Respect to the Management, Enforcement, and Monitoring of Puget Sound Tribal Salmon Fisheries, Salmon Fishing Activities Authorized by the U.S. Fish and Wildlife Service, and Fisheries Authorized by the U.S. Fraser Panel in 2016. June 24, 2016. NMFS Consultation No.: WCR-2016-4914. 196p.

NMFS. 2016h. Endangered Species Act Section 7(a)(2) Biological Opinion and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat (EFH) Consultation. National Marine Fisheries Service (NMFS) Evaluation of Three Hatchery and Genetic Management Plans for Early Winter Steelhead in the Dungeness, Nooksack, and Stillaguamish River basins under Limit 6 of the Endangered Species Act Section 4(d) Rule. April 15, 2016. NMFS Consultation No.: WCR-2015-2024. 220p.

NMFS. 2016i. Endangered Species Act Section 7(a)(2) Biological Opinion and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat (EFH) Consultation. National Marine Fisheries Service (NMFS) Evaluation of Two Hatchery and Genetic Management Plans for Early Winter Steelhead in the Snohomish River basin under Limit 6 of the Endangered Species Act Section 4(d) Rule. April 15, 2016. NMFS Consultation No.: WCR-2015-3441. 189p.

NMFS. 2017b. Endangered Species Act (ESA) Section 7(a)(2) Biological Opinion and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Response:. Impacts of the Role of the BIA Under its Authority to Assist with the Development of the 2017-2018 Puget Sound Chinook Harvest Plan, Salmon Fishing Activities Authorized by the U.S. Fish and Wildlife Service, and Fisheries Authorized by the U.S. Fraser Panel in 2017. May 3, 2017. NMFS Consultation No.: F/WCR-2017-6766. 201p.

NMFS. 2017b. Endangered Species Act Section 7(a)(2) Biological Opinion and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat (EFH) Consultation. NOAA's National Marine Fisheries Service's implementation of the Mitchell Act Final Environmental Impact Statement preferred alternative and administration of Mitchell Act hatchery funding. January 15, 2017. NMFS Consultation No.: WCR-2014-697. 535p.

NMFS. 2018c. Endangered Species Act (ESA) Section 7(a)(2) Biological Opinion and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Response. Impacts of the Role of the BIA Under its Authority to Assist with the Development of the 2018-2019 Puget Sound Chinook Harvest Plan, Salmon Fishing Activities Authorized by the U.S. Fish and Wildlife Service, and Fisheries Authorized by the U.S. Fraser Panel in 2018. May 9, 2018. NMFS, West Coast Region. NMFS Consultation No.: WCR-2018-9134. 258p.

NMFS. 2019. ESA recovery plan for the Puget Sound Steelhead Distinct Population Segment (Onchorynchus mykiss). National Marine Fisheries Service. Seattle, WA.

NMFS. 2019a. ESA Recovery Plan for the Puget Sound Steelhead Distinct Population Segment (Oncorhynchus mykiss). National Marine Fisheries Service. Seattle, WA. Retrieved from https://www.fisheries.noaa.gov/resource/document/esa-recovery-plan-puget-sound-steelhead-distinct-population-segment-oncorhynchus

NMFS. 2019b. Endangered Species Act (ESA) Section 7(a)(2) Biological Opinion and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Response: Impacts of the Role of the BIA Under its Authority to Assist with the Development of the 2019-2020 Puget Sound Chinook Harvest Plan, Salmon Fishing Activities Authorized by the U.S. Fish and Wildlife Service, and Fisheries Authorized by the U.S. Fraser Panel in 2019. May 3, 2019. National Marine Fisheries Service, West Coast Region. NMFS Consultation No.: WCR-2019-00381. 284p.

NMFS. 2019h. ESA Recovery Plan for the Puget Sound Steelhead Distinct Population Segment (Oncorhynchus mykiss). WCR/NMFS/NOAA. December 20, 2019. 174p.

NMFS. 2021e. Endangered Species Act Section 7(a)(2) Biological Opinion, and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Response for the Impacts of the Role of the BIA Under its Authority to Assist with the Development of the 2021-2022 Puget Sound Chinook Harvest Plan, the Role of the U.S. Fish and Wildlife Service in Activities Carried out under the Hood Canal Salmon Management Plan and in Funding the Washington Department of Fish and Wildlife under the Sport Fish Restoration Act in 2021-22, and the Role of the National Marine Fisheries Service in authorizing fisheries consistent with management by the Fraser Panel and Funding Provided to the Washington Department of Fish and Wildlife for Activities Related to Puget Sound Salmon Fishing in 2021-2022. May 19, 2021. NMFS Consultation No: WCRO-2021-01008. 407p.

NOAA Fisheries. 2005. Assessment of NOAA Fisheries' critical habitat analytical review teams for 12 evolutionarily significant units of West Coast salmon and steelhead. National Marine Fisheries Service, Protected Resources Division. Portland, Oregon.

Northwest Fisheries Science Center (NWFSC). 2015. Status review update for Pacific salmon and steelhead listed under the Endangered Species Act: Pacific Northwest. December 21, 2015. 356 pp.

Nunes, S.M., M.E. Josende, M. Gonzalez-Durruthy, C.P. Ruas, M.A. Gelesky, L.A. Romano, D. Fattorini, F. Regoli, J.M. Monserrat, and J. Ventura-Lima. 2018. Different crystalline forms of titanium dioxide nanomaterial (rutile and anatase) can influence the toxicity of copper in golden mussel Limnoperna fortunei? Aquatic Toxicology 205: 182-192.

Obrist, D., J.L. Kirk, L. Zhang, E.M. Sunderland, M. Jiskra, and N.E. Selin. 2018. A review of Global Environmental Mercury Processes in Response to Human and Natural Perturbations: Changes of Emissions, Climate, and Land Use. Ambio 47, 116–140 (2018). https://doi.org/10.1007/s13280-017-1004-9.

O'Neill, S.M., A.J. Carey, L.B. Harding, J.E. West, G.M. Ylitalo, and J.W. Chamberlin. 2020. Chemical tracers guide identification of the location and source of persistent organic pollutants in juvenile Chinook salmon (Oncorhynchus tshawytscha), migrating seaward through an estuary with multiple contaminant inputs. Science of the Total Environment 712: https://doi.org/10.1016/j.scitotenv.2019.135516

Palermo, F., W. Risso, J. Simonato, C. Martinez. 2015. Bioaccumulation of nickel and its biochemical and genotoxic effects on juveniles of the neotropical fish Prochilodus lineatus. Ecotoxicology and Environmental Safety 116: 19-28.

Peter, K.T., F. Hou, Z. Tian, C. Wu, M. Goehring, F. Liu, and E.P. Kolodziej. 2020. Environmental Science & Technology. 54 (10), 6152-6165

PFMC. 2014. Appendix A to the Pacific Coast Salmon Fishery Management Plan, as modified by Amendment 18. Identification and description of essential fish habitat, adverse impacts, and recommended conservation measures for salmon.

Primost, J., D. Marino, V.C. Aparicio, J.L. Costa, and P. Carriquiriborde. 2017.Glyphosate and AMPA, "pseudo-persistent" pollutants under real-world agricultural management practices in the Mesopotamic Pampas agroecosystem, Argentina. Environmental Pollution 229: 771-779.

PSIT, and WDFW. 2017a. Comprehensive Management Plan for Puget Sound Chinook: Harvest Management Component. December 1, 2017.

Puget Sound Partnership (PSP). 2021. Factors Limiting progress in salmon recovery. Salmon Science Advisory Group. QCI (2013) Integrated Status and Effectiveness Monitoring Project: Salmon Subbasin Cumulative Analysis Report: Sub-Report 3 – Estimating adult salmonid escapement using IPTDS. Quantitative Consultants, Inc. Report to BPA. Project #2003-017-00. pp 67-167.

Puget Sound Regional Council. 2020. Regional Macroeconomic Forecast. Accessed June 19, 2020, at https://www.psrc.org/regional-macroeconomic-forecast

Raymondi, R.R., J.E. Cuhaciyan, P. Glick, S.M. Capalbo, L.L. Houston, S.L. Shafer, and O. Grah. 2013. Water Resources: Implications of Changes in Temperature and Precipitation. In Climate Change in the Northwest: Implications for Our Landscapes, Waters, and Communities, edited by M.M. Dalton, P.W. Mote, and A.K. Snover, 41-58. Island Press, Washington, DC.

Reeder, W.S., P.R. Ruggiero, S.L. Shafer, A.K. Snover, L.L Houston, P. Glick, J.A. Newton, and S.M Capalbo. 2013. Coasts: Complex Changes Affecting the Northwest's Diverse Shorelines. In Climate Change in the Northwest: Implications for Our Landscapes, Waters, and Communities, edited by M.M. Dalton, P.W. Mote, and A.K. Snover, 41-58. Island Press, Washington, DC.

Relyea, R.A., and N. Diecks. 2008. An unforeseen chain of events: lethal effects of pesticides on frogs at sub-lethal concentrations. Ecological Applications 18: 1728–1742.

Rice, S.D., Thomas, R.E., Carls, M.G., Heintz, R.A., Wertheimer, A.C., Murphy, M.L., Short, J.W., Moles, A., 2001. Impacts to pink salmon following the Exxon Valdez oil spill: persistence, toxicity, sensitivity, and controversy. Rev. Fish. Sci. 9, 165–211.

Rochman, C.M., E. Hoh, T. Kurobe, and S.J. Teh. 2013. Ingested plastic transfers hazardous chemicals to fish and induces hepatic stress. Scientific Reports 3: 3263. DOI: 10.1038/srep03263.

Roubal, W. T., Collier, T. K., and Malins, D. C. 1977. Accumulation and metabolism of carbon-14 labeled benzene, naphthalene, and anthracene by young Coho salmon (Oncorhynchus kisutch). Archives of Environmental Contamination and Toxicology, 5, 513-529. doi:https://doi.org/10.1007/BF02220929

Ruckelshaus, M., K. Currens, W. Graeber, R. Fuerstenberg, K. Rawson, N. Sands, and J. Scott. 2002. Planning ranges and preliminary guidelines for the delisting and recovery of the Puget Sound Chinook salmon evolutionarily significant unit. Puget Sound Technical Recovery Team. National Marine Fisheries Service, Northwest Fisheries Science Center. Seattle.

Sandahl, J.F., D. Baldwin, J.J. Jenkins, and N.L. Scholz. 2007. A Sensory System at the Interface between Urban Stormwater Runoff and Salmon Survival. Environmental Science and Technology. 2007, 41, 2998-3004.

Santore, R.C., D.M. Di Toro, P.R. Paquin, H.E. Allen, and J.S. Meyer. 2001. Biotic ligand model of the acute toxicity of metals. 2. Application to acute copper toxicity in freshwater fish and Daphnia. Environmental Toxicology and Chemistry 20(10):2397-2402.

Scheuerell, M.D., and J.G. Williams. 2005. Forecasting climate-induced changes in the survival of Snake River spring/summer Chinook salmon (Oncorhynchus tshawytscha). Fisheries Oceanography 14:448-457.

Scholz, N.L., E. Fleishman, L. Brown, I. Werner, M.L. Johnson, M.L. Brooks, C.L. Mitchelmore, and D. Schlenk. 2012. A perspective on modern pesticides, pelagic fish declines, and unknown ecological resilience in highly managed ecosystems. BioScience 62: 428-434.

Scholz, N.L., M.S. Myers, S.G. McCarthy, J.S. Labenia, J.K. McIntyre, G.M. Ylitalo, L.D. Rhodes, C.A. Laetz, C.M. Stehr, B.L. French, B. McMillan, D. Wilson, L. Reed, K.D. Lynch, S. Damm, J.W. Davis, and T.K. Collier. 2011. Recurrent die-offs of adult coho salmon returning to spawn in Puget Sound lowland urbans streams. PLoS ONE 6: e28013. doi.10.1371/journal.pone.0028013.

Scully-Engelmeyer, K., E.F. Granek, M. Nielsen-Pincus, A. Lanier, S.S. Rumrill, P. Moran, E. Nilsen, M.L. Hladik, and L. Pillsbury. 2021. Exploring biophysical linkages between coastal forestry management practices and aquatic bivalve contaminant exposure. Toxics 9: 46-71. https://doi.org/10.3390/toxics9030046

Seiders, K., C. Deligeannis, and M. Friese. 2011. Focus on Fish Testing: Snake River Fish Tested for Chemicals. Washington State Department of Ecology, Olympia, WA. Publication No. 11-03-067. 6 pp. https://apps.ecology.wa.gov/publications/documents/1103067.pdf

Seiders, K., C. Deligeannis, and P. Sandvik. 2007. Washington State Toxics Monitoring Program: Toxic Contaminants in Fish Tissue and Surface Water in Freshwater Environments, 2004-2005. Washington State Department of Ecology, Olympia, WA. Publication No. 07-03-024.

Sevcikova, M., H. Modra, A. Slaninova, and Z. Svobodova. 2011. Metals as a cause of oxidative stress in fish: a review. Veterinarni Medicina 56: 537-546.

Shared Strategy for Puget Sound (SSPS). 2007. Puget Sound Salmon Recovery Plan – Volume 1. Shared Strategy for Puget Sound, 1411 4th Ave., Ste. 1015, Seattle, WA 98101. Adopted by NMFS January 19, 2007. 503 pp.

Sharma, R.K., and M. Agrawal. 2005. Biological effects of heavy metals: an overview. Journal of Environmental Biology 26: 301-313.

Skidmore, J.E. 1964. Toxicity of zinc compounds to aquatic animals, with special reference to fish. Quarterly Review of Biology 39: 227-248.

Sloan, C.A., B.F. Anulacion, J.L. Bolton, D. Boyd, O.P. Olsen, S.Y. Sol, G.M. Ylitalo, and L.L. Johnson. 2010. Polybrominated diphenyl ethers in out-migrant juvenile Chinook salmon from the lower Columbia River and Estuary and Puget Sound, Washington. Archives of Environmental Contaminant Toxicology 58: 403-414.

Sørhus, E., Edvardsen, R.B., Karlsen, O., Nordtug, T., van der Meeren, T., Thorsen, A., Harman, C., Jentoft, S., Meier, S., 2015. Unexpected interaction with dispersed crude oil droplets drives severe toxicity in Atlantic haddock embryos. PLoS One 10, e0124376.

Soto, A.M., K.L. Chung, and C. Sonnenschein. 1994. The pesticides endosulfan, toxaphene, and dieldrin have estrogenic effects on human estrogen-sensitive cells. Environmental Health Perspectives 102: 380-383.

Spence, B.C., G.A. Lomnicky, R.M. Hughes, and R.P. Novitzki. 1996. An ecosystem approach to salmonid conservation. ManTech Environmental Research Services, Inc. Corvallis, Oregon. National Marine Fisheries Service, Portland, Oregon.

Spromberg, J.A., and J.P. Meador. 2006. Relating chronic toxicity responses to population -level effects: A comparison of population-level parameters for three salmon species as a function of low-level toxicity. Publications, Agencies and Staff of the U.S. Department of Commerce. 216. https://digitalcommons.unl.edu/usdeptcommercepub/216

Spromberg, J.A. and N.L. Scholz. 2011. Estimating the Future Decline of Wild Coho Salmon Populations Resulting from Early Spawner Die-offs in Urbanizing Watersheds of the Pacific Northwest, USA. Integrated Environmental Assessment and Management. Volume 7, Number 4, pages 648-656.

Spromberg, J.A, D.H. Baldwin, S.E. Damm, J.K. McIntyre, M. Huff, C.A. Sloan, B.F. Anulacion, J.W. Davis, and N.L. Scholz. 2015. Coho salmon spawner mortality in western US urban watersheds: bioinfiltration prevents lethal storm water impacts. Journal of Applied Ecology. DOI: 10.1111/1365-2264.12534

Spromberg, J.A., et al., 2016. Coho Salmon Spawner mortality in western U.S. urban watersheds: bioinfiltration prevents lethal stormwater impacts. J.Applied Ecology 53:398-407.

SSPS. 2005. Puget Sound Salmon Recovery Plan. Volumes I, II and III. Plan Adopted by the National Marine Fisheries Service (NMFS) January 19, 2007. Submitted by the Shared Strategy Development Committee. Shared Strategy for Puget Sound. Seattle, Washington.

Stohs, S. and D. Bagchi. 1995. Oxidative mechanisms in the toxicity of metals ions. Free Radical Biology and Medicine 2: 321–336.

Stone, D. 2006. Polybrominated diphenyl ethers and polychlorinated biphenyls in different tissue types from Chinook salmon (Oncorhynchus tshawytscha). Bulletin of Environmental Contamination and Toxicology 76: 148-154.

Sunda, W. G., and W. J. Cai. 2012. Eutrophication induced CO2-acidification of subsurface coastal waters: interactive effects of temperature, salinity, and atmospheric p CO2. Environmental Science & Technology, 46(19): 10651-10659

Tague, C. L., Choate, J. S., & Grant, G. 2013. Parameterizing sub-surface drainage with geology to improve modeling streamflow responses to climate in data limited environments. Hydrology and Earth System Sciences 17(1): 341-354.

Tattam, I. A., J. R. Ruzycki, H. W. Li, and G. R. Giannico. 2013. Body size and growth rate influence emigration timing of Oncorhynchus mykiss. Transactions of the American Fisheries Society 142: 1406-1414.

Thompson, J. N. and D. A. Beauchamp. 2014. Size-selective mortality of steelhead during freshwater and marine life stages related to freshwater growth in the Skagit River, Washington. Transactions of the American Fisheries Society 143: 910-925

Tian, L., S. Yin, Y. Ma, H. Kang, X. Zhang, H. Tan, H. Meng, and C. Liu. 2019. Impact factor assessment of the uptake and accumulation of polycyclic aromatic hydrocarbons by plant leaves: morphological characteristics have the greatest impact. Science of the Total Environment 652: 1149–1155.

Tian, Z., et al. (2021). A ubiquitous tire rubber–derived chemical induces acute mortality in coho salmon. Science 371(6525): 185-189.

Tillmann, P. and D. Siemann. 2011. Climate Change Effects and Adaptation Approaches in Marine and Coastal Ecosystems of the North Pacific Landscape Conservation Cooperative Region. National Wildlife Federation. Retrieved from https://www.nwf.org/~/media/PDFs/Global-Warming/2014/Marine-Report/NPLCC_Marine_Climate-Effects_Final.pdf

Trudeau, M.P. 2017. State of the knowledge: Long-term, cumulative impacts of urban wastewater and stormwater on freshwater systems. Final Report Submitted to the Canadian Water Network. January 30, 2017.

Tsui, M.K., W. Wang, and L.M. Chu. 2005. Influence of glyphosate and its formulation (Roundup) on the toxicity and bioavailability of metals to Ceriodaphnia dubia. Environmental Pollution 138: 59-68.

USDC. 2013. Endangered and threatened species; Designation of critical habitat for Lower Columbia River coho salmon and Puget Sound steelhead; Proposed rule. U.S Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service. Federal Register 78:2726-2796.

USDC. 2014. Endangered and threatened wildlife; Final rule to revise the Code of Federal Regulations for species under the jurisdiction of the National Marine Fisheries Service. U.S Department of Commerce. Federal Register 79:20802-20817.

USGCRP. 2009. Global climate change impacts in the United States. U.S. Global Change Research Program, Washington, D.C.

Vanderputte I., J. Lubbers, and Z. Kolar. 1981. Effect of pH on uptake, tissue distribution and retention of hexavalent chromium in rainbow trout (Salmo gairdneri). Aquatic Toxicology 1: 3-18.

Varanasi, U., E. Casillas, M. R. Arkoosh, T. Hom, D. A. Misitano, D. W.Brown, S. L. Chan, T. K. Collier, B. B. McCain, and J. E. Stein. 1993. Contaminant exposure and associated biological effects in juvenile Chinook salmon (Oncorhynchus tshawytscha) from urban and nonurban estuaries of Puget Sound. (NMFS-NWFSC-8). Seattle, WA: NMFS NWFSC Retrieved from https://www.nwfsc.noaa.gov/publications/scipubs/techmemos/tm8/tm8.html

Varanasi, U., W.L. Reichert, J.E. Stein, D.W. Brown, and H.R. Sanborn. 1985. Bioavailability and biotransformation of aromatic hydrocarbons in benthic organisms exposed to sediment from an urban estuary. Environmental Science and Technology 19: 836-841.

Wainwright, T. C., and L. A. Weitkamp. 2013. Effects of climate change on Oregon Coast coho salmon: habitat and life-cycle interactions. Northwest Science 87(3): 219-242.

Walsh, C.J., A.H. Roy, J.W. Feminella, P.D. Cottingham, P.M. Groffman and R.P. Morgan. 2005. The urban stream syndrome: current knowledge and the search for a cure. Journal of the North American Benthological Society 24:706-723.

Wang, F., C.S. Wong, D. Chen, X. Lu, F. Wang, and E. Zeng. 2018. Interaction of toxic chemicals with microplastics: a critical review. Water Research 139: 208-219.

Wang, L., J. Lyons and P. Kanehl. 2001. Impacts of urbanization on stream habitat and fish across multiple spatial scales. Environmental Management 28:255-266.

Washington Department of Ecology (Ecology). 2017. General Use Level Designation for Basic (TSS) and Phosphorus Treatment. Prepared for BaySaver Technologies, LLC Bay Filter System.

Washington Department of Ecology (Ecology). 2014. 2012 Stormwater Management Manual for Western Washington as Amended in December 2014 (The 2014 SWMMWW).

Publication Number 14-10-055 Washington State Department of Ecology Water Quality Program.

Washington Department of Ecology (Ecology). 2006. PBDE Flame Retardants in Washington Rivers and Lakes: Concentrations in Fish and Water, 2005-06. Publication No. 06-03-027. August 2006. 116 pp. https://apps.ecology.wa.gov/publications/documents/0603027.pdf

Washington Department of Ecology (Ecology). 2021. https://ecology.wa.gov/Waste-Toxics/Reducing-toxic-chemicals/Addressing-priority-toxic-chemicals.

Washington Department of Transportation. 2020. Standard Specifications for Road, Bridge, and Municipal Construction. Publication M 41-10.

Water Resource Inventory Area 9 (WRIA 9). 2021. Green/Duwamish and Central Puget Sound Watershed Salmon Habitat Plan 2021 Update. Making Our Watershed Fit for a King. Approved by the Watershed Ecosystem Forum February 11, 2021.

Washington Department of Fish and Wildlife (WDFW). 2009. Fish passage and surface water diversion screening assessment and prioritization manual. Washington Department of Fish and Wildlife. Olympia, Washington. WDFW 2021

Winder, M. and D. E. Schindler. 2004. Climate change uncouples trophic interactions in an aquatic ecosystem. Ecology 85: 2100–2106.

Winder, M. and D. E. Schindler. 2004. Climate change uncouples trophic interactions in an aquatic ecosystem. Ecology 85: 2100–2106.

Young, A., Kochenkov, V., McIntyre, J.K., Stark, J.D., and Coffin, A.B. 2018. Urban stormwater runoff negatively impacts lateral line development in larval zebrafish and salmon embryos. Scientific Reports 8: 2830.

Zabel, R.W., M.D. Scheuerell, M.M. McClure, and J.G. Williams. 2006. The interplay between climate variability and density dependence in the population viability of Chinook salmon. Conservation Biology 20(1):190-200

Zhang, S., H. Yao1, Y. Lu1, X. Yu1, J. Wang, S. Sun1, M. Liu, D. Li1, Y. Li and D. Zhang. 2017. Uptake and translocation of polycyclic aromatic hydrocarbons (PAHs) and heavy metals by maize from soil irrigated with wastewater. Scientific Reports 7: 12165. DOI:10.1038/s41598-017-12437-w

6. APPENDICES

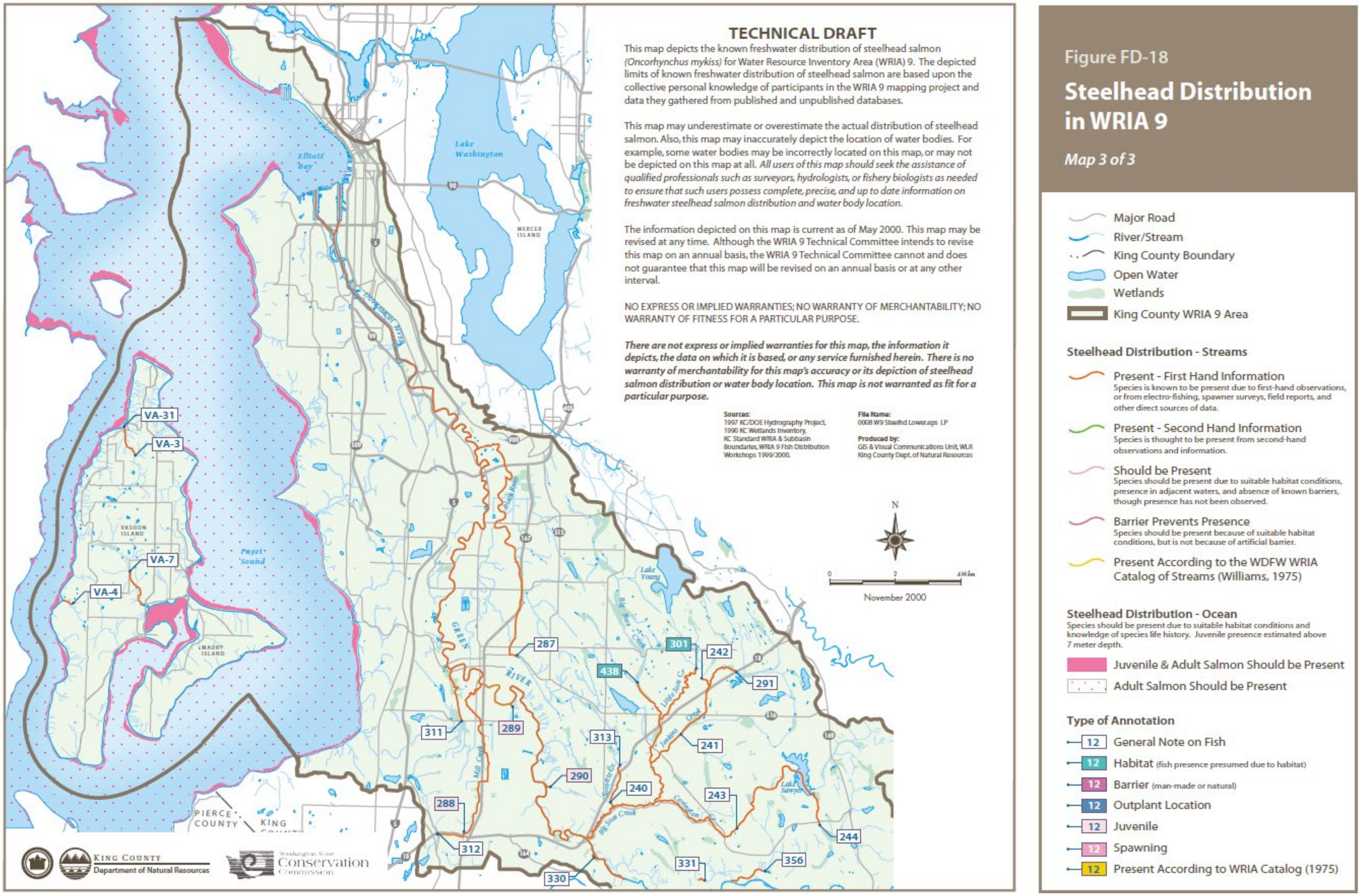


Figure A - 1. Distribution of PS steelhead lifestages and associated habitat use in the Duwamish/Lower Green River Basin.

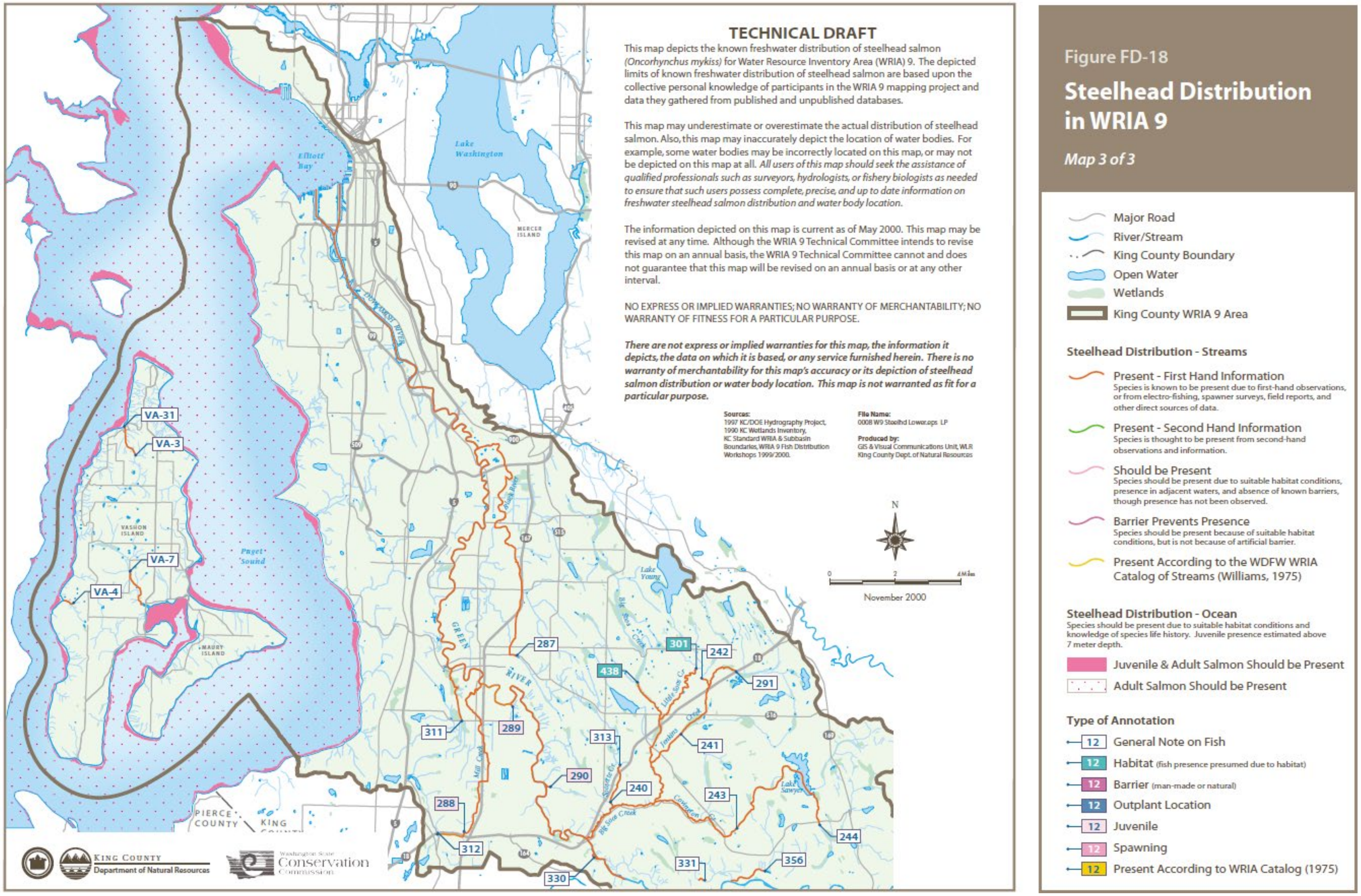


Figure A - 2. Distribution of PS Chinook salmon lifestages and associated habitat use in the Duwamish/Lower Green River Basin.