

DRAINAGE SYSTEMS ANALYSIS

Aquatic Habitat

Technical Memorandum

October 28, 2020

Seattle Public Utilities

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Salmon in Longfellow Creek, Seattle. Holli Margell, 2009. http://nativelightphoto.com/

Thornton Creek Confluence Restoration, Seattle. Natural Systems Design, 2014. http://naturaldes.com

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Abbreviations

BCL	Budget Control Level
City	City of Seattle
CSO	combined sewer overflow
DSA	Drainage System Analysis
ESA	Endangered Species Act
GIS	Geographic information system
GISP	ArcGIS enterprise server
GSI	Green Stormwater Infrastructure
ISP	Integrated System Plan
SME	Subject Matter Expert
SPR	Seattle Parks and Recreation Department
SPU	Seattle Public Utilities
SDOT	Seattle Department of Transportation
SOTW	State of the Waters
TM	Technical Memorandum
WAC	Washington Administrative Code
WADNR	Washington Department of Natural Resources
WDFW	Washington Department of Fish and Wildlife
WFC	Wild Fish Conservancy (formerly Washington Trout)
WRIA	Water Resources Inventory and Assessment
WQ	water quality
USFWS	U.S. Fish and Wildlife Service

Executive Summary

This Aquatic Habitat Topic Area Technical Memorandum (TM) describes aquatic habitat conditions and fish usage in Seattle's five main creek watersheds (Thornton, Piper's, Longfellow, Fauntleroy, and Taylor). The TM consolidates data from a wide variety of sources and highlights areas and sites previously identified as priorities for salmon recovery, shoreline restoration, or creek daylighting.

Much of the information consolidated within this TM was found in older reports and databases, some of which are 20 years old. Relevant data were used to create new Geographic Information System (GIS) maps to support Seattle Public Utilities' (SPU) Drainage System Analysis (DSA). It should be noted that, while minor updates were made to the data based on recently completed project information or mapping efforts, this effort did not include new field inventories or analysis.

This TM presents the background information on the Aquatic Habitat Topic Area, the analysis methods, results of the analysis, a discussion of results, and recommendations on how the results could be used for SPU's upcoming Integrated System Plan (ISP). Additional information is provided on data gaps, potential future work characterizing aquatic habitat conditions, and other possible uses for this information outside of the ISP.

The results of SPU's investigation are presented here through a number of PDF maps, a series of GIS data layers, and several data tables listing information about identified projects. These work products are included in the TM appendices.

Recommendations on how individual sub-topic area data sets can be used to support the ISP, as well as outside the ISP are included within each sub-topic area section. In addition, recommendations on how information from multiple sub-topic areas could be combined to inform the ISP, or other work, through broader analyses, is included in Section 9 of this document.

1. Introduction

This Aquatic Habitat Topic Area TM covers aquatic habitat conditions in Seattle. This TM consolidates existing and disparate data sources (some of which are over 20 years old) that describe the condition of aquatic creek habitats, documents fish usage in creeks, and highlights areas and sites previously identified as priorities for salmon recovery, shoreline restoration or creek daylighting.

This TM presents background information, a discussion of results, and recommendations on how the results could be used for the upcoming ISP. Additional information is also provided on data gaps, potential future work associated with the sub-topic areas, and other possible uses for this information outside of the ISP. The TM is organized into six separate sub-topic areas that cover creek habitat conditions, fish usage, and restoration opportunities.

- **Creek Habitat Conditions**
  - *Riparian Tree Canopy Density* (Section 3) – characterizes the density of riparian tree canopy cover along the City's main salmon streams.
  - *Stream Channel Habitat Quality* (Section 4) – characterizes existing instream channel conditions for the City's main salmon streams as high (best available), medium, or low (poor) based on multiple instream and riparian characteristics which are combined into a composite score. This section also characterizes fish habitat quality (spawning habitat and rearing/refuge habitat).
  - *Channel Erosion Stage* (Section 5) – characterizes channel condition on a continuum that ranges from degrading (actively incising/eroding) to aggrading (actively depositing sediment) to heavily armored (frozen) to re-stabilizing (adjusting to increased runoff, usually in response to the reconnection of channel and floodplain)
- **Fish Usage**
  - *Stream Typing* (Section 6) – summarizes the stream typing classifications (also known as water typing) for each of the urban creeks in the City which define streams with characteristics capable of supporting fish life. Water typing is based on Washington State Department of Natural Resources (WADNR) water typing protocols outlined in the Forest Practices Board Manual Section 13, and definitions found in WAC 222-16-031).
  - *Fish Use* (Section 7) – summarizes existing fish use in Seattle's urban creeks including species present, and most upstream sighting for each species including migratory salmon and resident fish. This section also identifies stream reaches with identified salmonid spawning and rearing habitat, along with the distribution of redds (egg nests) in areas accessible to salmon at the time of the habitat surveys (2002).
- **Restoration Opportunities**
  - *Shoreline and Creek Restoration Opportunities* (Section 8) – includes previously identified shoreline restoration priorities along Puget Sound, Lake Washington, and the Duwamish Waterway, as well as creek daylighting opportunities in urban stream systems.

Table 1-1 summarizes the geographic scope of each sub-topic area.

Table 1-1: Geographic Scope of Sub-topic Areas

Sub-topic Area	Main Salmon Streams	Other Seattle Streams	Duwamish River	Marine or Lake Washington Shorelines
Riparian Tree Canopy Density	❖			
Stream Channel Habitat	❖			
Channel Erosion Stage	❖			
Stream Typing	❖	❖		
Fish Usage	❖	❖		
Shoreline Restoration			❖	❖
Creek Daylighting	❖	❖		

The GIS data and other information included on the maps provided in the appendices and referenced in the body of this TM, covers just a fraction of the available data and information available in relation to stream conditions and fish use. Consequently, it is recommended that data are added and potentially updated during the development of the ISP to ensure they accurately reflect current conditions and can provide a more robust understanding of both the problems and potential opportunities in Seattle's urban watersheds.

2. Background

SPU's Strategic Business Plan identifies "protecting public health and the environment" as core work that supports SPU's mission to provide high-quality utility services. SPU's drainage and wastewater systems affect both aquatic habitat and aquatic species by impacting elements such as water quality and quantity, physical stream channel and shoreline conditions, functions, and processes, species use, and habitat.

Untreated stormwater in Seattle discharges to lakes, rivers, urban creeks, and marine receiving waters. Combined sewer overflows (CSOs) also periodically discharge to these waterbodies. Drainage ditches, culverts, and pipes installed to support development have altered the watercourses. The volume and velocity of flows has increased in some cases, causing erosion, and reducing natural water filtration and groundwater discharge/recharge dynamics.

Drainage and sewer pipes run through and under streams and wetlands, and many watercourses have been filled in, buried, and/or constrained within pipes. Aquatic habitats have also been significantly degraded as the City developed through neighborhood development, road construction, and the corresponding spread of impervious surfaces. Most of this development occurred prior to current environmental protections and before SPU was formally created as a utility.

SPU's drainage and wastewater system operations are affected by aquatic habitat conditions and species use because the work is regulated by federal, state, and local laws and policies, including the City's Stormwater Code. These laws and policies, which were established to protect public health and the environment, are described in the Regulatory Summary Topic Area, which was developed as part of the DSA. Many of these environmental regulations not only protect existing habitat, but are designed to improve the health of the environment over time.

SPU has a large quantity of information on the physical condition, ecological heath, and habitat use of the many aquatic areas located within the City, but this information is organized in a wide variety of reports, databases, and maps, some of which are over 20 years old.

The intent of this TM is to consolidate existing data into GIS data layers and maps that can be used by SPU to guide planning, policy, and capital investment strategies. Four ways the collected information can be used to directly support SPU's work, or broader City interests are listed below.

1. The information on aquatic habitat (creek habitat conditions, fish usage, and restoration opportunities) can inform SPU efforts to build and maintain its utility infrastructure to minimize and mitigate impacts to high value aquatic areas.
2. The information on restoration opportunities can be used to identify places where SPU may be able to add value to its work by improving aquatic habitat, or conversely, to help reduce impacts to aquatic habitats.
3. The information on fish usage and stream typing can be used to understand where and how work in streams will be regulated by local, state, and federal agencies; and what reaches are regulated to ensure fish passage.
4. Information on aquatic habitat (creek habitat conditions, fish usage, and restoration opportunities) can support the City's commitments to environmental protection and environmental justice and service equity by identifying aquatic habitat restoration and protection needs to ensure equitable access to healthy habitats and environmental science and stewardship efforts.

3. Riparian Tree Canopy Density

The Riparian Tree Canopy Density sub-topic area consolidates existing information on the density of the tree canopy along Seattle's five main creek watersheds and salmon streams (Thornton, Piper's, Longfellow, Fauntleroy, and Taylor).

3.1 Introduction

Green spaces, which include both vegetation and tree canopy, have been proven to support human health and well-being. Trees have been shown to provide measurable health benefits by reducing physiological stress, including a reduction in both blood pressure and heart rate (Juyoung et al., 2014). Additionally, forested areas, with their associated natural features, help to provide resiliency against the impacts of climate change and land use development.

Riparian Tree Canopy Density is just one of several indicators of stream health and habitat quality. Primary beneficial functions include:

- Absorbs greenhouse gases and improves air quality by trapping particulate matter.
- Reduces erosive peak flows by slowing down rainfall as it percolates through the canopy, and by providing stream bank integrity.
- Increases infiltration into the water table by slowing down surface flow as it flows through the canopy, and allowing it to percolate into the ground.

- Provides shade to keep stream water cool in summer, and creates a microclimate that protects stream corridors from temperature extremes during the winter.
- Contributes terrestrial insect detritus and leaf litter into the creek, which provide food for salmon and other aquatic species.
- Provides large woody material (i.e., tree limbs, dead trees) which is an essential structural element for maintaining hydraulic complexity that supports habitat diversity.

Section 3.2 provides background information, discusses the results of the analysis, and provides recommendations on how information on Riparian Tree Canopy Density can be used for the upcoming ISP. Information is also provided on data gaps, and potential future work associated with riparian tree canopy and other riparian vegetation data. Other possible uses for this information outside of the ISP are included in Section 9.

3.2 Background

Recognizing the importance of tree canopy and riparian vegetation in supporting aquatic habitat, SPU started riparian assessments in 2003 to evaluate the condition of the riparian vegetation along the five main creek watersheds in Seattle: Thornton, Piper's, Longfellow, Taylor, and Fauntleroy. The surveys collected data on riparian extent (width and longitudinal connectivity), canopy composition, understory composition, canopy density, stream shading, slope, and land use type. In the City's 2007 State of the Waters (SOTW) report (State of the Waters Report; Vol. 1: Seattle Watercourses), riparian conditions were assessed by reach, and scored on a scale from 1 to 10, with 10 being the best score. Six key factors/indicators were averaged into an overall composite score, with riparian width, connectivity, and canopy composition weighted twice as highly as the remaining factors:

Table 3-1. Riparian Quality Assessment Criteria

Key Factors/Indicators	Rating Categories
Riparian Width[a]	• Low: <20 ft • Medium: 20-50 ft • High: >50 ft
Canopy Composition/Type[a]	• None • Deciduous • Mix deciduous/coniferous • Coniferous[b]
Connectivity[a] The number of breaks/spaces (>100 ft) in the forest lining a riparian corridor.	• Low: >2 breaks/1,000 ft • Medium: 1-2 breaks/1,000 ft • High: <1 break/1,000 ft
Canopy Density Vegetative cover >15 ft above channel	• None: <1 tree/50 ft • Partial: 1-3 trees/50 ft • Full: >2 trees/50 ft
Stream Cover Vegetative cover >15 ft above channel	• Low 0-24% • Medium 25-75% • High >75%

Understory Composition Overall species diversity	• Low: lawn and/or invasive species • Medium: mixed native and non-native • High: native vegetation

Source: City of Seattle 2007 State of the Waters report

a. Factors assigned twice the weight of the other three factors analyzed.

b. Considered a 'Preferred' condition because urban riparian areas tend to have very few coniferous trees.

The original purpose of this sub-topic was to recreate the composite score based on riparian condition, but the protocol for creating the composite score is not included in the SOTW report, and initially could not be located. Fortunately, the original data used to create the SOTW maps was readily available in the ArcGIS enterprise server (GISP), making it possible to create maps depicting multiple attributes of riparian condition, as needed, including the Riparian Tree Canopy Density layer used in this TM.

The description for creating the composite score that was used in the SOTW report maps, was ultimately located on a CD containing appendices for the SOTW; a copy of it is provided in Appendix A. This appendix also provides a description of most of the key attributes available in both riparian databases (ArcGIS geodatabase and MS Access database).

3.3 Methods

For this TM, a GIS layer of tree canopy density was created using existing riparian data from the 2007 SOTW report (City of Seattle, 2007). The data was pulled from GISP.

For the GIS layer developed in association with this TM, the four riparian canopy density classes listed below were used to describe each percent cover category.

Riparian Canopy Density Classes

- Unknown
- Not Present/ Intermittent
- Partial
- Full

Unlike most of the map products produced in this TM which used a single line to represent conditions on both sides of the creek channel, the Riparian Tree Canopy Cover data was collected separately for each side of the creek and is therefore displayed as two separate parallel lines. The GIS layer package includes two separate line features that each run parallel along the creek centerline and represent riparian canopy density on the left and right stream banks. These lines were created by editing the line properties using the symbol property editor in ArcGIS and creating line offsets (2.0 for right bank) and (-2.0 for left bank). Additionally, the query builder was used to construct queries to filter data by right or left bank (Sample_Type_Code) to ensure data was properly displayed for the two offset line features.

3.4 Results

Data products associated with this sub-topic include a GIS data layer and PDF maps (Appendix B) showing the density of riparian tree canopy cover.

Review of the maps reveal that Fauntleroy and Taylor Creeks have full canopy cover throughout much of their length, with gaps in coverage in the lowermost reaches. While the upper and middle reaches of Taylor Creek are characterized by full canopy density, the lower sections of the creek have not present/ intermittent canopy cover. However, this area will be revegetated as the Taylor Creek culvert replacement and stream restoration is completed (currently in design stage). Piper's Creek has canopy cover along most of the creek length, but only about half of the creek length has full canopy cover. Most of the lower half of Piper's Creek has full canopy cover whereas much of the upper half of the creek is characterized by partial canopy cover and only the very upper most section is lacking in canopy cover. Longfellow and Thornton creek both have more variable canopy cover with extensive areas with partial or not present/ intermittent tree canopy density. These differences can be attributed largely to land ownership and past development as described more below in Section 4.5.

3.5 Discussion

The Riparian Tree Canopy Cover maps prepared for this TM depict only one of the multiple riparian vegetation datasets available in the Access and ArcGIS databases referenced in this section and do not fully characterize the riparian vegetation condition. Riparian Tree Canopy Density data was collected in 2003 to support habitat and salmon recovery needs, so it is a limited data set. It includes only the portions of the five largest streams in Seattle that are considered capable of supporting fish, also known as Type F waters (Section 5). This data was limited to places where visual observations of tree canopy cover could be made from the creek channel. There are gaps in the data where access to the creek channel was not possible and/or where a creek channel no longer exists (i.e., piped sections of creeks). Also, many of the tributaries are located on difficult to access steep slopes. Smaller tributaries, not capable of supporting fish, were not surveyed.

High-quality riparian habitat is characterized by mature, mixed coniferous and deciduous forest that exists in a wide band (buffer) around the stream, providing shade, woody debris, and leaf litter (nutrients) to the stream channel, as well as offering bank stability and stormwater runoff filtration. High-quality riparian habitat within Seattle tends to be located in public parklands-notably the large parks that include portions of Carkeek Park (Piper's Creek), and Lakeridge Park (Taylor Creek). Parkland spaces generally enable riparian corridors to be wide, exceeding 200 feet in some locations. In addition, stewardship of parklands (through the Green Seattle Partnership) helps to control invasive plant species and support native trees and shrubs.

Low-quality riparian areas are typically dominated by invasive plants (i.e., Himalayan blackberry, English ivy), lawns, and ornamental landscaping rather than mature native forests. Often roadways, houses, and other buildings are located close to a stream, sometimes within 10 feet, restricting the width and growth of a native forest. As a result, riparian areas are highly fragmented, if they exist at all, and cannot supply the stream with consistent shading, nutrients, bank stability and/or filtration. This low-quality riparian habitat tends to dominate residential and commercially-zoned areas. For example, Longfellow and Thornton Creeks are bordered by primarily residential and other human-centric land uses, and this has led to encroachment along those streams and conversion of riparian forests to other uses (e.g., lawns, roadways, and buildings).

Similarly, low-quality riparian areas along the other three major watercourses in Seattle– Taylor, Piper's, and Fauntleroy Creek– are found along residential stream sections, outside park areas. Trees may be less desirable in areas where they may block views, or be perceived as safety hazards or nuisances (roots too close to foundations, falling limbs, root intrusion in pipes, etc.), or create undesired maintenance.

Finally, it should also be noted that these riparian tree canopy density data were not developed or analyzed through a lens of racial and social equity. However, it may be beneficial for the DSA and ISP to consider these issues in an attempt to better address equity through utility investments in open spaces and facilitate access to healthy aquatic habitats as discussed in Section 3.6.

3.6 Recommendations for Future Use

This section describes how data from the Riparian Tree Canopy Density sub-topic area could be used to inform the ISP, to inform implementation of specific projects or programmatic activities that are developed through the ISP, and to inform other SPU work outside of the ISP. Additional recommendations on how information from multiple sub-topic areas could be combined to inform the ISP or other work, through broader analyses, is included in Section 8 of this TM.

3.6.1 How information could be used for ISP

The information on Riparian Tree Canopy Density can be used for the ISP to:

1. Provide environmental benefits by:
    a. Aligning tree planting investments with the City's and SPU's urban forestry goals. For instance, tree planting could be used to restore urban forest health by replacing trees that have reached the end of their lifespan, to shade out invasive species, and to increase diversity with respect to stand species, age range, and canopy levels.
    b. Encouraging the use of tree planting throughout the City to stabilize steep slopes prone to landslides and to increase climate and ecological resilience.
    c. Using tree planting to improve habitat and water quality (e.g., reduce summer temperatures and increase dissolved oxygen levels) in areas used by salmon and where temperature is expected to be problem because the stream reach lacks shade.
    d. Using tree planting to support habitat for fish (e.g., organic inputs to streams, wood recruitment for both instream cover and structure to retain streambed spawning gravel), and for birds and other wildlife
2. Support better utility work by:
    a. Identifying opportunities for stream corridor improvements that could be completed in conjunction with other utility work (e.g., creek culvert replacement, GSI in Urban Villages projects, landslide mitigation projects, repair, modification, or relocation of stormwater outfalls to creeks, and floodplain and creek channel reconnection for flood reduction/GSI).
    b. Reducing sediment input into SPU ponds and facilities, which requires costly dredging by using tree planting (and other re-vegetation) instead as a slope stabilization method.
    c. Using tree planting to provide recruitment of large, instream wood structure that provide grade controls that store sediment and reduce incision rates in watercourse channels (e.g., increasing resilience to stormwater runoff, and reducing costs associated with dredging and sediment management).

3. Address environmental justice and service equity by:
    a. Engaging underserved communities in restoration partnerships, environmental stewardship, and/or citizen science.
    b. Providing underserved communities with education and employment opportunities in urban forestry (and other environmental fields), through work study programs (in partnership with local schools, colleges, and universities), internships, and occupations.
    c. Increasing the number of trees in public open spaces within underserved communities to absorb greenhouse gases, improve air quality, reduce stress, and improve overall health.

3.6.2 How information could be used outside of ISP

Recommendations on how riparian canopy density data could be used in combination with other sub-topic area information outside of the ISP is included in Section 9 of this TM.

3.7 Additional Information

Information provided in the sub-topic area complements other sub-topic areas included in this TM and other DSA Topic Areas. Together, the combined sub-topic areas and Topic Areas can provide a better understanding of overall conditions within, and habitat use of, Seattle’s urban creeks, the Duwamish Waterway, and the shorelines along Puget Sound and Lake Washington.

3.7.1 Related DSA Topic Areas

Related DSA Topic areas include:

- Fish passage
- Floodplain reconnection
- Water Quality

3.7.2 Additional Work/Data Gaps

Data used to create the Riparian Tree Canopy Density GIS map, were collected in 2003 and are almost 20 years old. While these data provide baseline conditions (for restoration efforts), they were collected on only the five main creek watersheds and limited to Type F waters (those considered capable of supporting fish). Updated and expanded surveys (by field and/or remote sensing methods) could be a worthwhile investment by SPU and/or a combination of other City departments. Aerial photo-grammetrical technologies (e.g., low elevation LiDAR flights) have improved dramatically over the last 20 years such that the technology is increasingly cost efficient and accurate for obtaining these data.

Possible additional work may include:

- Use existing data to develop GIS layers and maps based for each of the individual datasets that were part of the riparian vegetation condition composite score (invasive species, riparian buffer width, connectivity, understory species composition, and canopy density). This would allow for more robust and flexible future analyses and could also be supplemented and updated with remote sensing information.

- Fill in gaps in Riparian Tree Canopy Density data through physical surveys or using remote sensing techniques in the following areas:
    - The upper mainstem and tributaries of the creeks that were not mapped. This data would be useful because of their influence on fish-bearing waters (temperature, water quality), and on slope stability (sediment delivery).
    - The unmapped urban streams, marine riparian shorelines, and shorelines of the Duwamish which were not included in the original surveys.
- Create a city-wide tree canopy density data layer, through LIDAR, or a combination of LIDAR, new surveys and/or compilation of existing data sources. These data would provide a much more accurate picture of tree canopy density in riparian and non-riparian areas and can be analyzed to differentiate between conifer and deciduous tree canopy. Parks Department may have additional information on canopy density in areas that could be used similarly to ways mentioned in Section 3.7.
- Collect more detailed data on the composition of deciduous vs. evergreen species. This information could be used to inform removal of dying deciduous trees which become hazardous to infrastructure as limbs fall in riparian areas, and to inform urban reforestation efforts. Urban forestry SMEs have identified the need for increased conifers in our urban forests which have much longer lifespans than deciduous trees, are more valuable as instream structure (lasting up to 1,000 years buried in streambeds), and have foliage year-round (to intercept precipitation, provide micro-climate temperature modulation, reduce greenhouse gases, improve air quality, and provide health benefits).
- Collect new data on the other riparian vegetation variables that comprised the composite score (invasive species, riparian buffer width, connectivity, understory species composition, and canopy density) with a priority placed on data related to salmon streams.

4. Stream Channel Habitat Quality

The Stream Channel Habitat Quality sub-topic area includes information on the type and quality of stream habitat within Seattle's five main creek watersheds that support salmon (Thornton, Piper's, Longfellow, Fauntleroy, and Taylor). Two types of maps were generated to characterize stream habitat presented in this TM: the first, represents a high level overview of general instream habitat quality based on a composite score generated for the SOTW report (Appendix C, stream channel habitat conditions), and the second, represents the distribution of salmonid habitat in the five main creek watersheds (Appendix D, quality of potential fish habitat spawning and rearing/refuge).

4.1 Introduction

This section of the TM presents background information on data collection/survey protocols and databases, a description of analytical methods used to generate the maps, and mapping results, and recommendations on how information on Stream Channel Habitat Quality can be used for the upcoming ISP (Discussion). Additional information is also provided on data gaps, and potential future work associated with aquatic habitat quality data. Other possible uses for this information outside of the ISP are provided in Section 9.

4.2 Background

Stream channel, habitat and fish use assessment data are intended to provide baseline information for SPU's instream capital projects (planning, design, implementation, permitting and performance monitoring), and for tracking the City's contributions to regional salmon recovery and stream stewardship efforts, as it was focused on habitat features important for fish, salmonids, in particular. This section describes the past efforts and previously collected data used in this TM.

SPU conducted numerous surveys of instream habitat conditions, fish habitat conditions and fish use between 1999 and 2010 to understand existing conditions, inform project planning and for performance monitoring as summarized in Table 4-1 below. A subset of these data sources was used to create new GIS maps for this TM as described more fully in Section 4.3.

For this sub-topic area, background information for instream habitat quality and potential fish habitat quality are presented separately for each of the five main creek watersheds and salmon streams in Seattle.

Table 4-1: Summary of Habitat, Fish Use, and Riparian Survey Data Sources

Survey Name	Survey Date	Survey Location and Frequency	Purpose/Description	Database Name	Reference
Channel Condition	2001	Thornton, Piper's, Longfellow, Taylor	Geomorphic survey of baseline channel conditions prior to most instream projects	MS Access Channel database and GISP	--[b]
	2003	Fauntleroy			
Habitat Surveys	2001-2004	All five main creek watersheds	Survey of instream habitat baseline conditions, including distribution of potential salmonid spawning and rearing habitat, prior to most projects	MS Access Habitat database and GISP	--[c,d]
Riparian Surveys (see in Section 3)	2003	All five main creek watersheds	Riparian survey of baseline conditions prior to most projects. Intended to provide information about stream cover, etc., to supplement habitat condition	MS Access Riparian database and GISP	--[c]
Spawning Surveys (adult salmonids)[a]	1999–2007	Weekly, Sept-May. All five creeks (Wild Fish Conservancy)	Status and trends monitoring of salmonid adult spawning activity (salmon and trout), redd distribution (fish habitat use), and fish access (most upstream sighting). Pilot test to use eDNA to replace surveys, beginning 2018	EQuIS Fish Use database and GISP	--[d,e]
	2015-2018	Sporadically, Oct-Dec. Thornton (SPU)			
	2010-2018	Weekly Sept-Dec. Piper's community-led			
Smolt Trapping (salmonid juveniles)[a]	2001-2008	Over a 2- to 3-week period in May. Lower Thornton and Longfellow	Measure of spawning success, particularly for coho and cutthroat	EQuIS Fish Use database and GISP	--[c,d]
Snorkel and Electrofishing (juveniles)[a]	2015-2019	Monthly. Lower Taylor and Mapes Creek (USFWS)	Fish use, diet and condition for project performance (pre- and post-construction), especially to track juvenile Chinook)	Not yet entered in EQuIS Fish Use database	--[f]
PIT Tagging [a]	2015-2019	Annually. Thornton Floodplain Projects (SPU)	Fish use, distribution, diet and condition for project performance (pre- and post-construction)	Not yet entered in EQuIS Fish Use database	--[g]

a. Indicates data sources not used to generate the maps and data in this TM, but available to overlay with TM maps.

b. Stocker and Perkins 2008

c. SOTW report 2007

d. Draft Fish in Seattle's Urban Creek Report (2009)

e. Wild Fish Conservancy, 2008

f. USFWS report 2019

g. SPU data

4.2.1 Instream Habitat Quality

Instream habitat quality reflects multiple factors including instream flow, water quality and riparian habitat. High-quality instream habitat areas are typically characterized by physical complexity (diversity), such as instream structure (wood, boulders), channel meanders and connections between the stream channel and its floodplain, all of which allow habitat features (pools, in-channel wetlands) to form and reform (persist). Instream habitat quality is degraded through altered hydrology (flashy peak flows caused by conversion of vegetation to impervious surfaces), polluted stormwater runoff and degraded riparian buffers all contribute to degraded instream conditions.

To assess instream habitat conditions, data was collected by SPU in the early 2000s from two types of surveys: 1) geomorphic surveys of channel conditions conducted during 2001 and 2003 (methods and results summarized in Stoker and Perkins, 2008), and 2) stream habitat surveys, conducted between 2001 and 2004 (methods summarized in SOTW report 2007, Appendix E).

Multiple indicators/attributes (Table 4-2) were used to characterize each of the three components (channel, sediment, and biological function), and scored for each reach, based on the reach channel gradient/type (Appendix F). The scores for all three components were then averaged into a single overall composite score of habitat quality for each reach, and these are represented in the general instream habitat quality maps provided in Appendix C.

Table 4-2: Indicators used to Generate the General Instream Habitat Quality Maps

Instream Habitat Component	Integrity Question	Indicators of Integrity
Channel morphology/channel condition	Does the channel show signs of excessive degradation due to altered flow regime and/or encroachment?	Channel erosion stage, channel stability, bank erosion, bank armoring, channel encroachment, channel widths/depths, floodplain connection, habitat type distribution (e.g., pools, riffles), instream structure
Sediment transport and delivery	Are there signs of significant disruption to the channel's expected sediment regime?	channel and bank geology, dominant bed substrate, bank armoring
Biological function	Does the channel currently support biological function OR does it offer the physical habitat conditions necessary to support biological function?	habitat units, spawning habitat quality, pool quality, instream structure, salmonid spawning locations

The habitat surveys conducted between 2001 and 2004 followed the Habitat Inventory Methods of Timber Fish and Wildlife, adapted slightly for urban conditions and low flow periods. Stream distances were surveyed with hip chains, which are used to measure a distance traveled. The survey started at Station 0 at the channel or tributary mouth and progressed as the surveyor moved upstream. Hip chain distances were checked for accuracy on selected segments against GPS locations, and were found to be accurate to within 30 feet.

The hip chain recorded the sequence and length of all habitat units (riffle, glide, pool, or a wetland) along an entire reach habitat data, by tracking the starting and ending points (distances on the hip chain) of each unit. Data associated with spawning habitat quality were collected only from riffles and glides, and data associated with juvenile rearing and refuge habitat were collected only from pools and wetlands. Pools are also important to adult salmon entering streams to spawn, because they provide holding areas until fish are ready to spawn, and refuge from predators. Consequently, riffles and glides located adjacent to pools rated a higher quality for spawning habitat than those without any adjacent pools.

4.2.2 Fish Habitat Quality

The quality of fish habitat determines a stream's capacity to support fish populations at various life stages including adult spawning and juvenile rearing. Habitat surveys completed in 2001-2004 were used characterize fish habitat quality (salmon spawning and refuge and rearing).

Spawning habitat data were collected only in riffles and glides. Determinations of habitat quality were based on: gravel size, substrate embeddedness (or lack thereof, i.e., loose gravel), in-stream cover, and proximity to pools (which function as holding and refuge areas for adults).

Rearing and Refuge data were collected only in pools (and for the few present, in-channel wetlands). Habitat quality determinations were based on: water depth, pool complexity, and instream cover (partially submerged structures, usually large wood, that provide hiding spots and protection (refuge) from predators and peak flows).

The line features for both spawning and refuge habitat are relatively short segments (typically below 200 ft), which when displayed at the scale of the watershed may appear as points rather than lines. The data is best viewed in GIS when zoomed in to the individual stream reach scale instead of the watershed scale. Stream sections that do not have a line segment were identified as not providing potential spawning or rearing habitat.

In the 2009 Fish in Seattle's Urban Creek Draft Technical Report, quality ratings were defined (Table 4-3) based on the presence of one, two or three (all) indicators/attributes for each type of salmonid habitat (spawning and rearing/refuge).

Table 4-3: Description of Fish Habitat Quality Ratings

Quality Ratings	Spawning	Rearing
Poor to fair	Only spawning-sized gravels present	Only minimum pool dimensions (size and depth criteria) were met
Fair to good	Some features present	Some features present
Best available	Indicates all features present	Indicates all features present

4.3 Methods

For this sub-topic area, methods for instream habitat quality and potential fish habitat quality are presented separately. This information identifies (1) potential adult spawning and juvenile rearing habitat, including its relative quality, on the five main creek watersheds and salmon streams in Seattle (based on quality of physical habitat features).

4.3.1 Instream Habitat Quality

The instream habitat quality maps included in Appendix C were recreated using data originally developed for the SOTW report and based on the composite score. The data was extracted from GISP.

4.3.2 Fish Habitat Quality

The Fish Habitat Quality maps generated for this TM are focused on salmonid adult spawning and juvenile rearing/refuge habitat (Appendix D). To develop the maps, fish habitat quality data were extracted from GISP and the quality rating categories were recreated based on descriptions from the 2009 Fish Technical Report (Anand et al., 2009).

4.4 Results

The data products associated with this sub-topic include GIS data layers and PDF maps included in Appendices C and D. The maps show the following conditions for the five main creek watersheds and salmon streams in Seattle: 1) instream habitat quality, 2) salmon rearing and refuge habitat quality, and 3) salmon spawning habitat quality.

4.4.1 Instream Habitat Quality

The maps in Appendix C, which show the overall quality of instream habitat, indicate that quality varies considerably among the five main creek watersheds. Although new graphs were not created for this TM, Figure 51 from the SOTW report (reproduced below as Figure 4-1) shows the percent of stream length characterized as high-, medium-, and low-instream habitat quality for each of the five streams.

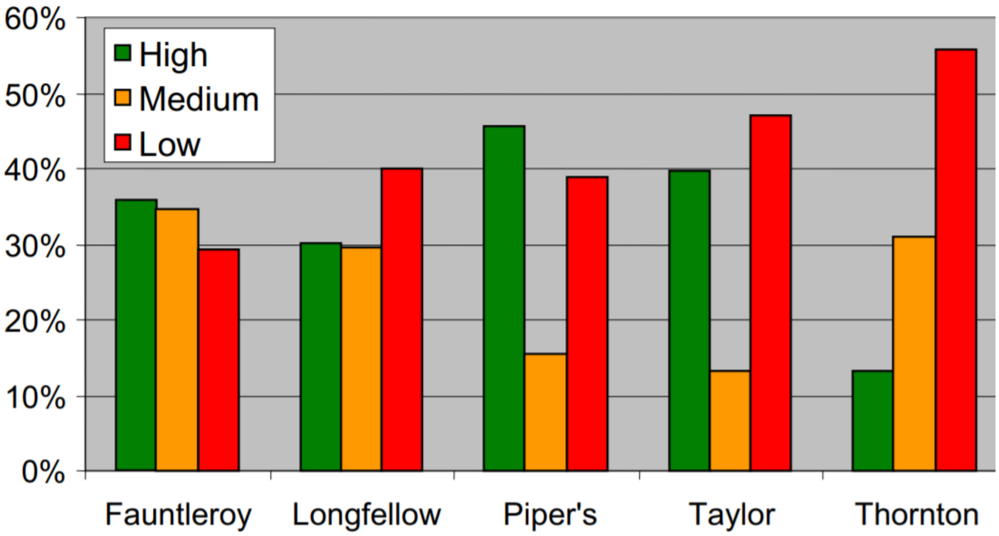

Figure 4-1: Percentages of High, Medium, and Low-Instream Habitat Quality in Major Seattle Watercourses

Source: SOTW 2007, Figure 51

Piper's and Taylor creeks both offer the largest proportion of high-quality instream habitat (45% and 40%, respectively) which is likely due to the large public ownership and less developed watershed. However, these watersheds also have a large proportion of low-quality habitat conditions (48% and 39%, respectively) and little in the medium-quality habitat. Thornton Creek has the greatest proportion of low-quality instream habitat (over 55%) and lowest proportion of high-quality habitat (13%). Thornton Creek is Seattle's largest urban watershed and it has significant development along the creek and much less protected public lands than other watersheds. Fauntleroy and Longfellow Creeks both have a relatively even distribution of all the habitat quality categories. However, Longfellow does have a larger proportion of low-quality instream habitat (40%) than Fauntleroy (29%).

SPU capital projects are underway in both Taylor and Fauntleroy Creek watersheds, which will improve instream habitat conditions; a planned project in Longfellow Creek is in the Options Analysis phase.

4.4.2 Fish Habitat Quality

Similar to instream habitat quality, the maps in Appendix D show the overall quality of fish habitat indicate that quality varies considerably among the five main creek watersheds (Figure B-#). Unlike the instream habitat maps, which provide a high-level overview, the fish habitat maps are quite detailed for both salmonid adult spawning and juvenile rearing/refuge habitat. The two types of fish habitat needed to be displayed on separate maps, because overlapping one layer with the other would obscure most of the underlying layer. Because the fish habitat data was pulled from pools, riffles, and glides and varies at a fine scale, the results resemble point data when viewed at the scale of an entire stream reach but are actually comprised of line segments indicating actual lengths of habitat.

All five creeks offer spawning and rearing/refuge habitat throughout their Type F waters. Although much of the habitat is of poor to fair quality there are pockets of higher quality habitat identified as best available. In some systems much of the best available habitat is located upstream of fish passage barriers such as in Taylor and Longfellow creeks.

The following is a summary of spawning and rearing/refuge habitat condition and availability by creek system:

- **Fauntleroy**: Spawning habitat is found throughout Fauntleroy creek, most characterized as fair to good. Only the lower portion of the creek has the best rated spawning habitat. Rearing and refuge habitat is more limited and predominantly exists only in the lower half or the mainstem. Similar to spawning habitat, the lower channel is the only area containing best available rearing and refuge habitat. The channel running through Fauntleroy Park contains many step-pools in a steeper gradient channel (4-5%), which could provide rearing habitat, but most of these did not meet the minimum size and depth criteria to be considered pools.
- **Longfellow**: creek has spawning and rearing habitat throughout except in the upper reaches and lower channel which is piped. The highest quality spawning habitat is limited to a few areas including areas within the West Seattle golf course and higher gradient upstream reaches. The majority of spawning habitat is a mix of poor to fair, and fair to good quality habitat. Rearing/refuge is likewise well distributed throughout the stream and primarily a mix of best available and fair to good rated stretches. The areas between Willow and Graham streets and Holden to Myrtle streets are worth noting for rearing potential.
- **Piper's**: Piper's Creek, despite having a significant amount of protected land, has limited spawning habitat, and few areas of high-quality spawning habitat. Most of the spawning habitat is along lower Venema Creek a tributary to the mainstem. Rearing and refuge habitat is also less extensive in Piper's

creek than in the other streams evaluated in this TM. The best rearing and refuge habitat are found in the lower mainstem. Fair to good, or low to fair quality rearing habitat is found in the lower sections of Venema Creek and only sporadically throughout the middle section of the mainstem.

- **Taylor**: Spawning habitat is found throughout Taylor Creek with roughly equal amounts quality categories. The best available spawning habitat in Taylor occurs in the lower gradient floodplain reaches downstream of the canyon, and in the upper canyon, at the confluence of the forks. These trends are similar for rearing and refuge habitat, although the best available rearing and refuge habitat is mostly limited to the lower section of the creek downstream of Rainier Ave S.
- **Thornton**: Spawning habitat is found throughout Thornton Creek mainstem and north and south branches much of it in poor to fair, or fair to good quality categories. The best available spawning habitat is limited to the mainstem is at NE 95th St. and around Meadowbrook Pond/Confluence Floodplain (between 40th Ave NE and 35th Ave NE). Thornton South Branch spawning habitat is found primarily in the Kingfisher Natural Area ravine, and upstream of Beaver Pond Park (between 5th and 8th Ave NE). The best available spawning habitat in Thornton North Branch is between Lake City Way and the confluence of the North Branch and Littlebrook Creek.

Rearing/refuge habitat is prevalent throughout north and south branches, but more limited in the mainstem which is characterized by patchy areas of poor-quality rearing and refuge habitat. The best available rearing is also in the Beaver Pond Park area. Most of the South Branch spawning and rearing/refuge habitat is located upstream of a fish passage barrier near Ravenna/30th Ave NE. The best available rearing/refuge habitat is located between Licorice Fern (downstream of the golf course) and the confluence of the North Branch and Littlebrook Creek. All this habitat is located upstream of a barrier (a series of three weirs in the North Branch, located immediately upstream of the confluence with Littlebrook).

4.5 Discussion

This section discusses the TM results presented in Section 4.4 for instream habitat quality and fish habitat. These data were not developed or analyzed through a lens of social equity but will be useful for the DSA and ISP in better addressing racial and social equity through utility investments in open space and access to healthy aquatic habitats as discussed in Section 4.6.

4.5.1 Instream Habitat Quality

In general, instream conditions reflect adjacent land uses and land ownership. For example, Taylor, Piper’s, and Fauntleroy creeks offer the largest proportion of high-quality instream habitat (45%, 40%, and 36% respectively), and all three are in forested parks, on public land. The correlation between adjacent park land and higher quality instream habitat is evident at the reach scale as well. For example, in Longfellow Creek, the only reaches with a high-quality rating, are located within publicly owned Parks’ properties: West Seattle Golf Course and the Delridge Natural Area. The remainder of the Longfellow watercourse ranges from poor to moderate. Watercourse reaches rated in poor condition for instream habitat are consistently located in areas with significant land use development that encroaches on the stream and riparian areas (such as roads, culverts, buildings, bank armoring and lawns).

Although the Stream Channel Habitat Quality GIS layers are based on data collected nearly two decades ago, this information does (and was intended to) provide a baseline before the City initiated many of its drainage capital projects that slow and treat surface water runoff (separation of drainage and wastewater with combined sewer overflow (CSO) retrofits, installations of Green Stormwater Infrastructure (GSI), floodplain connections, partnering with Parks in the Green Seattle Partnership to restore urban forests). Despite some changes over the last 20 years, the instream habitat quality layers and the scores or ratings upon which they are based, have not changed significantly. Most of changes impacted small portions of the creeks, and reflect changes in the stream channel alignment, where it has been altered either through natural migration, or by stream projects over the last two decades. These changes in stream alignment have been captured in the Urban Watercourse GIS layer, but not in the layers used to develop the SOTW, and subsequently the TM maps, and thus be aware that there will be discrepancies when the two layers are viewed together.

Even in the highest-quality habitat reaches of the Seattle’s major creeks, the lack of large wood, floodplain connection, and loose gravel is a widespread problem and even the best available habitat in urban creeks is usually not nearly as functional as that found in less developed landscapes, especially forested areas. There are many opportunities for improvement throughout all five creeks, with some reaches in need of extensive restoration (low-quality areas)

4.5.2 Fish Habitat Quality

Instream habitat structures, acting as grade control, and edge habitat (channel meanders and connections between channel and floodplain), create and sustain fish habitat by slowing erosive peak flows, and by retaining gravel and instream cover (large wood, boulders, and undercut banks) necessary for fish habitat. The lack of large wood, floodplain connection and loose gravel, is a widespread problem throughout all five creeks and helps to explain some of the patterns in fish habitat described in this TM.

The loss of high-quality spawning and rearing/refuge habitat in Seattle’s main streams is a result of decades of stream channel modifications associated with development in the City. Sections of the City’s urban creeks have been straightened, realigned to one side of their historic floodplain, stripped of riparian vegetation, and rock-lined to protect adjacent land-use. This holds true even for creek channels located in parks where fish habitat quality would be expected to be more pervasive and generally in good condition. For example, sections of lower Piper’s Creek which lie within protected public ownership has limited fish habitat. A portion of the creek is confined to a channel running along the base of the north slope, while the bulk of the historic floodplain now contains parking lots, lawn, and trails. Similarly, lower Longfellow Creek downstream (north) of Genesee St SW, runs through a Parks’ natural area, but the creek flows through a deeply incised channel lined with rip rap and rock gabions while the floodplain, now a terrace above the channel, contains forested riparian areas, open space, lawn, and a trail.

Some of best remaining rearing and refuge habitat is in the wetlands associated with dams (beaver dams and manmade). Longfellow Creek for instance has lots of beaver activity, and most of the wetland areas created by their dams provide some of the highest quality rearing/refuge habitat. The Willow-Graham Street beaver ponds area is a notable example. Unfortunately, not all of the good quality spawning and rearing and refuge habitat is currently accessible to migratory salmon due to the large number of fish passage barriers as described in a separate TM (DSA Task 4 TM: Fish Passage Barriers).

Changes in the distribution and quality of fish habitat affect salmon species because not all salmon species and life stages have the same habitat needs. In general, adult Chinook salmon only spawn in the lower sections of the City's largest creek (Thornton) but they rear in both small and large creeks. Nonnatal streams in south Lake Washington, such as Taylor and Mapes Creeks, provide critical rearing and refuge habitat for juvenile Chinook salmon migrating from the Cedar River to Puget Sound (Tabor et al., 2011). Chum salmon by contrast are only found in Seattle creeks with direct access to Puget Sound (Piper's and Longfellow). Juvenile chum salmon out migrate to Puget Sound shortly after hatching, and thus the availability of spawning habitat tends more limiting than rearing habitat for this species. Coho salmon and cutthroat trout spawn and rear fry in all five creeks, and thus both types of habitat are necessary to support these species in Seattle's creeks.

Thus there are many opportunities to improve spawning and rearing habitat as part of a larger drainage capital projects, such as, floodplain reconnection for stormwater management (slowing erosive peak flows and temporarily storing floodwater and sediment, and culvert replacements to remove constrictions in the conveyance system connected to watercourses. Despite degraded physical habitat conditions, the response of salmonids to earlier instream capital projects indicates it is possible to make a significant different with restoration. Two notable examples of successful restoration of fish habitat directly resulting in increased fish use are the Mapes Creek daylighting project and Thornton Confluence culvert replacement and floodplain reconnection project. Following the daylighting of the lower 400 feet of Mapes Creek in 2014, thousands of juvenile Chinook salmon were found using the mouth, delta and lower channel for rearing and refuge, February through the end of May, each year following construction (Tabor, 2019). On Thornton Creek, the first documented Chinook salmon redds in the area near the confluence of the mainstem with the north and south branches were found a few years after the floodplain was reconnected in 2014. The channel prior to construction was incised and the streambed was rock or concrete-lined. As part of the restoration project, appropriately sized spawning gravels were added.

4.6 Recommendations for Future Use

This section describes how data from the Stream Channel Habitat Quality sub-topic area could be used to inform the ISP, or to inform implementation of specific projects or programmatic activities that are developed through the ISP. Additional recommendations on how information from multiple sub-topic areas could be combined to inform the ISP, or other work, through broader analyses is included in Section 9.

4.6.1 How information could be used for ISP

The information on Stream Channel Habitat Quality (instream habitat quality and quality of fish habitat) can be used for the ISP to:

1. Provide environmental benefits by:
    a. Evaluate potential for habitat improvements in areas identified as having poor condition. This could be done in conjunction with other flood mitigation or climate resilience efforts initiated by SPU or others, and also referenced in Section 9). For instance, restoring riparian habitat and reconnecting floodplains can help temporarily store and slow peak flows, provide space for instream structures to retain sediment (including spawning gravels) and improve water quality by filtering it through the streambed and floodplain.

2. Support better utility work by:
    a. Directing capital investments to minor habitat enhancements designed as part of other utility projects (e.g., removal, rehabilitation, or relocation of infrastructure within or adjacent to urban creeks).
    b. Removing, modifying, and/or relocating SPU utility infrastructure such as water or sewer mains, or outfalls in areas of high-quality instream habitat. This could be done in advance of and/or concurrent with restoration efforts by SPU or others.
    c. Limiting placement of new utility infrastructure (e.g., outfalls, pump stations, CSO facilities etc.) along, under or over urban streams where it may preclude future restoration and result in continued stream degradation.

4.6.2 How information could be used outside of ISP

Recommendations on how information about stream channel habitat quality and quality of fish habitat could be used in combination with other sub-topic area information outside of the ISP is included Section 9.

4.7 Additional Information

Information in the Stream Channel Habitat Quality sub-topic area complements other sub-topic areas included in this TM and other Topic Areas. Together the combined sub-topic areas and Topic Areas can provide a better understanding of the overall condition and habitat use of Seattle's urban creeks, the Duwamish Waterway, and shorelines along Puget Sound and Lake Washington.

4.7.1 Related DSA Topic Areas

Related DSA Topic areas include:

- Fish passage
- Floodplain reconnection

4.7.2 Additional Work/Data Gaps

Potential additional work to fill data gaps identified during the development of the Stream Channel Habitat Quality sub-topic area include:

1. Create new, individual GIS layers for each of the existing individual data sets included in the composite scores for instream habitat conditions. As described in the background and methods section of this sub-topic area, a single GIS layer was created because it was not clear how the individual data sets were combined to create the composite score.
2. Rather than investing additional effort into creating new GIS layers based on old data, an alternative would be to complete new instream surveys for some or all the original data sets that comprised the composite score. In the meantime, the original maps produced in the 2007 SOTW report (City of Seattle, 2007) and 2009 Fish Technical Report (Anand et al., 2009) can be used as reference to inform individual projects or smaller, basin-scale planning.

5. Channel Erosion/Evolution Stage

The Channel Erosion/Evolution Stage sub-topic area provides information on channel condition for each of Seattle's five main creek watersheds that support salmon (Thornton, Piper's, Longfellow, Fauntleroy, and Taylor).

5.1 Introduction

This section presents background information, a discussion of results, and recommendations on how information on riparian canopy cover can be used for the upcoming ISP. Additional information is also provided on data gaps, and potential future work associated with channel erosion stage data. Other possible uses for this information outside of the ISP are provided in Section 9.

5.2 Background

The large increase in stormwater runoff following development causes a corresponding jump in channel erosion rates. Alteration of hydrologic patterns (including stormwater runoff) due to urbanization is the primarily cause of channel erosion in Seattle's creeks. The severity of channel erosion is also determined by other factors including geology, sediment load, gradient, valley width, grade controls, roughness elements that dissipate energy and make steps, encroachment and bank armoring, and the time the channel has had to adjust to the flow increases.

If all other factors are equal, there should be a general progression from earlier to later stages of channel evolution as one moves down the channel network. This occurs because 1) upstream erosion generates sediment that deposits downstream, causing aggradation and 2) downcutting destabilizes the bed upstream, causing headward (upstream) erosion of knickpoints.

A physical channel inventory of five main creek watersheds in Seattle was undertaken as part of a comprehensive watershed investigation of basin and stream channel conditions. The work was summarized in the 2008 *Seattle Creeks Physical Channel Conditions Report* (Stoker and Perkins, 2008) that documented channel and steam bank materials, geometry, and processes that influence the channel and riparian conditions.

Field work for the channel inventories was done in 2001 with some additional surveys in 2003, 2004, and 2007 (Taylor Creek). For the geomorphic surveys, data was collected on channel dimensions, bank erosion, bar and terrace heights, landslides, gullies, knickpoints, log jams, weirs, geologic material, bank armoring, down cutting, sediment deposition, encroachments, and the locations of inflows from storm drains.

Creeks were divided into reaches to allow better discussion of features specific to each area. Reach boundaries were placed at significant tributary inflows, at main changes in geologic materials, gradient, breaks in valley types, and at main administration or management boundaries.

5.3 Methods

For the Channel Erosion Stage sub-topic area, data were pulled from older GIS file located in GISP. These same data layers were used for the 2007 SOTW report (City of Seattle, 2007*)*. Those GIS layers were based on the physical condition inventories done between 2001-2007 and published in the 2008 Channel

Conditions report. The different stages of channel erosion are described in more detail below in Table 5-1. In a healthy creek system, stages 1, 4, and 5 would be more prevalent, whereas creek systems that are unstable are more likely to have a great extent of channel characterized in stages 2 and 3. Site characterized by more stage 4 segments would be considered restabilizing. The stages also help to explain the potential life cycle of urban streams. Undeveloped streams will start in the stable (pre-modified) first stage. With increased development, the stream channel is negatively impacted and transitions to stages 2 and 3. Only through restoration of watershed processes does the stream channel transition towards aggradation and eventual restabilization (stages 4 and 5).

Table 5-1: Stages of Channel Erosion

Stage	Characteristics
1. Pre-modified or Slight Downcut	Natural channel, stable banks with minimal mass wasting, high width/depth ratio, established woody vegetation.
2. Constructed or Frozen	Dredging and/or straightening of channel. Dredging and/or straightening of channel.
3. Degradation and Widening	Rapid bed erosion and active channel widening, leading to bank heightening and steepening.
4. Aggradation	Onset of bed aggradation, creation of bars, low angle surfaces from upper bank, woody vegetation reestablishes on low angle area; active bank erosion; continuous alluvial bed.
5. Restabilization	Reduction of bank heights by aggradation of bed and lower banks, woody vegetation extends upslope and narrows active channel width.

5.4 Results

Data products associated with the Channel Erosion Stage sub-topic area of this TM include:

- GIS layer and PDF maps (Appendix G) of channel erosion stage were developed for each of the five main creek watersheds and salmon streams based on the composite scores found in the SOTW report (City of Seattle, 2007).
- The maps reveal degrading stream channel conditions in most of Fauntleroy, Thornton, and Longfellow Creeks, whereas channel conditions in Taylor Creek are characterized predominantly as aggrading or slightly downcutting. Piper's Creek showed a more even distribution of channel evolution stages through its length.

5.5 Discussion

Urban aquatic habitat quality is largely the outcome of physical channel morphology (i.e., gradient and channel/valley width) combined with land use impacts. Channel evolution maps identify reaches that are relatively intact (green), and reaches that are impacted by land use, particularly yellow (frozen/constructed reaches) and red (degrading/incising reaches). Channel evolution maps, when viewed along with fish habitat quality maps also produced in this TM, can help provide context for the distribution and quality of spawning and rearing habitat. Where there is overlap between the land use impacted-reaches and absent or lower quality habitat, it is likely that habitat in these reaches would continue to decline or **remain** absent/poor quality. This is most apparent in Thornton Creek, which has long stretches of incised and/or constructed channel (confined by bank armoring), and in the bypass area of Longfellow Creek.

The GIS layer Channel Erosion Stage is based on data collected nearly two decades ago and may or may not still be reflective of current conditions (however, this a geomorphic indicator that is not subject to rapid change). Expected changes would occur where the stream channel has naturally migrated (rare in channelized urban watercourses) or has been altered by stream projects over the last few decades. This GIS layer has not been updated to reflect these changes, but the Urban Watercourse layer has been updated, so there will be discrepancies when the two layers are viewed together. A discussion of the channel erosion stage is included in the 2008 *Seattle Creeks Physical Channel Conditions* report (Stoker and Perkins, 2008) and the 2007 SOTW report (City of Seattle, 2007).

These data were not developed or prioritized through a lens of racial and social equity but may be useful for the DSA and ISP in better addressing racial and social equity through utility investments in open space and access to healthy aquatic habitats.

5.6 Recommendations for Future Use

This section describes how data from the Channel Erosion Stage sub-topic area could be used to inform the ISP and to inform implementation of specific projects or programmatic activities that are developed through the ISP. Additional recommendations on how information from multiple sub-topic areas could be combined to inform the ISP, or other work, through broader analyses is included in Section 9.

5.6.1 How information could be used for ISP

The channel erosion stage data can be used to:

1. Support better utility work by:
    - Identifying areas where there may be long-term solutions to address stream bank erosion and deposition, to reduce sediment input into SPU ponds, facilities, and stream culverts that require dredging.
    - Limiting placement of new utility infrastructure (e.g., outfalls, pump stations, CSO facilities etc.) along, under or over urban streams where it may preclude future restoration and result in continued stream degradation.
2. Address environmental justice and service equity by:
    - Engaging underserved community in restoration partnerships, environmental stewardship and/or citizen science focused on improving equity around access to healthy waters and habitat.

5.6.2 How information could be used outside of ISP

Recommendations on how information about stream channel erosion stage could be used in combination with other sub-topic area information outside of the ISP is included Section 9.

5.7 Additional Information

Information in the Channel Erosion/Evolution Stage sub-topic area is a complement to other Aquatic Habitat sub-topic areas included in this TM and other DSA Topic Areas. Together the combined sub-topic areas and other Topic Areas can provide a better understanding of the overall condition and habitat use of Seattle's urban creeks, the Duwamish Waterway, and shorelines along Puget Sound and Lake Washington.

5.7.1 Related DSA Topic Areas

Related DSA Topic Areas include:

- Floodplain Reconnection
- Water Quality

5.7.2 Additional Work/Data Gaps

The channel conditions data used to create the channel erosion stage GIS layer was collected almost 20 years ago in 2001. The surveys only focused on the five main creek watersheds. Updated and expanded surveys could be a worthwhile investment at this time by SPU and/or a combination of other City departments. Aerial imaging technology has improved over the last 20 years (e.g., LiDAR, drone photogrammetry) such that the technology is increasingly cost efficient and accurate for obtaining these data.

Possible additional work may include:

1. Complete new surveys to obtain information on channel evolution stage, erosion activity level, channel features, geology, substrate material, substrate density, gradient, channel geometry, and channel stability.
2. Update channel condition GIS layer by adding new information for stream reaches with completed CIP projects; and any new survey data on channel evolution stage, erosion activity level, channel features, geology, substrate material, substrate density, gradient, channel geometry, and channel stability.
3. Complete analysis that examines changes to channel erosion stage from this original data to current conditions.

The channel condition survey may be the highest priority to resurvey, as it is the most likely to have changed over the last two decades and is very relevant to current utility work in that erosion can result in high costs for dredging SPU's drainage facilities. Channel condition is a good indicator of erosion potential. New data on channel condition could help us identify priorities for addressing the cause of erosion (e.g., constricted channels, undersized infrastructure). Addressing erosion, could also improve habitat and water quality, and reduce impacts to adjacent properties. Channel condition data could also be used to support potential alternative stormwater compliance projects or in-lieu-fee efforts by SPU or others.

6. Stream Typing

The Stream Typing Use sub-topic area describes the water typing (also known as stream typing) classification is used in Washington State and explains how typing effects management of SPU assets.

6.1 Introduction

This section presents background information, a discussion of results, and recommendations on how information on stream typing can be used for the upcoming ISP. Additional information is also provided on data gaps, and potential future work associated with stream typing data. Other possible uses for this information outside of the ISP are provided in Section 9.

6.2 Background

Water typing is a classification system that was originally developed by the Washington Department of Natural Resources (WADNR) to regulate forest practices such as buffer width and stream crossings on forest lands (following Washington State Department of Natural Resources water typing protocols outlined in the Forest Practices Board Manual Section 13, and definitions found in WAC 222-16-031). It has been adopted by some City and county agencies for regulating development activities within riparian areas and is used by state and federal permitting agencies to determine where fish passage regulations apply.

The classification system is based on the presence of fish (or potential of a water body, stream, or section of a stream to support fish populations) based on channel conditions, and whether flow is seasonal or perennial. Man-made barriers to fish are not considered legal boundaries of fish habitat. Originally, the water typing classification was based on numeric categories (1-5) but was restructured more recently into 4 classes as described in Table 6-1. The presence of fish is the primary indicator of fish-bearing waters (types S and F, previously types 1 through 3), and the presence of natural barriers (particularly gradient changes) is the primary indicator of non-fish bearing waters (types Np and Ns, previously types 4 and 5).

Table 6-1: Water Typing (aka Stream Typing) Definitions

Type	Description
Type "S" (Shoreline)	Streams and waterbodies that are designated "shorelines of the state" as defined in chapter 90.58.030 RCW. **(formerly type 1)**
Type "F" (Fish-bearing)	Streams and waterbodies that are known to be used by fish or meet the physical criteria to be potentially used by fish. Fish streams may or may not have flowing water all year; they may be perennial or seasonal. **(formerly type 2 or 3)**
Type "Np" (Non fish-bearing, perennial flow)	Streams that have flow year-round and may have spatially intermittent dry reaches downstream of perennial flow. Type Np streams do not meet the physical criteria of a Type F stream. This also includes streams that have been proven not to contain fish using methods described in Forest Practices Board Manual Section 13. **(formerly type 4)**
Type "Ns" (Non fish-bearing, intermittent or seasonal flow)	Streams that do not have surface flow during at least some portion of the year, and do not meet the physical criteria of a Type F stream. **(formerly type 5)**

This classification system directly affects the maintenance and management of SPU's drainage infrastructure because environmental regulations and design requirements related to fish use differ between Type S and Type F waterbodies and do not apply to Type Np and Type Ns waterbodies.

While this TM does not fully describe all the permit prohibitions or restrictions associated with each of the water classifications, several more significant limitations include the following:

- Stream crossings on Type F waters must meet current fish passage design standards when replaced; if they are existing fish passage barriers, permits for repair will not be issued if the repair extends the life of the barrier.
- Instream work on Type F waters is restricted to a short construction fish window determined by the Washington Department of Fish and Wildlife (WDFW). For most of our urban creeks the fish window is July 1-August 31, with the potential for extension into September.
- Routine maintenance work in Type F waters such as culvert cleaning, vegetation removal, CCTV, etc. require environmental permits from the State, which may restrict work to the fish window and may include requirements for fish relocation.

6.3 Methods

GIS information on stream typing was taken from GISP and consolidated and updated to produce a GIS layer showing the known stream typing for all the urban creeks in Seattle.

Data sources included in the stream typing layer:

- Stream typing data for all Seattle's urban streams collected by U.S. Fish and Wildlife Service (USFWS) in 2005 and 2006 stream surveys (USFWS, 2010). This stream typing effort was conducted in 1999 and 2005 to identify fish-bearing and non-fish bearing waters as the basis of state regulatory requirements for water bodies and their riparian areas (Washington Trout, 2000). This analysis followed water typing protocol outlined in the State Forest Practices Rules (WAC 222-16-030 and WAC 222-16-031).
- SPU's previous GIS stream typing layer for the five main creek watersheds and salmon streams as was shown in the 2007 SOTW report (City of Seattle, 2007).
- Stream typing data from individual habitat characterizations that were completed in association with individual capital projects

The initial GIS stream typing layer (2003), which included only the five main creek watersheds and salmon streams, was updated to include all 49 creeks (USFWS, 2010), both of which were used to develop the 2007 SOTW GIS stream typing layer for the five main creek watersheds. SPU SMEs reviewed the resulting GIS layers to improve accuracy, especially for stream segments that had conflicting stream typing information. In such cases, a determination of the most likely typing was made based on best available data. Stream typing for the smaller urban creeks was added to the GIS layer using data from the 2010 USFWS report which was snapped to the urban watercourse layer in the spring of 2018. The layer was also updated with the current WADNR stream type classifications (S, F, Ns, or Np), and the old stream type classifications (1-5) are still included in the attribute table. The old system provides additional information, by splitting Type F into two water types based on the level of fish use: Type 2 (fish-bearing, high use–multiple species and life stages), and 3 (fish-bearing, low use by a few species and/or life stages)

6.4 Results

Data products associated with the Stream Typing sub-topic area of this TM include:

- GIS map layer and PDF maps (Appendix H) of known stream typing for all of Seattle's urban creeks
- Table 6-2 summarizing the proposing of Type F waters/creek

In addition to the individual map layers created, the stream typing data has also been updated and added as an attribute to the urban watercourse layer.

Table 6-2: Summary of Type F Waters in Seattle Creeks

Type F Creek Watersheds	City Quadrant Location	Fish Present	Salmonids present
Piper's	**NW**	**Y**	**Y**
Licton Springs	NW	N	N
Unnamed PS06	NW	N	N
Wolfe (Kiwanis Ravine)	NW	N	N
Scheuerman	NW	Y	N
Thornton	**NE**	**Y**	**Y**
Ravenna	NE	Y	Y
Washington Park (Arboretum)	NE	Y	Y
Longfellow	**SW**	**Y**	**Y**
Fauntleroy	**SW**	**Y**	**Y**
Schmitz	SW	N	N
Puget	SW	Y	Y
Taylor	**SE**	**Y**	**Y**
Mapes	SE	Y	Y
Durham	SE	Y	Y
Unnamed DW02	SE	N	N
Hamm North	SE	N	N

Note: The five main creek watersheds are listed above in ***boldface*** *type. The quadrants are divided into north and south by the Ship Canal/Montlake Cut, and into east and west by the Interstate 5 freeway (I-5).*

Seattle has 49 creek watersheds within its jurisdiction. The majority are too small or too steep to be fish-bearing (Type F). Seventeen creek systems have portions that are Type F waters (see Table 6-2 and the stream typing maps in this TM), although fish were documented in only 11 of them, and salmonids were found in 10 of them (USFWS, 2010). Several of these have manmade barriers, which would be expected to prevent access to the Type F waters, such as, Puget, Durham, Schmitz, and Ravenna Creeks. Not unexpectedly, most of the mainstem portions of the larger creek systems, and some of their larger tributaries, support salmon, and thus are regulated to protect fish life.

Type F waters are found in all parts of Seattle. The majority of these are found in Thornton Creek in the NE quadrant of the City, Piper's Creek in the NW quadrant, Taylor and Mapes Creeks in the SE quadrant, and Longfellow and Fauntleroy Creeks in the SW quadrant.

6.5 Discussion

In general, Seattle's creek channels are characterized by low gradient headwater areas draining through steeper ravines and emerging as low gradient channels that flow through alluvial floodplains to the creek mouth. The Seattle creeks drain to Puget Sound, Lake Washington, or to the Ship Canal/Montlake Cut, all areas that have migratory and resident salmonids, along with many other species of native and nonnative fish. Despite extensive land use changes, large sections of Seattle's creeks remain on the surface, and the relatively low gradient mainstem channels (0-8%) are considered accessible to fish (Type F), even though manmade barriers prevent access to large parts of some watersheds, particularly Longfellow, Taylor, Mapes, and Piper's Creeks.

The updated GIS stream typing layer produced for the DSA was snapped to the City's corporate urban watercourse layer in the spring of 2018. The stream typing data from this GIS layer was used as creek attribute data. However, the urban watercourse layer was then updated in the winter of 2019 with new geography and will continued to be modified over time as new information becomes available and as the creek changes. As a result, the GIS layer created for the DSA is not perfectly aligned with the corporate urban watercourse layer.

Some creek segments were typed as U for "unknown". An unknown stream type designation was applied if any of the following was found:

1. The creek was not included in previous typing efforts, or
2. The creek system is so modified that understanding its habitat potential is difficult and would require more evaluation, or
3. Because that segment of the creek is piped (culvert or mainline).

After the stream typing maps were created, SPU's culvert program, through a consultant contract, evaluated several culverts and mainlines that had an unknown barrier status. The consultant report suggested that some of the structures previously untyped would most likely be considered fish passage barriers and Type F waters by regulatory agencies. Because this information was not formally reviewed by regulatory agencies the stream typing maps here were not updated to reflect these changes. Updates to SPU's GIS data will be done on a case by case basis as stream typing for unknown sections of creek are confirmed.

The data were not developed or prioritized through a lens of racial and social equity but may be useful for the DSA and ISP in better addressing racial and social equity through utility investments in open space and access to healthy aquatic habitats as discussed in Section 9.

6.6 Recommendations for Future Use

This section describes how data from the Stream Typing sub-topic area could be used to inform the ISP and to inform implementation of specific projects or programmatic activities that are developed through the ISP, and to inform other SPU work outside of the ISP. Additional recommendations on how information from multiple sub-topic areas could be combined to inform the ISP, or other work, through broader analyses is included in Section 9 of this document.

6.6.1 How information could be used for ISP

Stream typing data can be used to understand how our utility work is regulated by:

1. Delineating the extent of potential fish habitat within Seattle's urban watercourses to understand where regulatory constraints related to fish passage apply. As described in the Fish Passage TM, instream drainage assets in Type F areas need to comply with fish passage regulations which can affect maintenance, repair, or replacement of drainage assets.
2. Generally aligning/realigning new and retrofitted piped drainage infrastructure, located in the vicinity of creek channels, to avoid Type F waters, when possible. For example, King County is realigning a portion of its sewer truck line which currently runs through Thornton North Branch, to relocate it outside of the channel and riparian areas.
3. Approaching future drainage infrastructure repair, replacement, or additions cautiously on non-typed waters. Habitat characterization is advisable to clarify regulatory constraints.
4. Using the combination of stream typing (Section 6), fish habitat quality (Section 4.2.2), fish use (Section 7) and fish passage barriers maps to identify priority areas for removing barriers and/or opportunities for added value/mitigation for capital projects that either are located instream, or will impact Type F waters.

6.6.2 How information could be used outside of ISP

The stream typing maps could be shared with other City departments to inform their planning efforts and help them identify potential constraints and risks associated with their creek infrastructure.

6.7 Additional Information

Information in the Stream Typing sub-topic area is a complement to other Aquatic Habitat sub-topic areas included in this TM and other DSA Topic Areas. Together the combined sub-topic areas and other Topic Areas can provide a better understanding of the overall condition and habitat use of Seattle's urban creeks, and restoration opportunities along the Duwamish Waterway, and shorelines of Puget Sound and Lake Washington.

6.7.1 Related DSA Topic Areas

Related DSA Topic Areas include:

- Fish passage
- Floodplain reconnection

6.7.2 Additional Work/Data Gaps

Recommended work includes:

1. Additional work may be warranted to confirm the typing of stream segments with an unknown stream type.
    a. An untyped segment of creek that has the same stream type on each side of it should be presumed to be the same type as the adjacent segment. For instance, in the figure to the right, all the culvert segments typed "unknown" between Type F segments and would also be assumed to be regulated as Type F waters.
    b. An untyped segment of creek that has different stream types on either side of it would need more evaluation to determine if the unknown typing should match the upstream or downstream typing.
    c. An untyped segment creek at the most upstream or downstream extent of an urban watercourse would need more evaluation to confirm if the stream type should match the adjacent areas, or if it should be a different type.
2. Consider whether a stand-alone, corporate GIS layer on stream typing would be useful. The Urban Watercourse layer is a corporate GIS layer and includes stream type as an attribute, but it is not a separate GIS layer. A benefit of having stream typing as a GIS layer, is that it could also be viewed through other programs such as UtiliView, making it more accessible to more City employees than ArcGIS currently allows.

7. Fish Use

The Fish Use sub-topic area consolidates existing information on fish use in Seattle's urban creeks. This section presents background information, a discussion of results, and recommendations on how information on fish usage can be used for the ISP. Additional information is also provided on data gaps, potential future work associated with fish usage data and other possible uses for this information outside of the ISP.

7.1 Introduction

The Fish Use sub-topic area work was primarily based on a GIS data layer of the fish usage data that was previously published in the City's SOTW report (City of Seattle, 2007) but was also supplemented with data from a variety of other sources as described below.

7.2 Background

The SOTW fish usage maps were based on weekly fish (salmon and migratory trout) sampling completed by Wild Fish Conservancy (WFC), formerly Washington Trout, September through May, between 1999 and 2008 for the five main creek watersheds and salmon streams. This was done in conjunction with stream typing and fish passage barrier surveys (see Section 6). Fish sampling by WFC included summer presence/absence surveys (WFC, 1999-2000). They spot-checked areas for the presence of fish (particularly higher in the tributaries) using electrofishing equipment. Captured fish were identified and their size, general condition, and relative abundance in the immediate area are recorded.

SPU's fish usage database, originally created based on SOTW data, has been supplemented with data from other more recent and periodic surveys completed in the five main creek watersheds and salmon streams including:

- The data from the 2010 USFWS report for the five main creek watersheds and salmon streams in Seattle.
- Sporadic spawning surveys conducted by SPU staff in Thornton Creek 2015-2019
- Surveys conducted by community volunteers on Piper's Creek (weekly spawning surveys 2010-present).
- Daily coho pre-spawn mortality surveys conducted by NOAA in Longfellow Creek during Fall months between 2002-2009
- Weekly coho pre-spawn mortality surveys conducted by Puget Soundkeepers volunteers during Fall months (2015-present).
- Smolt trapping by SPU staff (2-3 weeks in May, 2001-2007) Thornton and Longfellow

SPU has additional data on fish use, that was not incorporated into the GIS layers produced for this TM. This information is stored in EQuIS and can be made available upon request to SPU's Urban Ecosystem team. Available data sets include:

- Project performance monitoring (2016–ongoing) – by SPU for Thornton creek including:
    - Pit tagging, primarily of juvenile cutthroat every July. Tags are inserted into fish collected at the project site. A tag reader at the mouth Thornton Creek records the entry (returning fish) or exit (outmigration) of tagged fish.
    - Fish diet sampling collected from fish at Thornton Floodplain sites
    - eDNA sampling for Chinook and coho salmon within Thornton Floodplain sites

Fish use information can also be found in the 2010 U.S. Fish and Wildlife Service report which was based on summer presence/absence surveys and spot-checking with electrofishing equipment from 2005–2006. These surveys include all 49 creeks in Seattle.

7.3 Methods

For the Fish Use sub-topic area, GIS data originally derived from the SOTW was pulled from GISP and updated with more recent information on fish sightings and fish use on the five main creek watersheds and salmon streams in Seattle.

The GIS layers produced for this TM illustrate the most upstream extent of fish use in each watershed differentiated by individual species type. The fish use data were visualized in GIS layers using two different methods, which resulted in two different GIS layers. One method considered point data showing the most upstream location where each species has been observed. The other method consolidated information on fish use by species into groups of types of fish and overlaid with data showing fish habitat. Each of these layers are described in more detail below.

7.3.1 Most Upstream Fish Sighting by Species

The maps produced for this TM are a modified version of the layer seen in the 2007 SOTW report data. The Most Upstream Fish Sighting layer shows how far upstream individual species have been observed. The SOTW data was supplemented with fish survey information much of which was collected after the 2007 SOTW report. The locations of most upstream fish were modified to include the latest fish sighting data as of September 2018. The most upstream fish sighting was displayed with an individual color-coded point for each fish species.

7.3.1 Extent of Fish Habitat Use by Species Groups

The maps produced for this TM are a modified version of the layer prepared for the 2007 State of Waters report. Locations of most upstream fish were modified to represent the latest fish sighting data as of September 2018, and the extent of Type F waters was overlaid with the fish sightings making it easier to see what extent of potential fish habitat is currently being used by fish. This information was displayed using line features for extent of fish use and line features showing fish habitat (Type F waters) based on stream typing data (Section 6).

The extent of fish use by species was drawn in ArcGIS using information taken from the existing most upstream fish sighting and combining it into species groups defined as:

- Listed salmon/ trout: Includes documented chinook salmon
- Non-listed salmon/ migratory trout: Includes documented salmon (coho, chum, sockeye, pink) and/or migratory trout (adfluvial or sea-run cutthroat trout)
- Resident trout: Includes documented resident trout (cutthroat trout or rainbow trout)
- Other fish (Type F): Includes other predominantly native fish species (e.g., peamouth, sculpin, suckers. stickleback)
- No fish species (Type Np or Ns): No fish species have been observed in these waters.

The Extent of Fish Use by Type provides an alternative way to view fish presence/distribution in the urban creek by using a line feature instead of a point feature for most upstream fish sightings. Locations of most upstream fish were modified to represent the latest fish sighting data as of September 2018, and the extent of fish habitat (Type F waters) was overlaid with the fish sightings making it easier to see what extent of potential fish habitat is currently being used by fish. Each line segment represents a fish species or grouping of species and is drawn from the creek mouth to the most upstream area where that fish species or fish grouping was observed. It is displayed over the stream type, so it is possible to see what proportion of potential fish habitat is being used by fish.

7.4 Results

As described above, the fish use data were visualized using two different approaches which resulted in two separate GIS layers. One layer shows the most upstream fish use by species and the other shows how much of the available fish habitat (Type F waters) is used by different groups of fish species.

Data products associated with the Fish Use sub-topic area of this TM include:

GIS data layers and PDF maps (Appendix I) showing:

- Most upstream fish use by species
- Extent of fish habitat use by species grouping

The first set of maps, most upstream fish sighting by species, show where individual species are using specific streams. The Fauntleroy Creek map shows a lower number of fish species (4) and more limited use of creek habitat than the other creeks described in this TM. While there are some differences in the species present in Longfellow, Piper's and Taylor Creeks, they are roughly similar in terms of total number of species present (7, 8, and 6 respectively) and moderate distribution of fish throughout each creek. Thornton Creek has by far the greatest number of observed fish species (13) including native and non-native, and distribution throughout the watershed.

The second set of maps, overlays fish use with fish habitat to show the proportion of total fish habitat being used by groups of species. Of all the creeks, Fauntleroy has greatest amount of unused fish habitat. Within Longfellow Creek approximately three-fourths of the fish habitat is actively being used by fish although salmon use is limited to the lower third of the creek. Within Piper's Creek, approximately two-thirds of the habitat on the mainstem has documented fish use as does a fair amount of the Venema Creek tributary. In both the mainstem and in Venema Creek salmon use is limited to the lower portions of these creeks. In the Taylor Creek watershed only about half of existing fish habitat is being used with salmon use limited only to the mouth of the creek below Rainier Ave. Thornton Creek has the most extensive use of fish habitat of all the creeks. Fish use is documented throughout the mainstem, north branch and south branch with at least some species of salmonids in most of that habitat. Listed salmon use is documented throughout the mainstem and in the lower half of the south branch, but only in a small stretch of the north branch. In all the creeks except Fauntleroy, "other" fish species have a wider distribution are present further upstream than the migratory species.

7.5 Discussion

This section discusses the observed trends in fish use by individual species (Section 7.3.1) and observed trends related to the extent to which fish use existing fish habitat in each creek (Section 7.3.1). These data were not developed or prioritized through a lens of racial and social equity but may be useful for the DSA and ISP in better addressing racial and social equity through utility investments in open space and access to healthy aquatic habitats as discussed in Section 7.6.

Fish habitat use varies by naturally by stream characteristics and by species as well as by the availability and quality of habitat as highlighted in Section 4. Fish habitat use is also limited by the presence of fish passage barriers (see DSA Task 4 TM: Fish Passage Barriers). This section attempts to provide some explanation for the observed trends in fish habitat use in the City's largest salmon streams.

Several general conclusions can be drawn from these maps and are discussed below followed by examples from individual creeks.

- There is a fair amount of natural variability in the diversity and distribution of fish species across the streams. The two fish use layers show that certain fish species (i.e., cutthroat trout) are present throughout much of Seattle's watersheds, whereas other fish species such as sockeye salmon and chum salmon are less common in Seattle streams and are typically limited to the lower sections of each watershed. The wide range among the salmonid species reflects the significant differences in the life histories of each species and their ability to adapt to the habitat conditions that characterize urban watersheds. Chum salmon only come into lower tributaries connected to Puget Sound. Endangered Species Act (ESA)-listed Chinook salmon are found in each of the creeks described in this TM except for Fauntleroy, which is a smaller watershed than the others and not suitable for Chinook. Chinook salmon use is tracked most closely by SPU and other government agencies since they are federally listed as threatened under the. Also pre-spawn mortality associated with stormwater appears to be most significantly affecting coho salmon and may be limiting population numbers and movement of fish within Longfellow and Thornton.
- Not all available fish habitat is being used by migratory fish and this is frequently due to the presence of fish passage barriers, and/or gaps in the fish passage data. As described in more detail in the Task 4 TM on Fish Passage Barriers, there are instream structures or conditions that limit the passage of some or all fish species or life stages or are complete barriers to all species and life stages. In Longfellow, Taylor, and Fauntleroy creeks migratory salmon are only able to access the most downstream portions of the watershed due to known fish passage barriers. Over the next few years, SPU has plans to replace two culverts on Fauntleroy Creek and one culvert on Taylor Creek all of which represent complete fish passage barriers. These projects are expected to lead to an increase in the amount of fish habitat used by migratory salmon and other species.

  On Longfellow Creek, a complete fish passage barrier, is located within the West Seattle Golf course which blocks salmon access to available upstream habitat. There are no planned efforts to remove this high priority fish passage barrier, although it has been the focus of periodic discussions with Seattle Parks and Recreation, the Muckleshoot Indian Tribe, and various community members and groups interested in salmon recovery. This site will be evaluated by SPU in 2021 (Longfellow Natural Flood Storage project) as a potential location for floodplain reconnection which may present an opportunity to also address fish passage at this site. The culvert is also in close proximity to Sound Transit's future West Seattle light rail line which will impact Longfellow Creek and may trigger mitigation. This could provide another opportunity for collaboration between Sound Transit and City departments on fish passage, pedestrian and habitat improvements, and flood reduction efforts.

  In the Piper's and Thornton Creek watersheds there is greater use of existing fish habitat by migratory salmon compared with Taylor, Longfellow, and Fauntleroy Creeks, although both creeks still have a sizeable amount of potential fish habitat that is not being used by migratory fish. This may be due to a combination of fish passage barriers or may represent gaps in fish monitoring or low population numbers.

- The largest of Seattle's stream complexes (Thornton and Piper's) both have multiple tributaries throughout the watershed, a broader range of fish habitat use, and more use of habitat higher in the system by both migratory and non-migratory fish. While these watersheds do have numerous fish passage barriers, they are not completely blocking most of the habitat. These creeks both have larger channels, greater flow, and more spawning habitat higher in the system to support fish use.

7.6 Recommendations for Future Use

This section describes how data from the Fish Use sub-topic area could be used to inform the ISP, to inform implementation of specific projects or programmatic activities that are developed through the ISP, and to inform other SPU work outside of the ISP. Additional recommendations on how information from multiple sub-topic areas could be combined to inform the ISP, or other work, through broader analyses is included in Section 9.

7.6.1 How information could be used for ISP

The ISP could overlay information on fish use with data on instream and riparian canopy condition and habitat condition to identify the most ecologically valuable places to:

1. Provide environmental benefits
    a. The extent of known fish habitat use could be combined with data on fish passage barriers, identified in a separate DSA TM, to inform sequencing of culvert replacement projects to provide greatest and most immediate benefits to fish
2. Support better utility work by:
    a. Including habitat enhancement activities when possible at utility project sites (e.g., removal, rehabilitation, or relocation of infrastructure within or adjacent to urban creeks that support endangered salmon or multiple fish species).
    b. Removing, modifying, and/or relocating SPU utility infrastructure such as water or sewer mains, or outfalls in areas with endangered salmon or multiple fish species.
    c. Prioritizing source control efforts in basins that drain to creek segments that salmon use (e.g., more frequent sweeping during critical fish periods)
    d. Limiting placement of new utility infrastructure (e.g., outfalls, pump stations, CSO facilities) in areas with high fish use.
3. Address environmental justice and service equity by:
    a. Engaging underserved communities in restoration partnerships, environmental stewardship and/or citizen science focused on improving equity around access to healthy waters and habitat.
    b. Engaging tribes and tribal members in discussion about their priorities related to fish passage barrier correction and stream restoration.

7.6.2 How information could be used outside of ISP

The information in this TM could be used to identify appropriate areas for salmon viewing, citizen science, and development of school-based programs focused on environmental science.

7.7 Additional Information

Information in the Fish Use sub-topic area is a complement to other and other Aquatic Habitat sub-topic areas included in this TM and other DSA Topic Areas. Together the combined sub-topic areas and Topic Areas and can provide a better understanding of the overall condition and habitat use of Seattle's urban creeks, the Duwamish Waterway, and shorelines along Puget Sound and Lake Washington.

7.7.1 Related DSA Topic Areas

Related DSA Topic Areas include:

- Fish passage
- Floodplain reconnection

7.7.2 Additional Work/Data Gaps

Recommendations for additional and continued fish surveys that could inform planning efforts and to help evaluate performance of projects identified through the ISP include:

- Conduct presence/absence monitoring of fish species on the main salmon streams in Seattle at least every 2 years. This would allow SPU to observe any major changes in fish use that could signal a problem with infrastructure, stormwater, land use or habitat.
- Conduct, pre-and post-restoration project performance monitoring at sites where fish passage barriers are removed and/or other major creek or floodplain enhancement projects are completed to document changes in fish use. One to three years of pre-restoration monitoring of fish use and two to three years of post-construction monitoring of fish use is recommended. This could be as simple as one pass electroshocking for fish presence/absence and quantity (including fish diets and fish size).
- Use eDNA technology to inform salmon recovery needs in the City. SPU and USGS are testing Environmental DNA (eDNA) sampling to get a better understanding of whether this method could be used as a tool for mapping the distribution of anadromous fish in Seattle's urban creeks. eDNA is a relatively new tool used that can identify the presence or absences of specific organisms in the environment by detecting biological material (e.g., sloughed off skin or scales, fecal material, decomposing tissue etc.) that contains DNA. The benefit of this approach is that fish use can be detected even if fish are not present at the time of sampling. SPU began collecting eDNA samples on Thornton and Taylor Creek in 2018 to track salmon presence and absence of adult and juvenile (Chinook and coho). eDNA is recommended for both the fall and spring to evaluate anadromous species use. Fall sampling can identify returning adults while spring sampling can help to identify recently hatched, emerging and downstream migrating juveniles.

8. Shoreline Restoration and Creek Daylighting Opportunities

The Shoreline Restoration and Creek Daylighting Opportunities sub-topic area consolidates existing information on restoration opportunities so that information is readily available to inform the ISP. This includes restoration opportunities on shoreline areas identified as ecological priorities and previously identified and prioritized creek daylighting opportunities.

8.1 Introduction

This section provides background on sources of this information and how and why priorities were identified. This section also includes a discussion of results and recommendations on how information on restoration opportunities can be used for the upcoming ISP. Additional information is also provided on data gaps, potential future work, and other possible uses for this information outside of the ISP.

8.2 Background

Seattle's marine, lake, and riparian shorelines and urban creeks are an iconic part of our region and integral to the functioning of SPU's drainage system. Seattle's shoreline areas and creeks provide habitat for many species including federally endangered Chinook salmon, provide water access for residents of Seattle, and are the receiving waters for SPU's drainage system.

Priorities for shoreline protection and restoration have been identified through several different efforts and many are documented in the regional salmon recovery plans described below. Creek daylighting opportunities were also identified through previous City efforts which are also described in this section.

8.2.1 Shoreline Restoration

In response to the 1999 listing of Chinook salmon as a federally threatened species under the ESA, the City and other local governments engaged in regional salmon recovery planning efforts in the Lake Washington/Cedar/Sammamish Watershed, also referred to as Watershed Resource Inventory Area WRIA 8 (WRIA 8) and the Green/Duwamish Watershed (WRIA 9). Since 1999, the City has committed to short and long-term measures to help restore fish runs and fish passage for coho and Chinook salmon and steelhead trout. The WRIA 8 and 9 watershed plans both identify priority restoration and protection projects that are packaged in 4-year work plans. Projects can be put on the 4-year work plans if they are being actively worked on and/or if there are no major issues, aside from funding, preventing them from moving forward. The WRIA 8 work plan includes projects on Lake Washington shorelines, the Ship Canal and Puget Sound marine shorelines from north side of Discovery Park northward to the City limits. The WRIA 9 plan includes projects along the Duwamish and Puget Sound marine shorelines south from the tip of Discovery Park.

In 2006, WRIA 9 published two additional planning documents that identified priority areas: 1) Duwamish Blueprint (Clark et. al., 2006) and 2) WRIA 9 Prioritization of Marine Shorelines for Juvenile Salmonid Habitat Protection and Restoration (Anchor, 2006). The Duwamish Blueprint was developed to implement Program D-3 of the WRIA 9 Salmon Habitat Plan. It provides guidance on ecosystem restoration of the Duwamish estuary with focus on river miles 10-1 from Tukwila, near the I-5/SR-599 interchange, downstream to almost Harbor Island and the West Seattle Bridge. It was drafted in 2006 and updated in

2014. The 2006 Anchor report identified and prioritized habitat management areas and actions that would promote salmonid survival along the marine shorelines of WRIA 9. The report was intended to guide regional salmon recovery planning associated with the ESA-listed Chinook salmon and proposed listing of steelhead and coho salmon. Creek Daylighting

In 2006, City Resolution No. 30850 established the City's intent to develop a prioritized list of where daylighting pipes, culverts and creek mouths would benefit salmon and to analyze resources and incentives that could be used to encourage property owners to daylight pipes and culverts. The resolution requested that SPU, the Office of Sustainability and the Environment, and the Department of Planning and Development[1] conduct analyses and prepare a report that prioritize which pipes and culverts would benefit salmon the most, if daylighted.

A briefing paper was developed by SPU (Seattle Public Utilities et. al., 2006) that included maps of Seattle watercourses, known and potential salmon use of Seattle's streams, and a description of the method for evaluating potential daylighting projects that was used to generate a prioritized list of daylighting opportunities. The list only included daylighting projects that would benefit streams with fish habitat (Type F waters) and limited to public ownership. Some potential daylighting opportunities were screened out based on assumed feasibility issues or limited perceived value. The criteria which were used to prioritize the daylighting opportunities are shown below in Table 8-1. The opportunities were classified as high (80–120 points), medium (40–79 points) or low priority (0–39 points) based on the total score.

Table 8-1: Scoring Criteria for Daylighting Opportunities

Criteria	Possible points
Salmon downstream	20
Salmon upstream	-25
Ability to retain runoff	10
Water quality	2 to -10
Floodplain reconnection	25
Barriers	15
Riparian condition	10
Addition of light	5
Other (e.g., size)	10

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[1] In 2016, Seattle's Department of Planning and Development was split into two entities: Seattle Department of Construction and Inspections and the Office of Planning and Community Development.

8.3 Methods

This section describes the methods used to pull data from the following sources and to develop GIS layers for the DSA.

8.3.1 Shoreline Restoration

A Shoreline restoration opportunities GIS data layer and associated data table was created as part of this topic area by combining information from the following sources:

- WRIA 8 (Chinook only): WRIA 8 Chinook Conservation Plan (update in progress)
- WRIA 9 (Chinook only): 4-year work plan (update in progress), Prioritization of Marine Shorelines of WRIA 9 for Juvenile Salmonid Habitat Protection and Restoration (2006) (H/M/L), Duwamish Blueprint (2014)

8.3.2 Creek Daylighting

For this TM, the table of daylighting opportunities identified in the 2006 briefing paper (Seattle Public Utilities et. al., 2006) was reviewed, and ten projects were removed because they either were already completed, there wasn't sufficient information to understand what was previously proposed, or what was proposed no longer seemed feasible. A column was added to the table of daylighting opportunities that summarized proposed work, as the previous table was less clear on proposed actions and focused more on ecological benefits. Additional detail was added to some of the descriptions for clarity or to emphasize benefits. The revised table was used to create a creek daylighting opportunities GIS data layer for use in the ISP.

8.4 Results

This TM consolidates information on shoreline and creek daylighting opportunities that were prioritized in relation to potential value for salmon recovery. While most of the shoreline restoration opportunities would likely be implemented by other agencies or organizations, a few of the projects are specifically relevant to SPU:

- Lowman Beach Bulkhead Removal – This is being led by Seattle Parks and Recreation (SPR) with support from SPU as one of our drainage pipes currently runs through the project area and will be modified during the project with a small section of it being daylighted
- Henderson 49 CSO Reduction and Shoreline Restoration – much of this work was already completed by SPU although there is the potential for expanded shoreline restoration
- Matthews Beach Creek Restoration – this project would provide an opportunity for a significant coordinated investment strategy for SPR and SPU around salmon recovery needs, Park's needs, and utility issues (flooding, failing culvert, fish passage, conveyance capacity).
- Commodore Park and Wolfe Creek Restoration – Wolfe Creek is routed into King County's combined system near this location. The proposed restoration could restore shoreline habitat for salmon and reduce CSO volumes going to West Point Sewer Treatment Plant.

- 12th and Elmgrove St. – this stretch of shoreline owned by Port of Seattle (Port) is adjacent to upland property owned by SPU. There may be an opportunity for collaboration with the Port on shoreline restoration and public access which is supported by SPU and the community.

This TM also identified a relatively short list of prioritized daylighting opportunities compared to the full potential for daylighting in Seattle. This is due in part to the purpose for which the original list was developed which was to identify daylighting priorities that could contribute to salmon recovery. It was not intended to be a comprehensive prioritization of all the daylighting opportunities, did not fully evaluate daylighting as a tool for addressing flooding problems or creating new shoreline access, and filtered out many potential daylighting opportunities.

The opportunities that ranked high in this effort tended to be piped creeks with documented salmon use up and downstream, with few to no fish passage barriers downstream, good habitat quality and potential for floodplain reconnection. The first three opportunities on the list were located at or close to the mouth of the City's two largest creeks (Thornton and Longfellow) and are briefly described below. There was a noticeable drop in scores following these first three entries. After the first three projects on the list which scored high, there was a big jump in scores before the next projects on the list indicating a natural break.

- Thornton Mainstem (Mouth and Delta) – this entry overlaps with the Matthews Beach shoreline restoration opportunity also identified in this TM. Proposed work would include removal of bank armoring, replacing a lined channel partially owned by SPU, reconstructing and potentially re-aligning the stream channel, and reconnecting the floodplain. This is an area of chronic flooding, adjacent to a failing and undersized SPU culvert and next to Matthews Beach Park.
- Longfellow (SW Brandon – SW Juneau) – this site encompasses SPU's creek bypass, SPR property, right-of-way, and private property in an area with chronic flooding and historic inequities. This site is also one of the highest priority fish passage barriers in the City and in an area of high floodplain reconnection suitability. Feasibility of daylighting at this site is planned as part of the recently initiated Longfellow Creek Natural Flood Storage Project (C600490).
- Longfellow (Culvert outlet to Duwamish) – the Longfellow creek outfall to the Duwamish river is the downstream end of an extensive piped creek drainage system extending beneath the Nucor Steel mill and across Port property. It is the highest ranked fish passage barrier in the City. While daylighting the entire drainage system has tremendous feasibility daylighting the most downstream section of mainline pipe and creating and open channel to the Duwamish through Port property and

Data products associated with the Shoreline Restoration and Creek Daylighting Opportunities sub-topic area for this TM include:

GIS data layers and PDF maps

- Shoreline restoration opportunities (Appendix J)
- Creek daylighting opportunities (Appendix K)

Tables summarizing restoration opportunities

- Shoreline salmon recovery projects (Appendix J)
- Prioritized creek daylighting opportunities (Appendix K)

8.5 Discussion

8.5.1 Shoreline Restoration

The shoreline habitat restoration opportunities presented here are based primarily on existing data related to salmon recovery needs, as well as SPU subject matter expertise on salmon recovery and aquatic habitat. The salmon recovery priorities were pulled from the WRIA 8 and 9 4- and 10-year workplans (and projects proposed for the WRIA 9 salmon plan update). Projects are advanced to the 4-year workplans as potential or willing sponsors are identified and able to proceed. There may be sites that have great potential for salmon recovery and habitat but are not included due to private landownership or lack of a clear sponsor. As projects are completed or dropped; the priorities can shift.

This data was not developed or prioritized through a lens of racial and social equity but it may be useful to the DSA and ISP when addressing racial and social equity through utility investments in open spaces and access to healthy aquatic habitats, as discussed in Sections 8.6 and 9.

8.5.2 Creek Daylighting

Creek daylighting typically refers to restoring an underground, piped creek to an open channel by removing piped infrastructure and allowing the creek to flow more freely at the surface. In the original creek daylighting prioritization and in this TM, daylighting was used in a broader sense to refer to opportunities to restore more natural flow conditions to creeks. For instance, some of the opportunities listed would replace undersized culverts blocking fish passage with wider structures that allow fish passage barriers or may expand creek channels by removing bank armoring or through more complete floodplain reconnection. The daylighting opportunities identified here are just a subset of the many opportunities available in our urban creeks and are not an exhaustive list of all the potential daylighting opportunities that should be considered by SPU. This data was not developed or prioritized through a lens of and social equity but may be useful for the DSA and ISP in better addressing racial and social equity through utility investments in open space and access to healthy aquatic habitats as discussed in section 8.6.

8.5.3 Recommendations for Future Use

This section describes how data from the Shoreline Restoration and Creek Daylighting Opportunities sub-topic area could be used to inform the ISP, to inform implementation of specific projects or programmatic activities that are developed through the ISP, and to inform other SPU work outside of the ISP. Additional recommendations on how information from multiple sub-topic areas could be combined to inform the ISP, or other work, through broader analyses is included in Section 9 of this document.

8.5.4 How information could be used for the ISP

This information can be used in the ISP to identify locations where SPU could make investments in infrastructure projects or management and maintenance activities to contribute towards salmon recovery or meet other environmental priorities, and might also be used to identify areas where typical drainage and wastewater activities may conflict with environmental priorities.

The information on **shoreline restoration** potential can be used to:

1. Provide environmental benefits by:
    a. Identifying opportunities where SPU, as a signatory to the two regional salmon recovery plans, can contribute directly to salmon recovery efforts through capital projects (e.g., removal of fish passage barriers, culvert replacement or abandonment, floodplain reconnection, or removal of shoreline armoring and fill), or changes in system management and maintenance.
2. Support better utility work by:
    a. Directing capital investments to habitat enhancements designed as part of other utility projects (e.g., removal or relocation of infrastructure with negative impacts to salmon habitat, shoreline restoration at pump stations, outfalls and CSO facilities).
    b. Considering shoreline restoration projects identified here as potential mitigation projects if/as SPU is required to mitigate for utility impacts to shoreline habitat.
    c. Adopting aquatic habitat restoration as a tool for improving the resiliency of Seattle's shorelines to both climate change and urban development.
    d. Including salmon recovery needs in planning associated with the Duwamish Waterway and climate change resiliency.
    e. Evaluating opportunities for coordinated infrastructure and aquatic habitat improvements at Shoreline Street Ends – including with SDOT and SPR – with an emphasis on areas with historic racial and social inequities or lack of water and shoreline access.
    f. Limiting placement of new utility infrastructure (e.g., outfalls, pump stations, CSO facilities etc.) along shorelines where this work would preclude future restoration and require additional impacts such as shoreline armoring or discharge of untreated stormwater or wastewater.
    g. Removing, modifying, and/or relocating infrastructure in areas that are shoreline restoration priorities (and/or high-quality aquatic habitat). This could be done in advance of and/or concurrent with shoreline restoration efforts by SPU or others.
    h. Incorporating soft shoreline techniques and/or other best management practices as part of upgrades to and maintenance of utility outfalls and pump stations.
3. Address environmental justice and service equity by:
    a. Engaging underserved community groups and nonprofit organizations in shoreline restoration partnerships, environmental stewardship and/or citizen science.

The information on **creek daylighting opportunities** can be used to:

1. Provide environmental benefits by:
    a. Considering creek daylighting in priority locations that could improve fish passage and salmon recovery
2. Support better utility work by:

   a. Daylighting piped creeks where the pipes are unnecessary thereby divesting in un-necessary infrastructure.
   b. Daylighting piped creeks to address flooding where creation of an expanded creek channel or floodplain could add flood storage capacity and other benefits.
   c. Considering creek daylighting opportunities identified here (or other creek daylighting opportunities) as potential mitigation projects if/as SPU is required to mitigate for utility impacts to creek habitat.
3. Address environmental justice and service equity by:
   a. Considering creek daylighting to provide new access to creek habitat where there currently is limited access.

8.5.5 How information could be used outside of ISP

Provide environmental benefits by:

- Providing a GIS layer to local organizations and community groups facilitates the focus on shoreline restoration partnerships, environmental stewardship, and/or citizen science efforts on priority shoreline restoration sites.
- Providing an opportunity to simultaneously divest in piped infrastructure and invest in natural systems and creek conveyance through creek daylighting.

8.6 Additional Information

Information in this Shoreline Restoration and Creek Daylighting Opportunities sub-topic area complements other Aquatic Habitat sub-topic areas included in this TM and other DSA Topic Areas. Together the combined sub-topic areas and other Topic Areas and can provide a better understanding of the overall condition and habitat use of Seattle's urban creeks, the Duwamish Waterway, and shorelines along Puget Sound and Lake Washington.

8.6.1 Related DSA Topic Areas

Related DSA Topic areas include:

- Fish passage
- Floodplain reconnection

8.6.2 Additional Work/Data Gaps

Identifying additional creek daylighting opportunities could be facilitated through an overlay of the stream typing, culvert, and mainline GIS layer to look for intersections within Type F waters.

Updates to the salmon recovery plans and project lists are being performed this year and SPU has added some projects to the plans which are not reflected in this TM. Data gaps include identifying daylighting opportunities on smaller creeks that were not included in the initial prioritization. It may also be useful to re-evaluate feasibility at selected sites of interest, as feasibility can change over time with urban development, land use and ownership changes, public interests, technology, and overall needs.

Another potential data source for shoreline restoration opportunities is the 2017 Shoreline Street Ends Workplan developed by Seattle Department of Transportation which included an updated and prioritized list of street ends based on several different criteria, one of which was 'habitat potential'. However, the focus of that prioritization was primarily on public access improvements, and the 'habitat potential' was the lowest of the weighting criteria in the workplan. There is some overlap between the Shoreline Street Ends Workplan priority list and salmon recovery projects identified in this TM. A more thorough evaluation of the habitat potential at specific Shoreline Street Ends may be useful, particularly in areas where there is a nexus with utility needs.

9. Combined Recommendations for Future Use – Aquatic Habitat Topic Area

The individual Aquatic Habitat sub-topic areas above each included specific recommendations on potential uses of the sub-topic area data and GIS layers to inform the ISP and other utility work. In addition to these recommendations, there are several ways information from multiple sub-topic areas could be combined to inform the ISP, or other work, through broader analyses. This section provides some of these additional recommendations and identifies additional data resources that are available for more site-specific investigations.

9.1 Recommendations for Future Use

1. **Provide environmental benefits.**

   Aquatic habitat data sets and GIS layers compiled in this TM can be used to support planning and programmatic efforts to provide environmental benefits in the following ways:

   - **Identify best locations for salmon recovery efforts.**
     - Aquatic habitat and fish use data can be used to support salmon recovery and stream restoration work being done in Seattle by other City departments, other government entities, NGOs, or community groups.
     - Fish use and fish habitat data can be combined to determine if fish have and are using habitat and where improvements could be made. For example, spawning habitat can be overlaid with redd distribution to confirm reaches where fish actually spawn (have access and use the habitat for spawning).
     - Priority areas and project sequencing for salmon habitat restoration can be refined by combining data on riparian canopy cover, instream habitat quality, fish habitat quality, fish use, and fish passage barriers.
     - Aquatic habitat quality and fish use information can be used to help set an adequate budget for SPU's Beneficial Uses Budget Control Level (BCL) and direct these funds to correction of high priority fish passage barriers.
   - **Identify best locations for floodplain restoration efforts or other beneficial uses projects.**

  - Information on aquatic habitat quality, fish use, creek daylighting opportunities and other information such as flooding concerns and community needs can be used by SPU to identify, prioritize, and initiate future beneficial uses projects. These projects include green stormwater infrastructure, culvert repairs, and other investments in creek health. This information would help to ensure new capital investments for beneficial uses are focused on priority areas.
  - Information on channel evolution could be combined with data on fish habitat quality and fish use, as well and flooding needs identified in the DSA Flooding Topic Area to:
    - Direct investments to multi-benefit floodplain reconnection and stream enhancement projects.
    - Direct investments into projects focused on reducing stormwater runoff (e.g., GSI, urban tree canopy).
- **Inform urban forestry efforts.**
  - The data on canopy cover, fish habitat quality, channel condition, instream habitat condition and fish use could be used to inform riparian tree planting strategies to:
    - Address the need for more wood in urban creeks to support habitat complexity and resiliency.
    - Support human, plant, and animal communities (e.g., habitat for nesting birds, insects, small mammals).

2. **Better utility work.**

- **Information on stream typing, habitat condition and fish use can be used to:**
  - Prioritize culvert and stream maintenance in areas important for fish. This could include maintenance of trash racks, culverts, outfalls to creeks, weirs, large wood structures, bypass structures etc.).
  - Inform creek culvert project sequencing and capital investments to address both utility and service equity needs including tribal interests and tribal treaty rights.
- **Information on creek daylighting and floodplain reconnection suitability could be used to:**
  - Identify opportunities to reduce flooding adjacent to creeks or prevent potential flooding along creeks. This information can also be evaluating as a potential solution for flooding problems identified in the DSA Flooding TM.
    - There may be daylighting opportunities, that coupled with creek channel widening or floodplain reconnection, could reduce localized creek flooding and system flooding up or downstream, by adding flood storage capacity.
    - Conversely, daylighting in areas that currently experience flooding, without adding more natural flood storage could increase flooding.

3. **Support environmental protection, and environmental justice and service equity.**
    - **Information on aquatic habitat condition and shoreline restoration opportunities can be used to:**
        - Inform Seattle's Outside Citywide Initiative and the City's Equity and Environment Initiative. Many of the GIS layers shown on the maps included in this TM could be used to identify where there are gaps in community access to healthy water, high quality habitat and open space and then develop strategies to improve conditions such as:
            - Identifying areas of overlap between shoreline street ends, restoration opportunities and parks gaps in inform SPR's acquisition strategy (specially the need for new and/or improved access to healthy habitats and shorelines in historically underserved areas).
            - Identifying healthy stream sections that may be targets for additional habitat protection, as well as stream reaches that need restoration or stewardship to ensure equitable access to healthy water, habitat, and open spaces.
            - Focusing capital investments and partnerships in underserved areas where there is an opportunity to protect high-quality habitats, restore degraded habitats and provide new access to existing stream shoreline habitats.
            - Engaging residents, schools and local organizations in restoration partnerships, environmental stewardship and/or citizen science that help to build community.

9.2 Additional Data Resources and Future Work

Limiting Factors Analysis and Critical Needs Assessment. In 2003, SPU worked with regional experts to review the City's urban watershed assessment data to identify and prioritize factors adversely affecting ecosystem processes, and consequentially salmonid habitat, in Seattle's salmon-bearing watersheds. SPU carried out the first step by completing a limiting factor analysis for each of the five salmon-bearing watersheds, and then identified potential approaches using a critical needs assessment matrix for each watershed.

The backbone of the approach was a prioritized list of limiting factors identified by the regional watershed restoration experts, which was based on an assessment of the following critical needs in each watershed:

1. Altered hydrology (peak flow volume and discharge velocities),
2. Impacted water quality,
3. Loss of horizontal connectivity (floodplain disconnection),
4. Loss of longitudinal connectivity (barriers to flow, sediment, and fish),
5. Disrupted sediment processes,
6. Loss of hydraulic complexity (channel instream structure) and loss of riparian vegetation (shade and bank integrity).

A critical needs assessment was also completed for each watershed (Appendix L) compared existing conditions (with the reaches ordered from best to worst on the x-axis) to potential fish use (ordered from highest to lowest potential for spawning and rearing habitat, on the y-axis). The resulting matrix provided guidance on where and what kinds of projects would help to restore process in higher priority reaches for fish habitat.

While the impetus at the time for the critical needs assessment was the ESA listing of Chinook salmon, and subsequent regional salmon recovery planning, the information provided, and strategies suggested are also relevant to SPU's drainage system management. Degraded stream systems can lead to reduced flood storage capacity, erosion, and sediment problems, as well as water quality impacts. SPU could use this information in the ISP to develop solutions to drainage problems that focus on root causes and not just symptoms of drainage problems.

A review and update of the critical needs assessment and limiting factors analysis is recommended, as some of the recommended actions are underway already, and others could be considered in the ISP or as SPU initiates new projects, policies, or maintenance Best Management Plans.

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Appendix A: Riparian and Habitat Analytical Methods

Source: *City of Seattle State of the Waters Report; Vol. 1: Seattle Watercourses*

Table A-1: Criteria for Ranking Riparian Attributes

Table A-2: Riparian Assessment Scores for Each Creek Reach and Watershed

Riparian and Habitat Analytical Methods

The Riparian Condition Assessment uses data from the riparian surveys to evaluate the integrity of riparian ecosystem functions. As described in the Introduction of the State of the Waters Report, these functions include providing a source of instream structure and nutrients, stabilizing stream banks, increasing the sediment/water storage and filtration capacity in the floodplain, regulating stream temperatures, and providing wildlife habitat for terrestrial species.

The integrity of each of these functions was evaluated through an assessment of the following diagnostic indicators:

- Riparian width
- Riparian connectivity
- Understory and canopy composition
- Canopy density
- Stream cover

To assess overall riparian condition, each of these factors was assessed for each reach on a scale of 1 to 10, with 10 representing the best condition. These individual rankings were then averaged to produce an overall Riparian Condition score for each reach, with riparian width, connectivity, and canopy composition weighted twice as much as the remaining factors. Based on score distributions and sample reaches, thresholds were developed for ranking riparian quality as good, moderate, or poor. The rationale and criteria for ranking each individual factor are summarized in Table G-1. A summary table of rankings of individual factors and overall riparian condition is included in Table G-2, and the overall results of this analysis are presented in the Conditions section of the report, with visual representations in the map section (Habitat Quality maps for each creek).

Table A-1: Criteria for Ranking Riparian Attributes

Attribute	Rationale	Scoring Criteria			
		1	5	7.5	10
Riparian Width	Riparian width is measured perpendicular from the stream bank to the first break the vegetation. The wider the riparian buffer, the better the conditions for riparian and instream habitat.	No vegetation, <20 ft	20-50 ft		>50 ft
Understory Composition	Rankings for understory conditions are based on species diversity. The greater the diversity, the higher the quality ranking. Native species were considered a preferred condition.	Lawn, invasives (monocultures)	Mixed plant assemblages		Native vegetation
Canopy Type	Categories for canopy composition were based on deciduous or coniferous differentiation. In this ranking, coniferous composition was determined to be the preferred condition. According to Naiman and Bilby (1998) the majority of the Puget Sound Region was covered in a dense coniferous forest with patches of deciduous and deciduous mix in disturbed areas. Stream corridors historically would have contained a deciduous canopy composition, however coniferous canopy assemblages were ranked as the preferred conditions due to the overall lack/decline of this canopy type around the City.	No canopy	Deciduous canopy	Deciduous/ coniferous mix	Coniferous
Canopy Density	One of the functions of the riparian forest is to provide shade to maintain cool water conditions. Canopy density is a measure of vegetative cover at a height greater than 15 ft above the stream channel.	Not present/ intermittent (<1 tree per 50 ft)	Partial (1-2 trees per 50 ft)		Full (>2 trees per 50 ft)
Stream Cover	One of the functions of the riparian forest is to provide shade to maintain cool water conditions. Stream cover is a measure of vegetative cover less than 15 ft above the stream channel.	0-24%	25-75%		>75%
Connectivity	Connectivity is a measure of the number of forest breaks (>100’) along the forest corridor. For the purposes of this ranking, the connectivity measure was derived from forest breaks including no vegetation and culverts. Unsurveyed areas were not included as forest breaks, as general forest conditions for each of these reaches is unknown, just not catalogued within the survey.	>2 forest breaks per 1000 ft	1-2 forest breaks per 1000 ft		< 1 forest break per 1000 ft

Table A-2: Riparian Assessment Scores for Each Creek Reach and Watershed

Reach	**Length**	**Riparian Width**			**Understory**			**Canopy Type**			**Canopy Density**			**Stream Cover**			**Connectivity Total**	**Weighted Avg/ Reach**
		RB	**LB**	**Total**	**RB**	**LB**	**Total**	**RB**	**LB**	**Total**	**RB**	**LB**	**Total**	**RB**	**LB**	**Total**		
Fauntleroy Creek																		
FA01	35	0.00	0.00	**0.00**	0.00	0.00	**0.00**	0.00	0.00	**0.00**	0.00	0.00	**0.00**	0.00	0.00	**0.00**	**0**	98.0
FA02	205	0.00	0.00	**0.00**	5.00	1.34	**3.17**	1.34	1.34	**1.34**	0.00	0.00	**0.00**	1.34	1.34	**1.34**	**10**	3.0
FA03	2095	4.22	4.22	**4.22**	3.58	3.58	**3.58**	3.57	4.18	**3.88**	6.01	6.01	**6.01**	6.01	6.01	**6.01**	**5**	4.6
FA04	350	10.00	10.00	**10.00**	10.00	10.00	**10.00**	7.50	7.50	**7.50**	10.00	10.00	**10.00**	10.00	10.00	**10.00**	**10**	9.4
FA05	1750	10.00	10.00	**10.00**	6.43	4.05	**5.24**	7.50	7.50	**7.50**	10.00	10.00	**10.00**	10.00	10.00	**10.00**	**10**	8.9
																	System Score – Fauntleroy	**6.2**
Longfellow Creek																		
LF01	3020	0.00	0.00	**0.00**	0.00	0.00	**0.00**	0.00	0.00	**0.00**	0.00	0.00	**0.00**	0.00	0.00	**0.00**	**0**	98.0
LF02	1880	6.06	6.76	**6.41**	6.22	6.22	**6.22**	1.52	1.52	**1.52**	1.65	3.03	**2.34**	2.34	2.34	**2.34**	**5**	4.1
LF03	750	6.67	6.66	**6.66**	2.67	2.67	**2.67**	1.33	1.33	**1.33**	2.67	2.67	**2.67**	1.33	1.33	**1.33**	**5**	3.6
LF04	4550	9.63	9.63	**9.63**	5.81	6.60	**6.21**	5.50	5.71	**5.60**	9.35	9.02	**9.19**	6.19	6.19	**6.19**	**10**	8.0
LF04.GC01	1675	3.79	3.79	**3.79**	5.13	5.13	**5.13**	2.27	2.27	**2.27**	4.54	4.54	**4.54**	4.84	4.84	**4.84**	**0**	3.0
LF05	6200	4.73	5.51	**5.12**	5.47	5.67	**5.57**	3.44	3.85	**3.64**	2.21	3.26	**2.74**	1.25	1.25	**1.25**	**5**	4.1
LF06	1820	0.00	0.00	**0.00**	0.00	0.00	**0.00**	0.00	0.00	**0.00**	0.00	0.00	**0.00**	0.00	0.00	**0.00**	**0**	98.0
LF07	600	6.42	10.00	**8.21**	0.00	0.00	**0.00**	1.42	1.42	**1.42**	2.83	2.83	**2.83**	2.83	1.42	**2.13**	**10**	4.9
LF08	2005	2.82	4.06	**3.44**	1.55	1.55	**1.55**	4.04	4.04	**4.04**	7.61	7.31	**7.46**	9.18	9.18	**9.18**	**10**	5.9
																	System Score – Longfellow	**4.3**
Piper's Creek																		
PI01	2160	0.00	9.38	**4.69**	9.38	9.38	**9.38**	4.69	4.69	4.69	9.38	9.38	**9.38**	9.38	9.38	**9.38**	**10**	7.4
PI01.VE01	640	7.66	7.86	**7.76**	9.69	9.71	**9.70**	6.76	6.82	6.79	9.69	9.71	**9.70**	4.84	4.86	**4.85**	**10**	8.1
PI01.VE02	210	10.00	10.00	**10.00**	10.00	10.00	**10.00**	7.50	7.50	7.50	10.00	10.00	**10.00**	10.00	10.00	**10.00**	**10**	9.4
PI01.VE02.MO	800	10.00	10.00	**10.00**	10.00	10.00	**10.00**	5.00	5.00	5.00	0.00	0.00	**0.00**	10.00	10.00	**10.00**	**10**	7.8
PI01.VE03	2350	10.00	10.00	**10.00**	10.00	10.00	**10.00**	7.50	7.50	7.50	10.00	10.00	**10.00**	10.00	10.00	**10.00**	**10**	9.4
PI02	340	0.00	0.00	**0.00**	0.00	0.00	**0.00**	0.00	0.00	0.00	0.00	0.00	**0.00**	0.00	0.00	**0.00**	**0**	98.0
PI03	5090	8.25	8.66	**8.46**	8.66	8.06	**8.36**	4.33	4.33	4.33	5.48	5.42	**5.45**	8.66	8.66	**8.66**	**10**	7.6
PI04	1135	2.29	4.36	**3.33**	2.07	2.07	**2.07**	4.25	4.25	4.25	4.36	4.36	**4.36**	6.72	6.72	**6.72**	**0**	**3.1**
PI05	1630	0.00	0.00	0.00	2.73	1.69	**2.21**	2.05	0.00	**1.02**	0.00	0.00	**0.00**	0.00	0.00	**0.00**	**5**	**1.6**

																	System Score - Piper's	**7.5**
Taylor Creek																		
TA01	920	0.00	0.00	**0.00**	3.15	3.58	**3.37**	4.73	6.22	**5.48**	0.00	0.00	**0.00**	3.15	2.35	**2.75**	**0**	1.9
TA02	620	6.25	4.84	**5.54**	7.18	7.18	**7.18**	5.38	5.85	**5.61**	7.18	6.25	**6.71**	5.93	5.93	**5.93**	**0**	4.7
TA03	355	10.00	10.00	**10.00**	10.00	10.00	**10.00**	7.50	7.50	**7.50**	10.00	10.00	**10.00**	5.00	5.00	**5.00**	**10**	8.9
TA04	315	10.00	10.00	**10.00**	10.00	10.00	**10.00**	7.50	7.50	**7.50**	10.00	10.00	**10.00**	5.00	5.00	**5.00**	**10**	8.9
TA05	1275	10.00	10.00	**10.00**	10.00	10.00	**10.00**	7.50	7.50	**7.50**	10.00	10.00	**10.00**	5.00	5.00	**5.00**	**10**	8.9
TA05.EF01	776	8.12	8.98	**8.55**	7.22	2.30	**4.76**	6.31	6.39	**6.35**	4.72	7.12	**5.92**	5.35	5.19	**5.27**	**5**	6.2
TA05.WF01	575	10.00	10.00	**10.00**	10.00	10.00	**10.00**	7.50	7.50	**7.50**	6.43	4.35	**5.39**	10.00	10.00	**10.00**	**10**	8.9
TA05.WF02	650	10.00	10.00	**10.00**	5.89	2.88	**4.39**	6.25	5.00	**5.63**	0.00	0.00	**0.00**	10.00	10.00	**10.00**	**10**	7.3
TA05.WF03	1975	9.35	9.57	**9.46**	7.68	8.79	**8.23**	4.67	4.78	**4.73**	9.35	9.57	**9.46**	9.35	9.57	**9.46**	**10**	8.4
																	System Score – Taylor	**7.2**
Thornton Creek																		
TM01	1020	0.00	0.00	**0.00**	6.47	5.00	**5.74**	4.78	4.78	**4.78**	5.15	5.15	**5.15**	5.15	5.15	**5.15**	**10**	5.1
TM01.MP01	3200	2.75	1.75	**2.25**	3.36	3.36	**3.36**	3.27	4.09	**3.68**	4.02	2.98	**3.50**	2.38	2.38	**2.38**	**10**	4.6
TM01.MT01	420	5.00	10.00	**7.50**	10.00	10.00	**10.00**	3.51	3.51	**3.51**	7.02	0.00	**3.51**	8.51	8.51	**8.51**	**10**	7.1
TM02	1780	4.27	3.99	**4.13**	4.52	4.55	**4.54**	6.08	5.06	**5.57**	6.12	5.96	**6.04**	4.41	5.96	**5.18**	**0**	3.9
TM03	3300	0.15	0.00	**0.08**	4.52	4.23	**4.37**	7.20	6.63	**6.91**	4.67	4.73	**4.70**	2.98	3.45	**3.22**	**10**	5.1
TM04	1236	3.64	3.64	**3.64**	5.81	6.42	**6.11**	5.38	3.58	**4.48**	4.19	5.35	**4.77**	1.82	3.58	**2.70**	**10**	5.5
TN01	2170	0.00	1.80	**0.90**	1.62	1.37	**1.50**	3.60	5.37	**4.49**	2.72	3.87	**3.29**	0.90	2.42	**1.66**	**5**	3.0
TN01.LB01	3190	3.13	4.03	**3.58**	1.88	1.49	**1.68**	4.69	4.53	**4.61**	3.13	3.79	**3.46**	3.47	4.02	**3.75**	**0**	2.8
TN01.LB02	315	4.21	0.00	**2.10**	8.41	8.41	**8.41**	8.41	8.41	**8.41**	0.00	0.00	**0.00**	0.00	0.00	**0.00**	**5**	4.4
TN02	7400	2.05	3.67	**2.86**	3.93	3.44	**3.68**	6.09	5.59	**5.84**	6.97	9.52	**8.24**	5.53	5.15	**5.34**	**10**	6.1
TN03	6730	2.99	3.29	**3.14**	3.35	3.28	**3.31**	2.67	2.50	**2.59**	3.09	3.51	**3.30**	3.27	3.19	**3.23**	**10**	4.6
TN03.LI01	1640	0.00	0.00	**0.00**	0.00	0.00	**0.00**	0.00	0.00	**0.00**	0.00	0.00	**0.00**	0.00	0.00	**0.00**	**0**	98.0
TN03.LI02	1750	0.99	0.00	**0.49**	1.27	1.57	**1.42**	3.34	3.44	**3.39**	2.26	2.40	**2.33**	2.73	2.04	**2.39**	**5**	2.7
TN03.LI03	820	4.76	4.76	**4.76**	5.91	5.91	**5.91**	4.15	4.15	**4.15**	8.29	8.29	**8.29**	8.29	8.29	**8.29**	**5**	5.6
TN03.LI04	2090	4.40	4.11	**4.26**	6.34	5.14	**5.74**	3.72	5.65	**4.68**	3.88	5.74	**4.81**	5.31	5.55	**5.43**	**5**	4.9
TN04	10130	1.22	1.09	**1.15**	1.73	0.99	**1.36**	3.70	3.66	**3.68**	2.35	1.89	**2.12**	3.20	3.20	**3.20**	**5**	2.9
TS01	1510	0.00	0.00	**0.00**	0.00	0.00	**0.00**	4.19	3.18	**3.68**	3.00	5.30	**4.15**	0.00	4.97	**2.48**	**0**	1.6
TS01.KR01	1375	0.00	0.00	**0.00**	0.00	2.78	**1.39**	3.19	0.00	**1.60**	0.00	0.00	**0.00**	0.00	0.00	**0.00**	**0**	0.5
TS02	2775	1.76	3.77	**2.77**	2.92	4.45	**3.69**	4.92	6.83	**5.87**	4.01	4.41	**4.21**	6.11	6.74	**6.42**	**0**	3.5

TS02.WI01	5090	1.39	1.24	**1.32**	2.56	2.55	**2.55**	3.13	3.20	**3.17**	2.82	2.91	**2.87**	3.84	3.93	**3.89**	**5**	3.1
TS03	1455	7.53	4.29	**5.91**	1.03	0.80	**0.91**	4.73	3.23	**3.98**	5.36	4.49	**4.92**	2.61	4.88	**3.75**	**10**	5.5
TS04	4020	7.33	4.16	**5.74**	6.03	4.78	**5.40**	7.34	6.00	**6.67**	7.79	4.16	**5.97**	6.32	5.64	**5.98**	**10**	6.9
TS04.VI01	2800	1.79	1.79	**1.79**	2.36	1.91	**2.13**	3.60	3.78	**3.69**	2.98	2.21	**2.60**	3.30	3.32	**3.31**	**0**	2.1
TS05	2130	6.16	4.60	**5.38**	3.09	5.87	**4.48**	5.13	4.43	**4.78**	6.36	6.07	**6.21**	4.34	4.05	**4.20**	**10**	6.1
																	System Score - Thornton	**3.9**

Ranking Key: Poor = 0 - 4.7 Moderate = 4.8 - 7.2 Good = 7.3 - 10.0

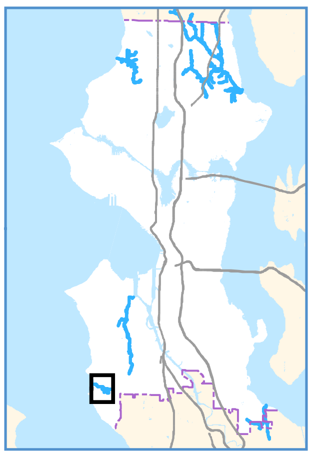
Appendix B: Riparian Tree Canopy Cover Maps

List of Maps

Seattle Public Utilities

Drainage System Analysis Task 6.1 Aquatic Habitat

Riparian Canopy Cover - Fauntleroy Creek



LEGEND

Riparian Canopy Cover

- Unknown
- Not Present/ Intermittent
- Partial
- Full

- Urban Watercourse (Open Channel)
- Urban Watercourse (Piped)
- 🟩 Parks

Author: SPU Shin Date: 9/22/2020 File Path: X:\Separated Systems\Business_Areas\DSA\GIS\Library\MXD\Task 6\Task6-1_RiparianVegetation.mxd

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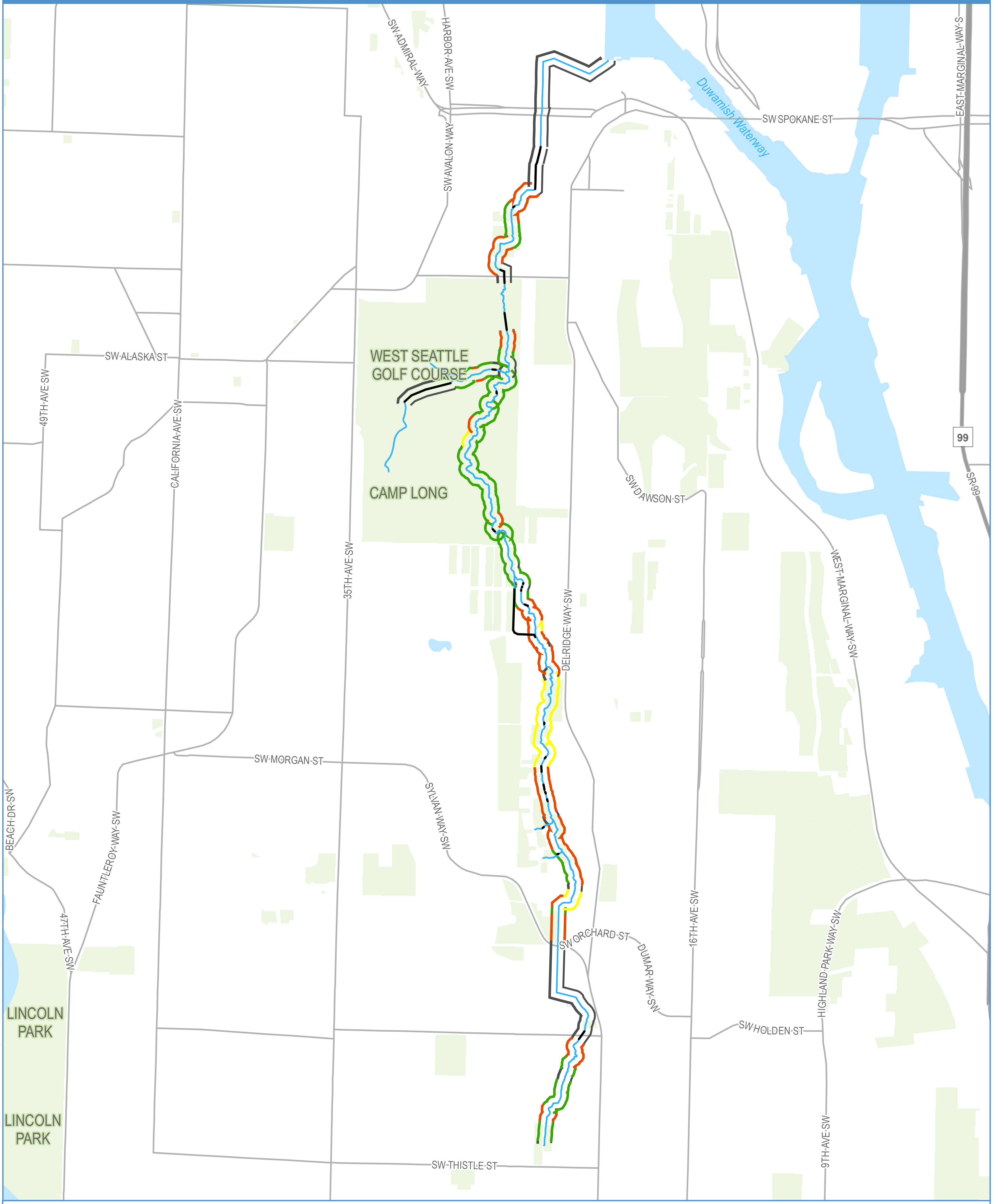
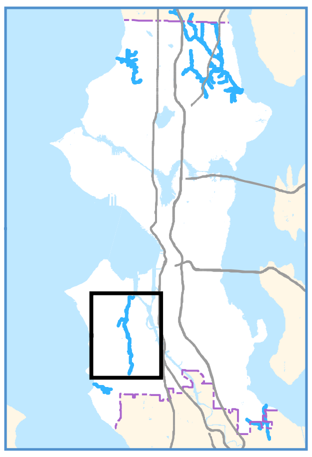
Drainage System Analysis Task 6.1 Aquatic Habitat

Riparian Canopy Cover - Longfellow Creek





LEGEND

Riparian Canopy Cover

- Unknown
- Not Present/ Intermittent
- Partial
- Full

- Urban Watercourse (Open Channel)
- Urban Watercourse (Piped)
- Parks

Author: SPU Shin Date: 9/22/2020 File Path: X:\Separated Systems\Business_Areas\DSA\GISLibrary\MXD\Task 6\Task6-1_RiparianVegetation.mxd

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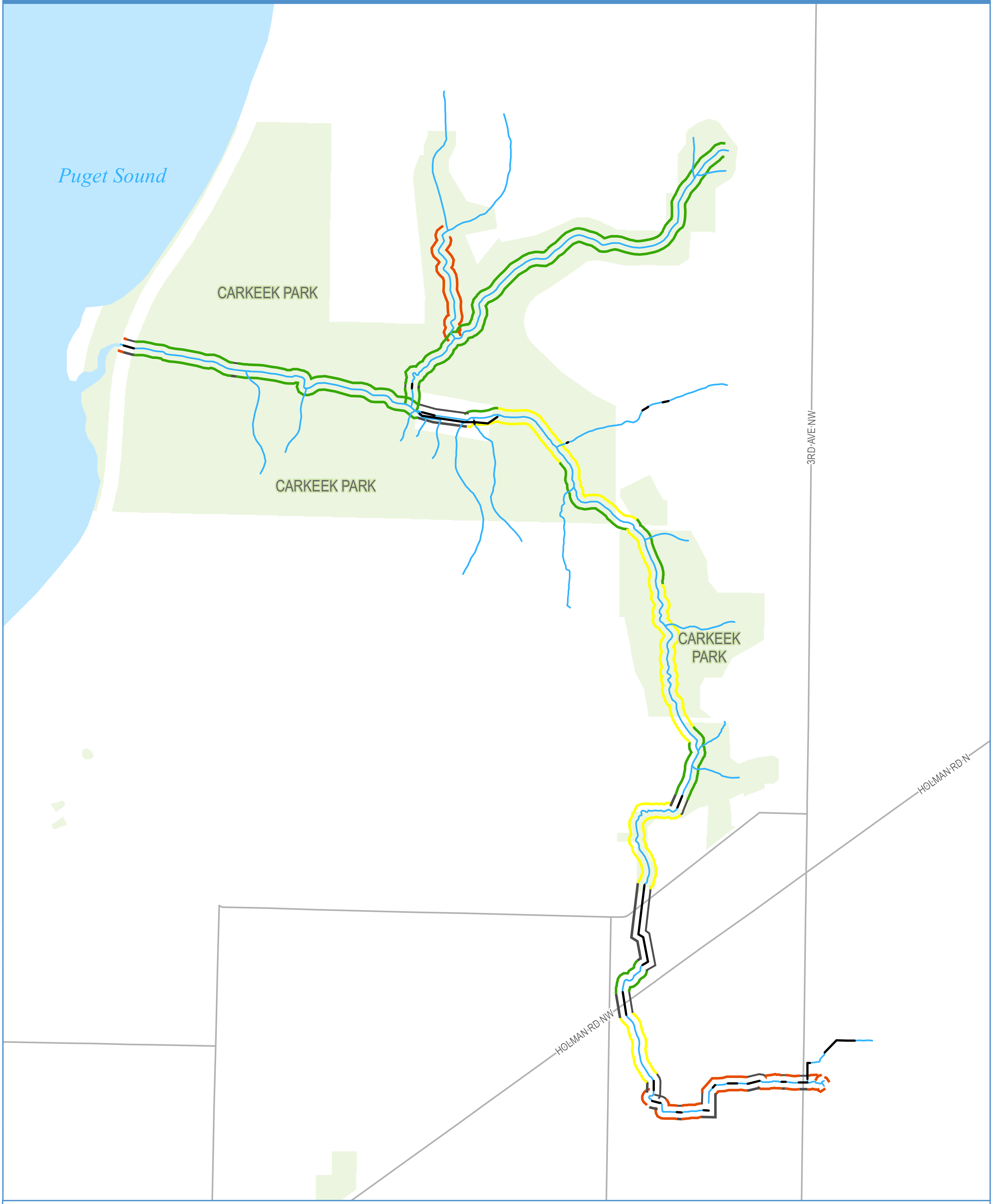
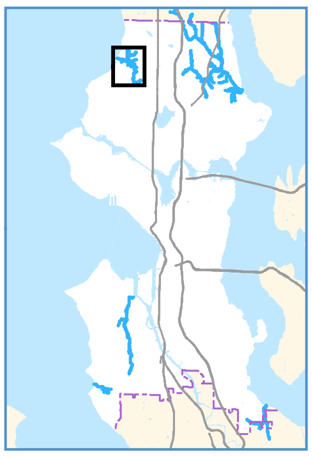
Drainage System Analysis

Task 6.1 Aquatic Habitat

Riparian Canopy Cover - Piper's Creek

N





LEGEND

Riparian Canopy Cover

- Unknown
- Not Present/ Intermittent
- Partial
- Full

- Urban Watercourse (Open Channel)
- Urban Watercourse (Piped)
- 🟩 Parks

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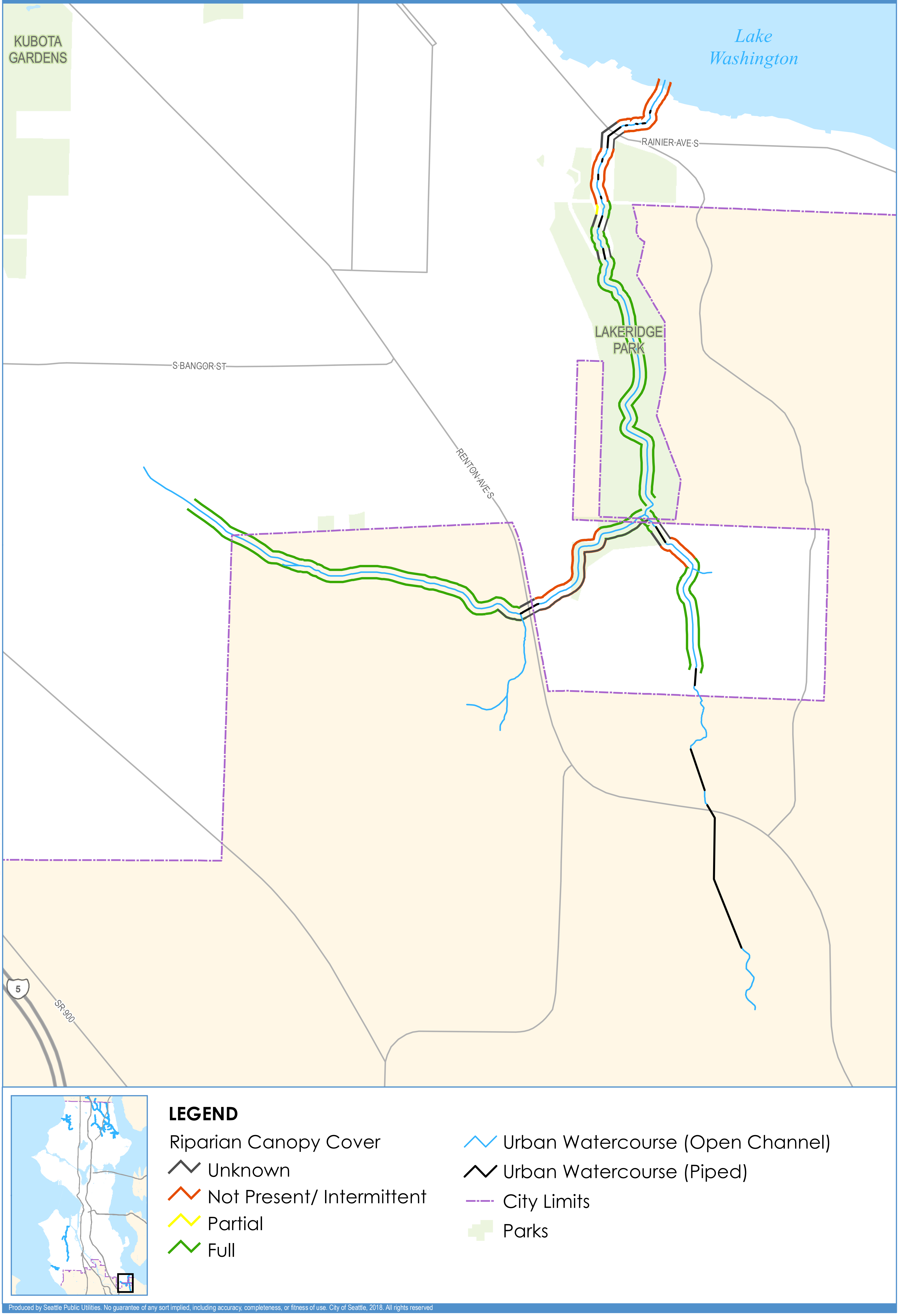
Drainage System Analysis   Task 6.1 Aquatic Habitat

Riparian Canopy Cover - Taylor Creek



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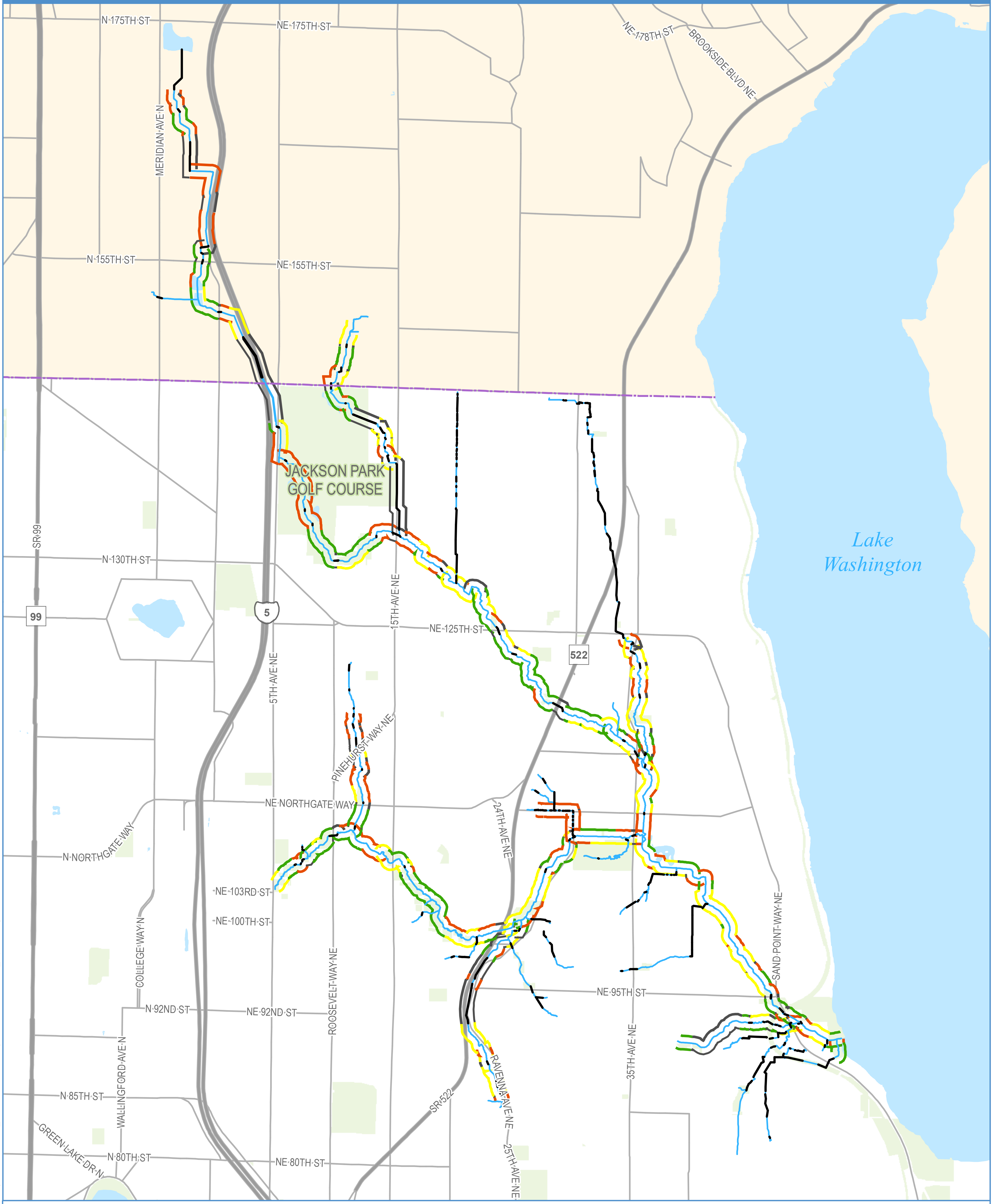
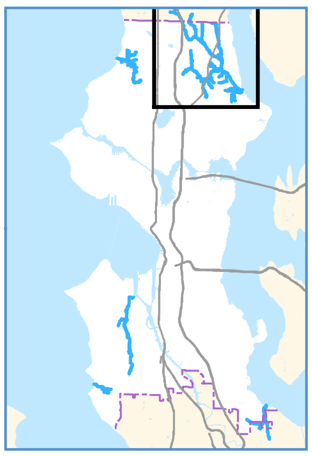
Drainage System Analysis Task 6.1 Aquatic Habitat

Riparian Canopy Cover - Thornton Creek





LEGEND

Riparian Canopy Cover

- Unknown
- Not Present/ Intermittent
- Partial
- Full

- Urban Watercourse (Open Channel)
- Urban Watercourse (Piped)
- City Limits
- Parks

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Appendix C: Stream Channel Habitat Conditions Maps

List of Maps

Drainage System Analysis Task 6.2A Aquatic Habitat

Instream Habitat Quality - Fauntleroy Creek

LEGEND

Instream Habitat Quality

- 🟩 High
- 🟧 Medium
- 🟥 Low

Focus Urban Watercourse

Parks

Based on composite scores of channel morphology, sediment regime, and physical habitat conditions for supporting stream biota generated for the 2007 State of Waters report.

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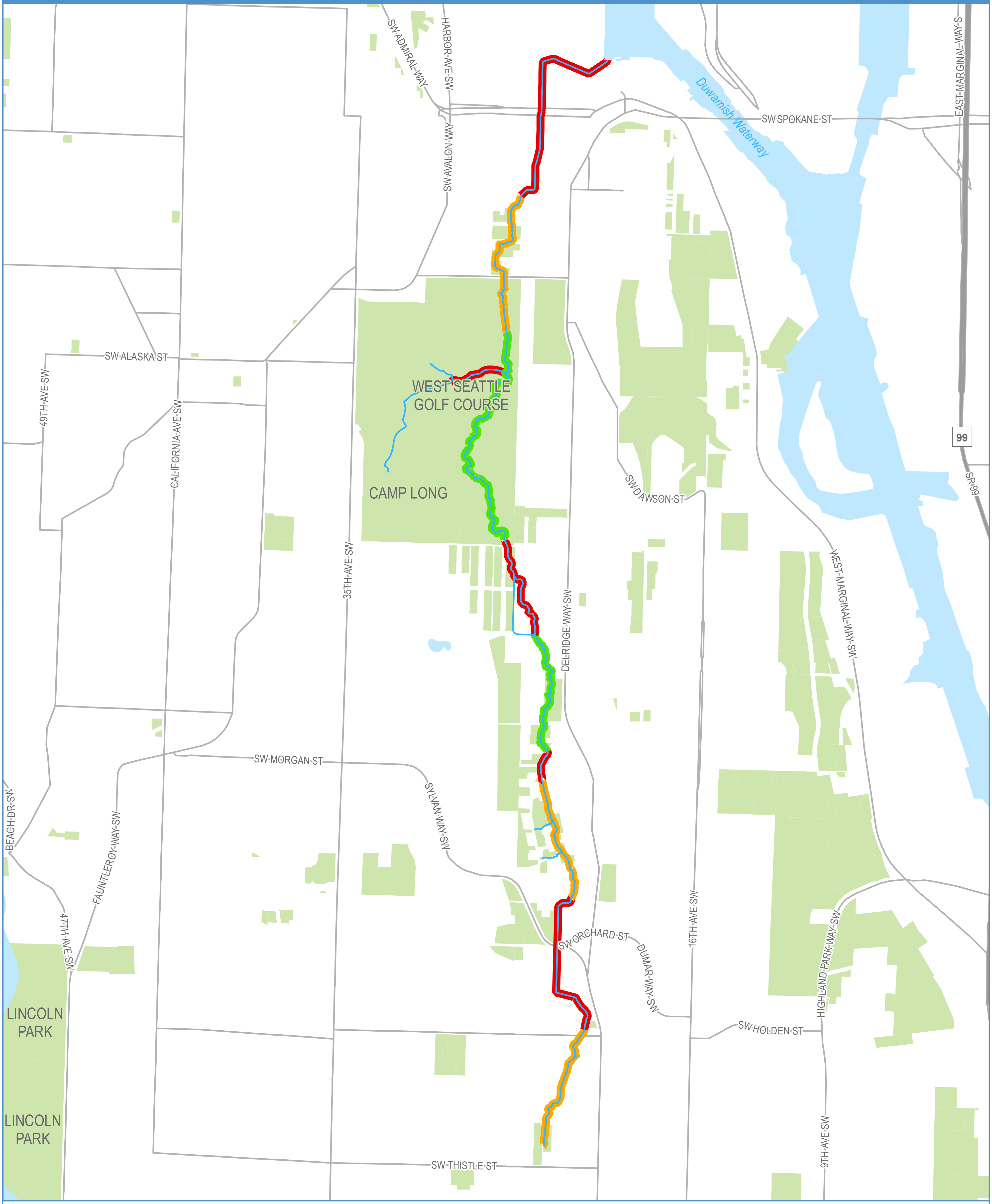
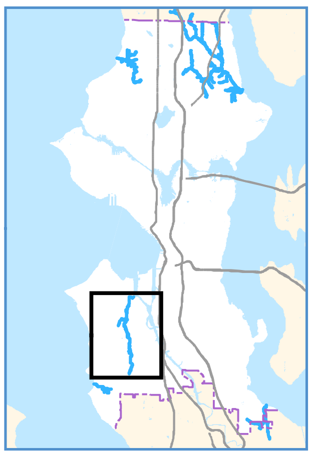
Drainage System Analysis Task 6.2A Aquatic Habitat

Instream Habitat Quality - Longfellow Creek





LEGEND

Instream Habitat Quality
- 🟩 High
- 🟧 Medium
- 🟥 Low

Focus Urban Watercourse

🟩 Parks

Based on composite scores of channel morphology, sediment regime, and physical habitat conditions for supporting stream biota generated for the 2007 State of Waters report.

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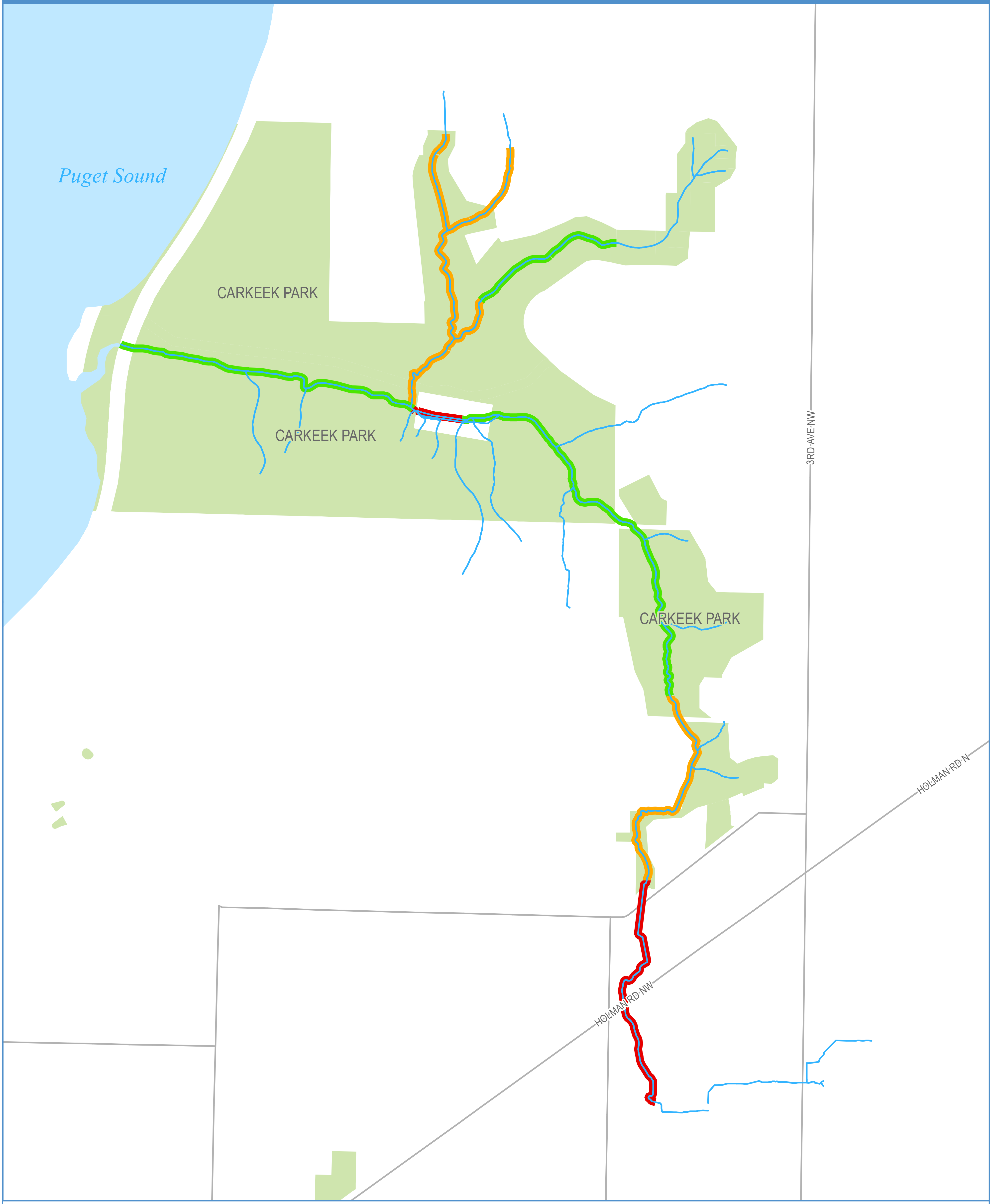
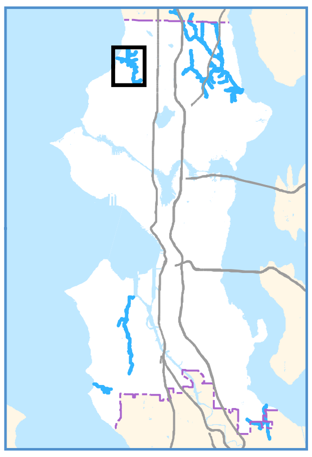
Drainage System Analysis Task 6.2A Aquatic Habitat

Instream Habitat Quality - Piper's Creek





LEGEND

Instream Habitat Quality

- 🟩 High
- 🟧 Medium
- 🟥 Low

Focus Urban Watercourse

🟩 Parks

Based on composite scores of channel morphology, sediment regime, and physical habitat conditions for supporting stream biota generated for the 2007 State of Waters report.

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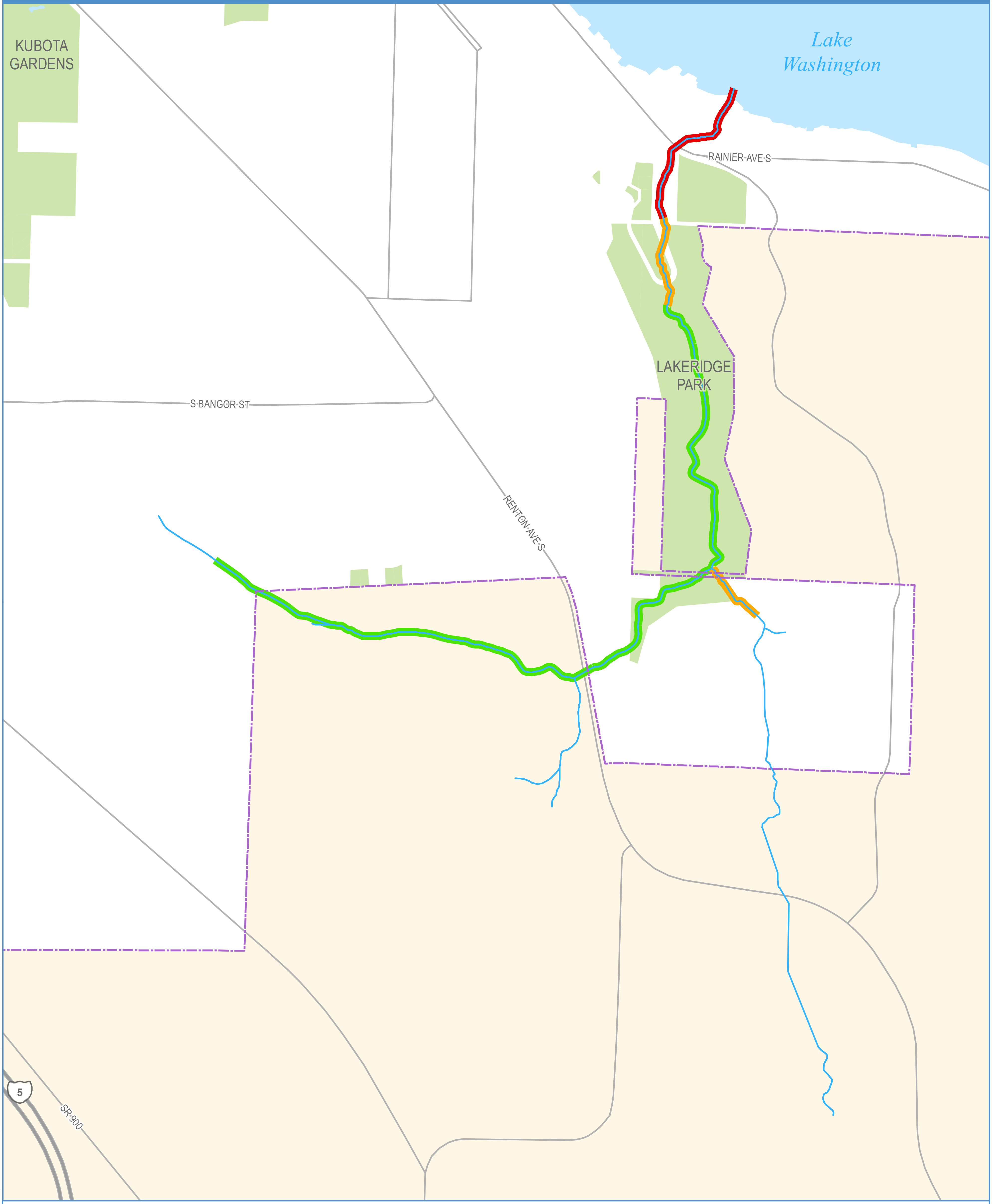
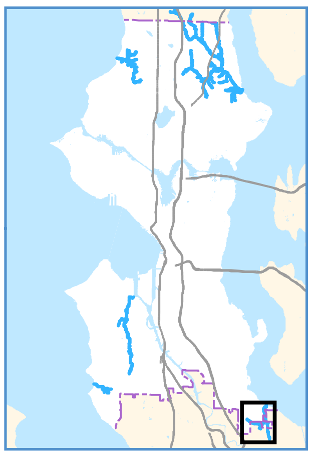
Drainage System Analysis   Task 6.2A Aquatic Habitat

Instream Habitat Quality - Taylor Creek





LEGEND

Instream Habitat Quality

🟩 High

🟧 Medium

🟥 Low

Focus Urban Watercourse

City Limits

🟩 Parks

Based on composite scores of channel morphology, sediment regime, and physical habitat conditions for supporting stream biota generated for the 2007 State of Waters report.

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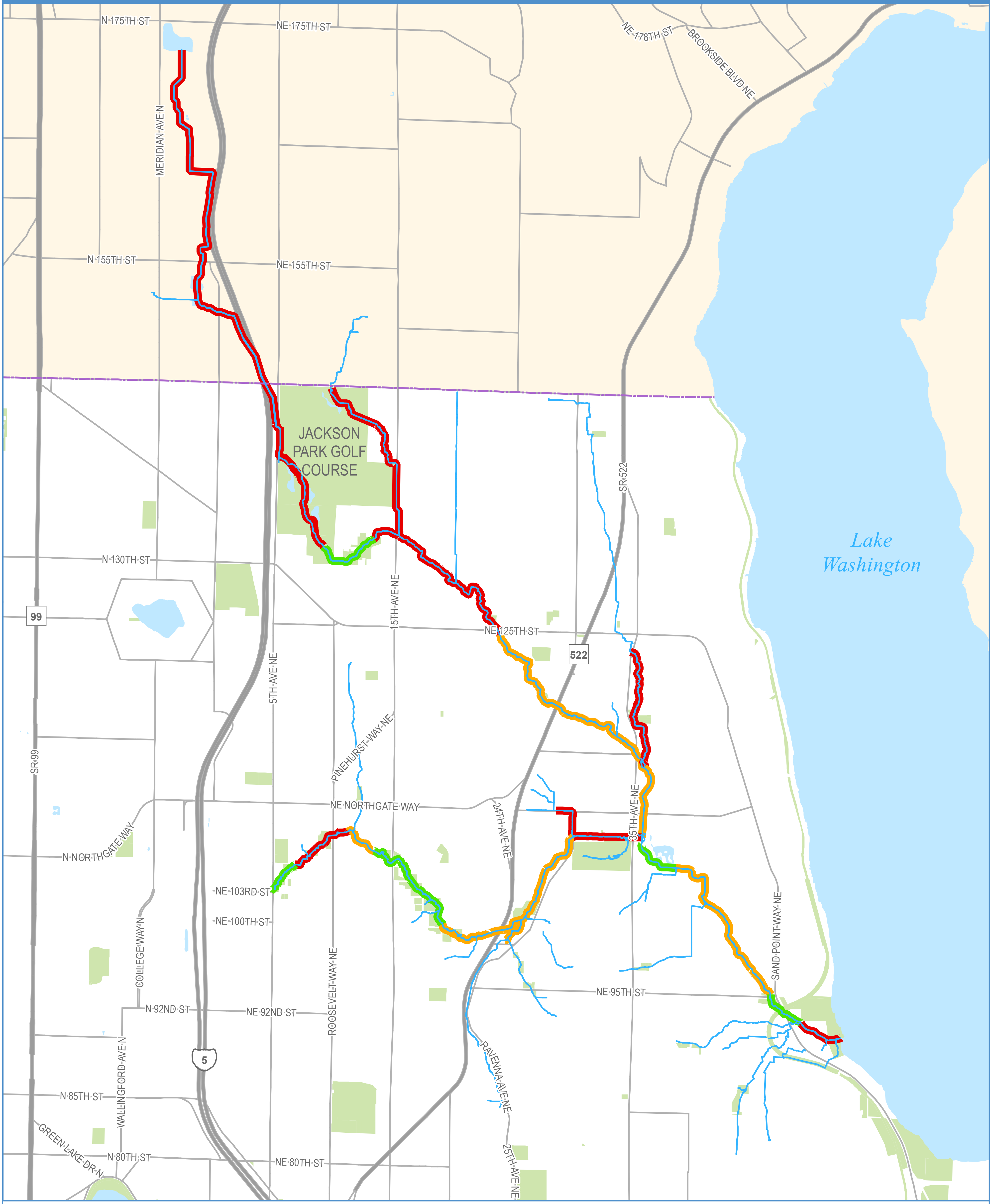
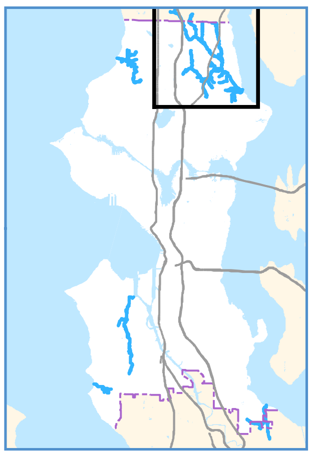
Drainage System Analysis   Task 6.2A Aquatic Habitat

Instream Habitat Quality - Thornton Creek





LEGEND

Instream Habitat Quality
- 🟩 High
- 🟧 Medium
- 🟥 Low

- Focus Urban Watercourse
- City Limits
- Parks

Based on composite scores of channel morphology, sediment regime, and physical habitat conditions for supporting stream biota generated for the 2007 State of Waters report.

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Appendix D: Salmon Spawning, Rearing and Refuge Habitat Maps

List of Maps

Seattle Public Utilities

Drainage System Analysis   Task 6.2B Aquatic Habitat

Salmon Spawning Habitat Quality - Fauntleroy Creek

Author: SPU Shin   Date: 3/10/2020   File Path: X:\Separated Systems\Business_Areas\DSA\GIS\Library\MXD\Task 6\Task6-2B_SpawningHabitatQuality.mxd

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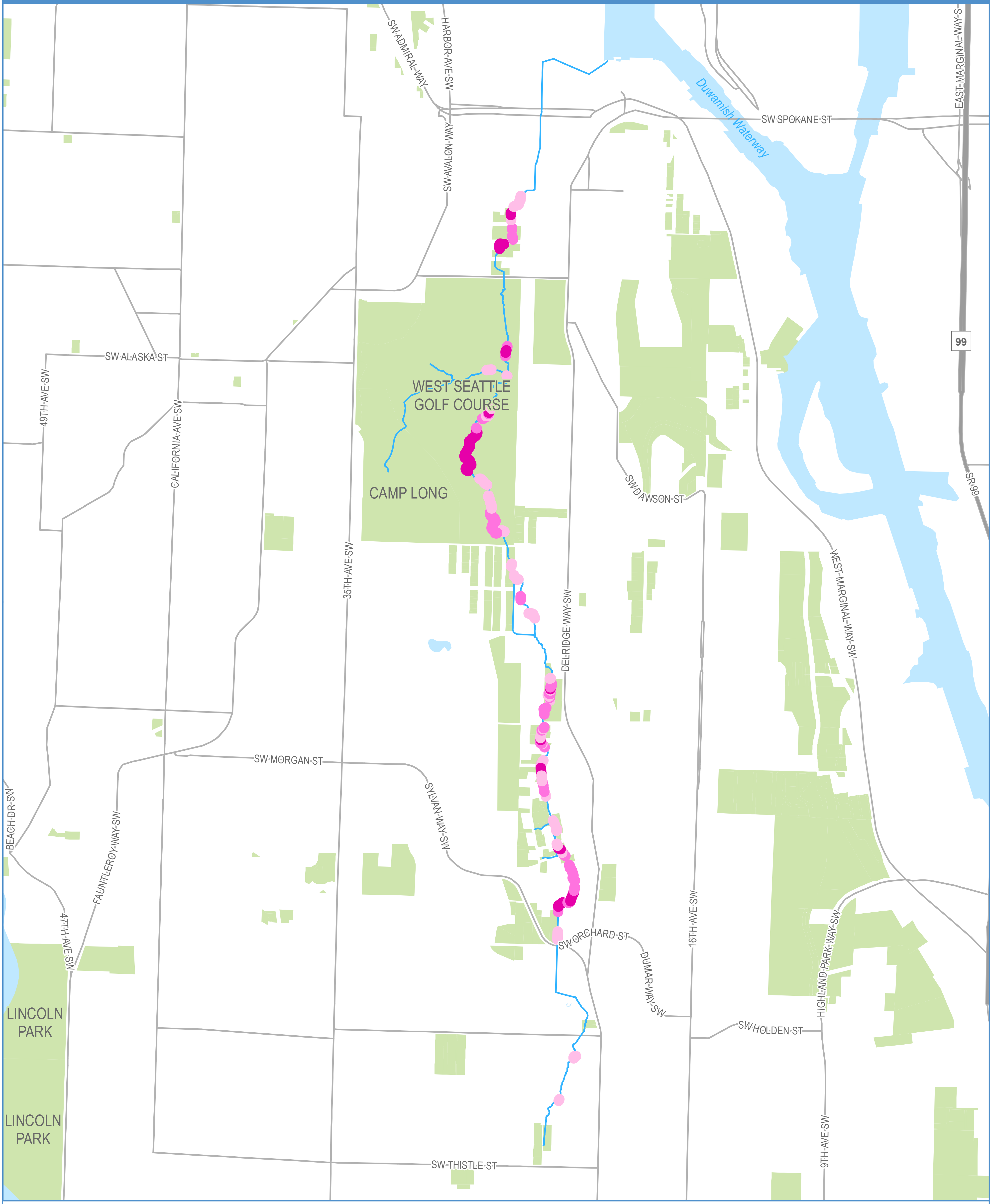
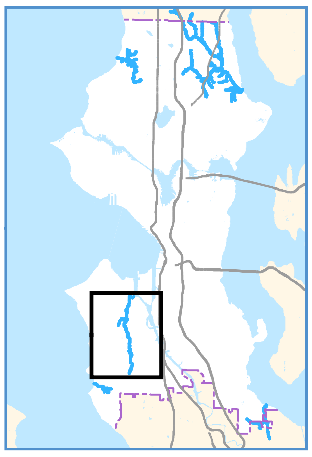
Drainage System Analysis Task 6.2B Aquatic Habitat

Salmon Spawning Habitat Quality - Longfellow Creek





LEGEND

Quality of Potential Spawning Habitat in Riffles and Glides

- Best Available
- Fair to Good
- Poor to Fair

Focus Urban Watercourse

Parks

Author: SPU Shin Date: 3/10/2020 File Path: X:\Separated Systems\Business_Areas\DSA\GISLibrary\MXD\Task 6\Task6-2B_SpawningHabitatQuality.mxd

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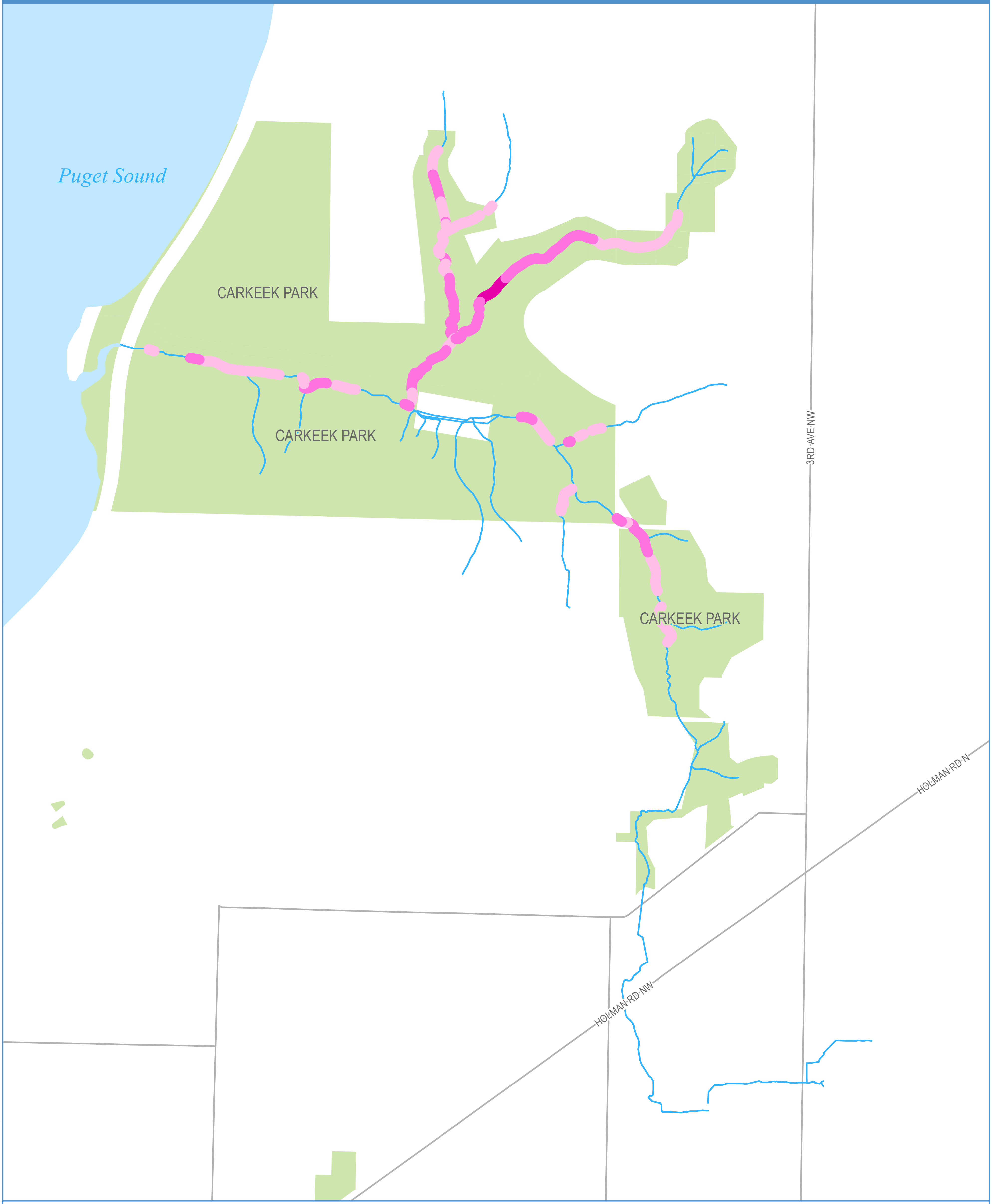
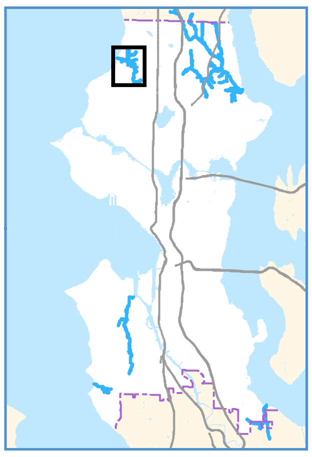
Drainage System Analysis   Task 6.2B Aquatic Habitat

Salmon Spawning Habitat Quality - Piper's Creek





LEGEND

Quality of Potential Spawning Habitat in Riffles and Glides

- Best Available
- Fair to Good
- Poor to Fair

- Focus Urban Watercourse
- 🟩 Parks

Author: SPU Shin   Date: 3/10/2020   File Path: X:\Separated Systems\Business_Areas\DSA\GIS\Library\MXD\Task 6\Task6-2B_SpawningHabitatQuality.mxd

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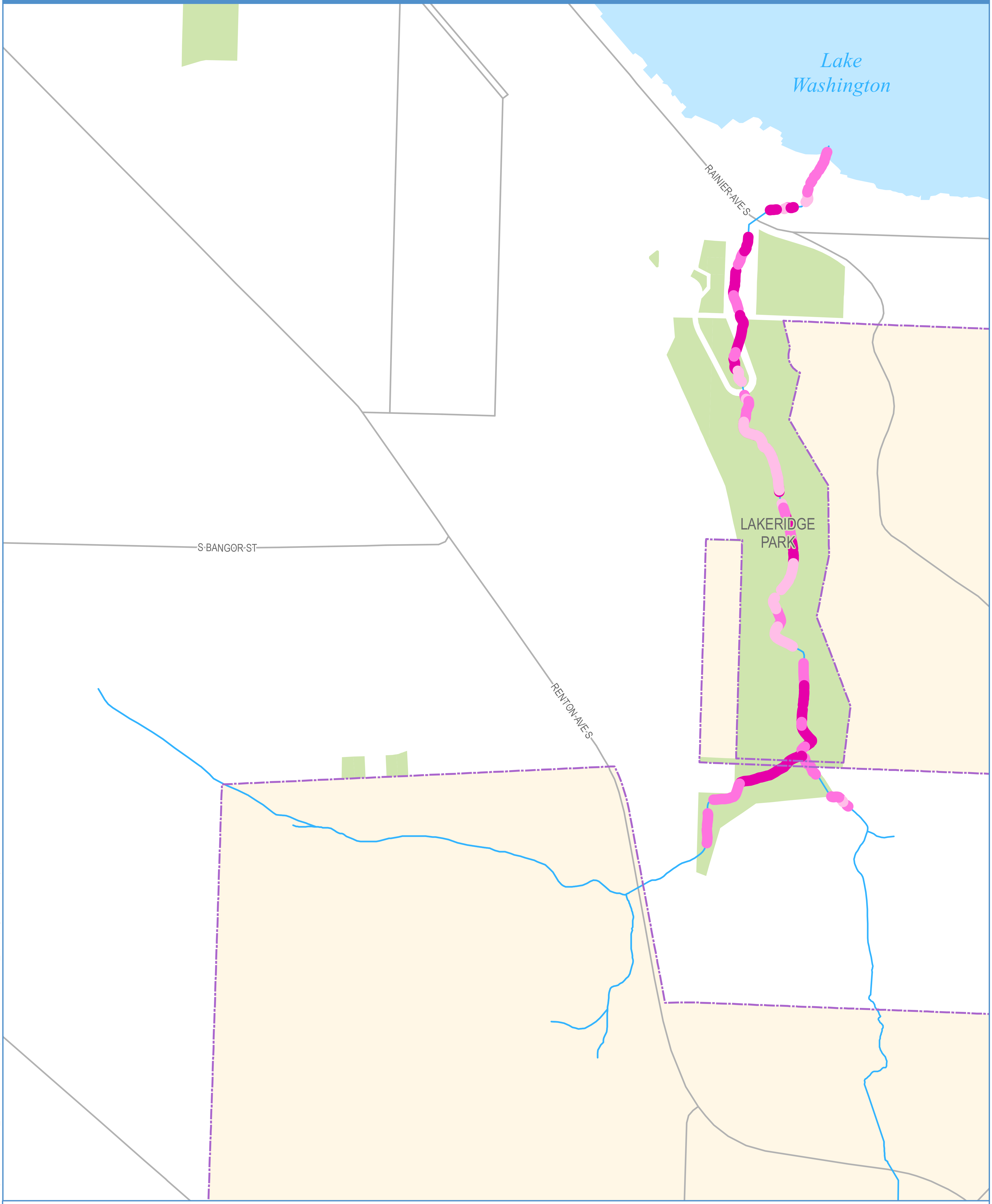
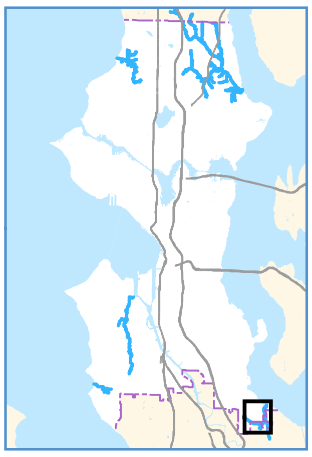
Drainage System Analysis Task 6.2B Aquatic Habitat

Salmon Spawning Habitat Quality - Taylor Creek





LEGEND

Quality of Potential Spawning Habitat in Riffles and Glides

- Best Available
- Fair to Good
- Poor to Fair

- Focus Urban Watercourse
- City Limits
- Parks

Author: SPU Shin Date: 3/10/2020 File Path: X:\Separated Systems\Business_Areas\DSA\GIS\Library\MXD\Task 6\Task6-2B_SpawningHabitatQuality.mxd

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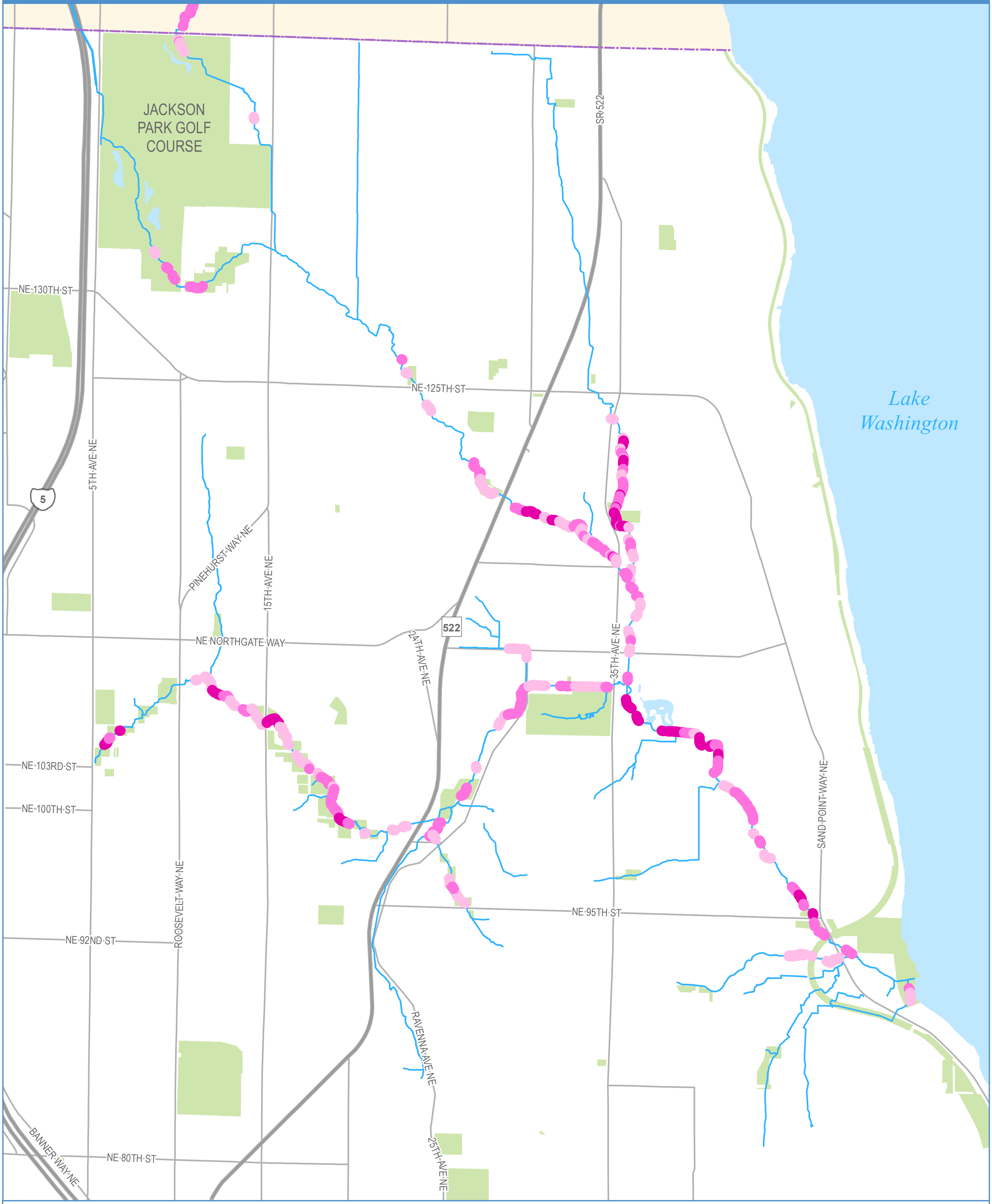
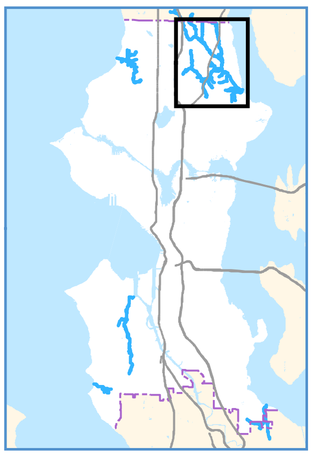
Drainage System Analysis   Task 6.2B Aquatic Habitat

Salmon Spawning Habitat Quality - Thornton Creek





LEGEND

Quality of Potential Spawning Habitat in Riffles and Glides

- Best Available
- Fair to Good
- Poor to Fair
- Focus Urban Watercourse
- City Limits
- Parks

File Path: X:\Separated Systems\Business_Areas\DSA\GIS\Library\MXD\Task 6\Task6-2B_SpawningHabitatQuality.mxd

Date: 3/10/2020

Author: SPU Shin

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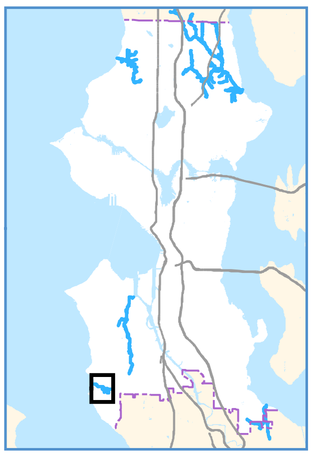
Drainage System Analysis Task 6.2B Aquatic Habitat

Potential Salmon Rearing and Refuge Habitat - Fauntleroy Creek



LEGEND

Quality of Potential Salmon Rearing and Refuge Habitat in Pools and Wetlands

🟥 Best Available

🟧 Fair to Good

🟨 Poor to Fair

Focus Urban Watercourse

🟩 Parks

Author: SPU Shin Date: 3/10/2020 File Path: X:\Separated Systems\Business_Areas\DSA\GIS\Library\MXD\Task 6\Task6-2B_RearingRefugeHabitat.mxd

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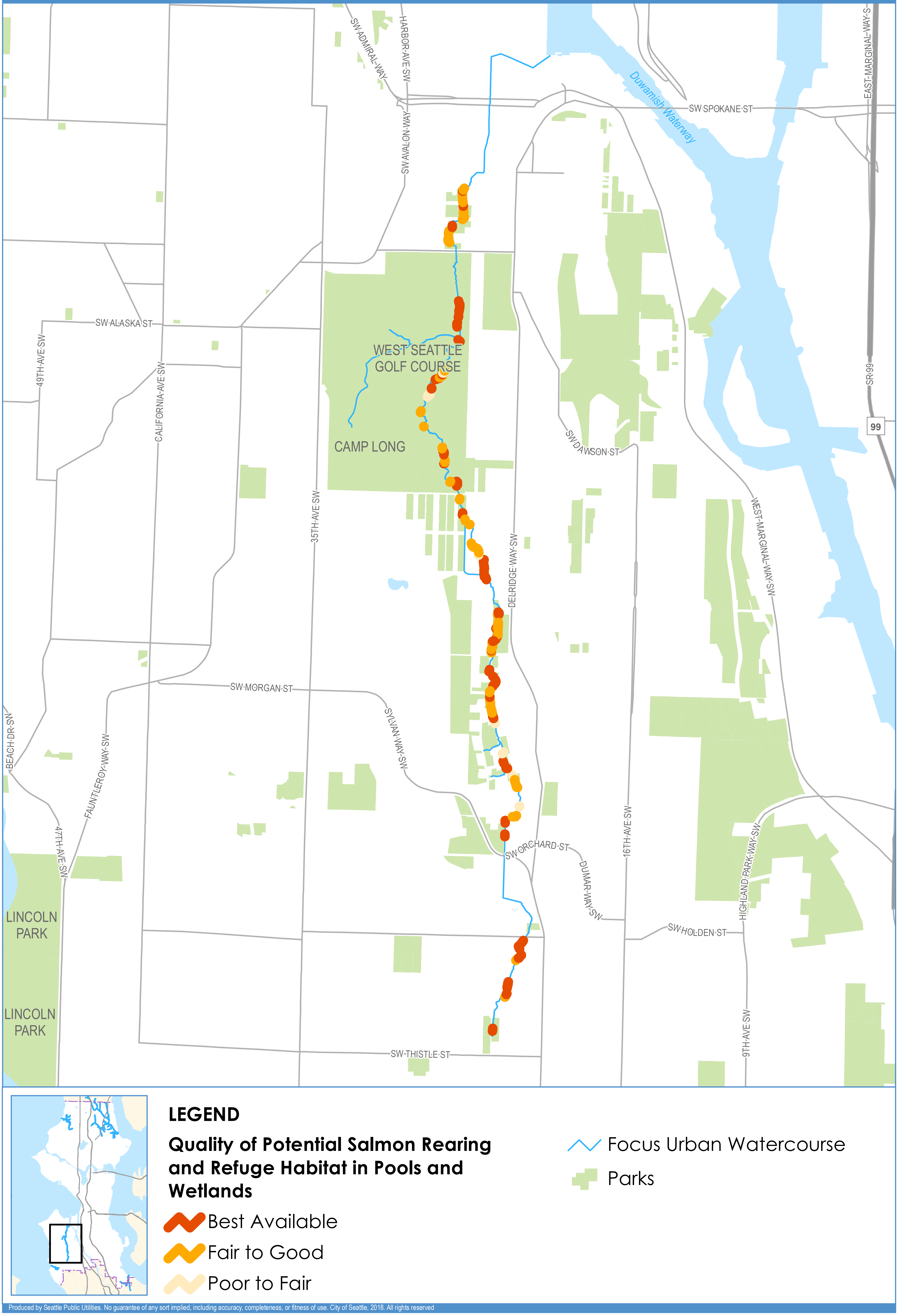
Drainage System Analysis   Task 6.2B Aquatic Habitat

Potential Salmon Rearing and Refuge Habitat - Longfellow Creek



Author: SPU Shin   Date: 3/10/2020   File Path: X:\Separated Systems\Business_Areas\DSA\GIS\Library\MXD\Task 6\Task6-2B_RearingRefugeHabitat.mxd

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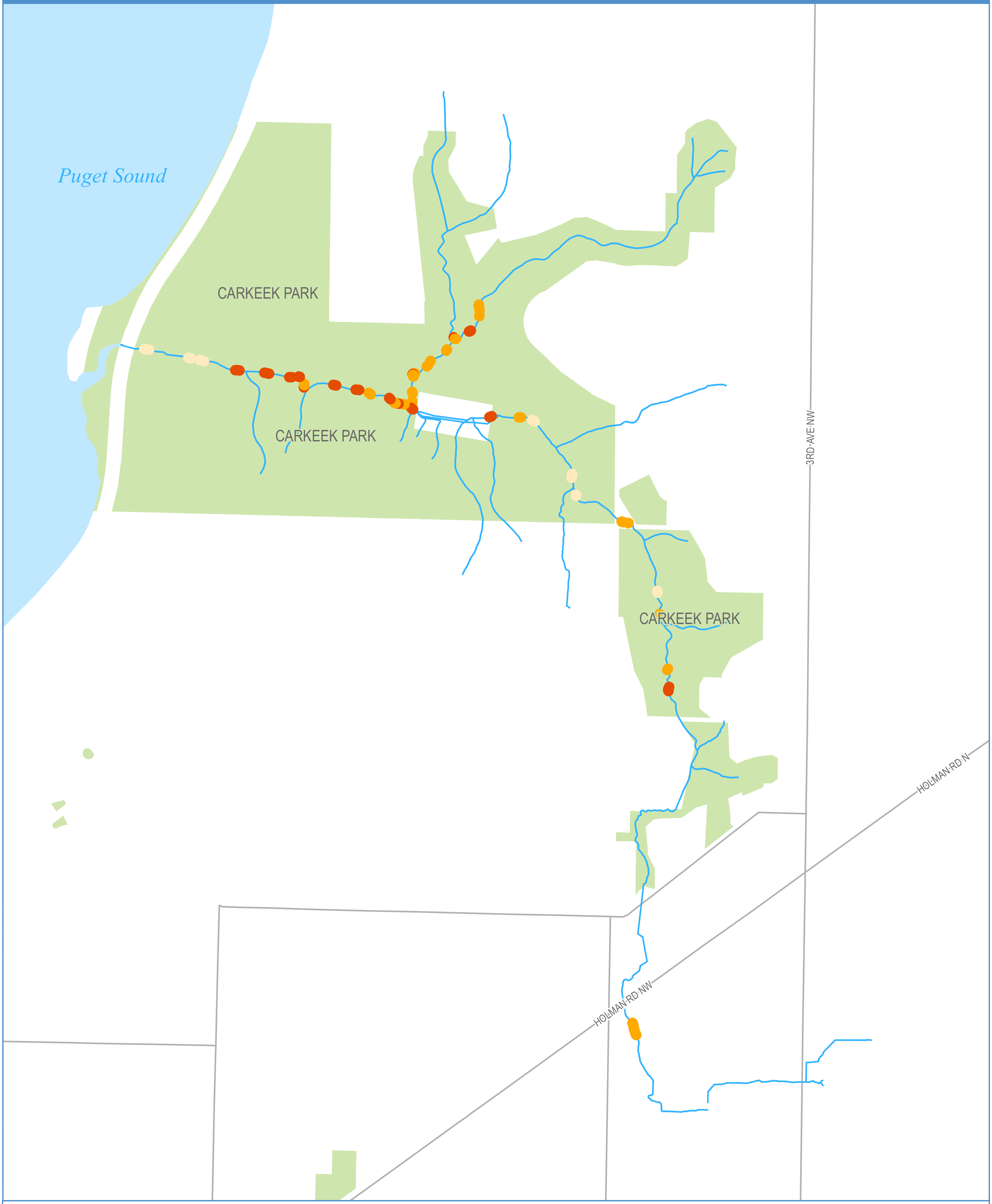
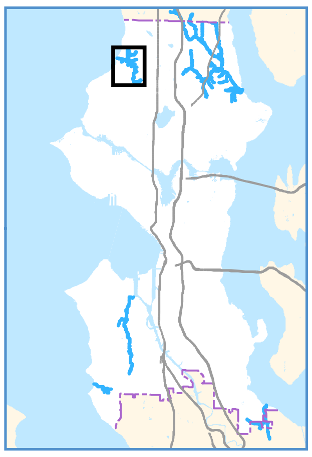
Drainage System Analysis Task 6.2B Aquatic Habitat

Potential Salmon Rearing and Refuge Habitat - Piper's Creek





LEGEND

Quality of Potential Salmon Rearing and Refuge Habitat in Pools and Wetlands

- 🟥 Best Available
- 🟧 Fair to Good
- 🟨 Poor to Fair

Focus Urban Watercourse

🟩 Parks

File Path: X:\Separated Systems\Business_Areas\DSA\GIS\Library\MXD\Task 6\Task6-2B_RearingRefugeHabitat.mxd

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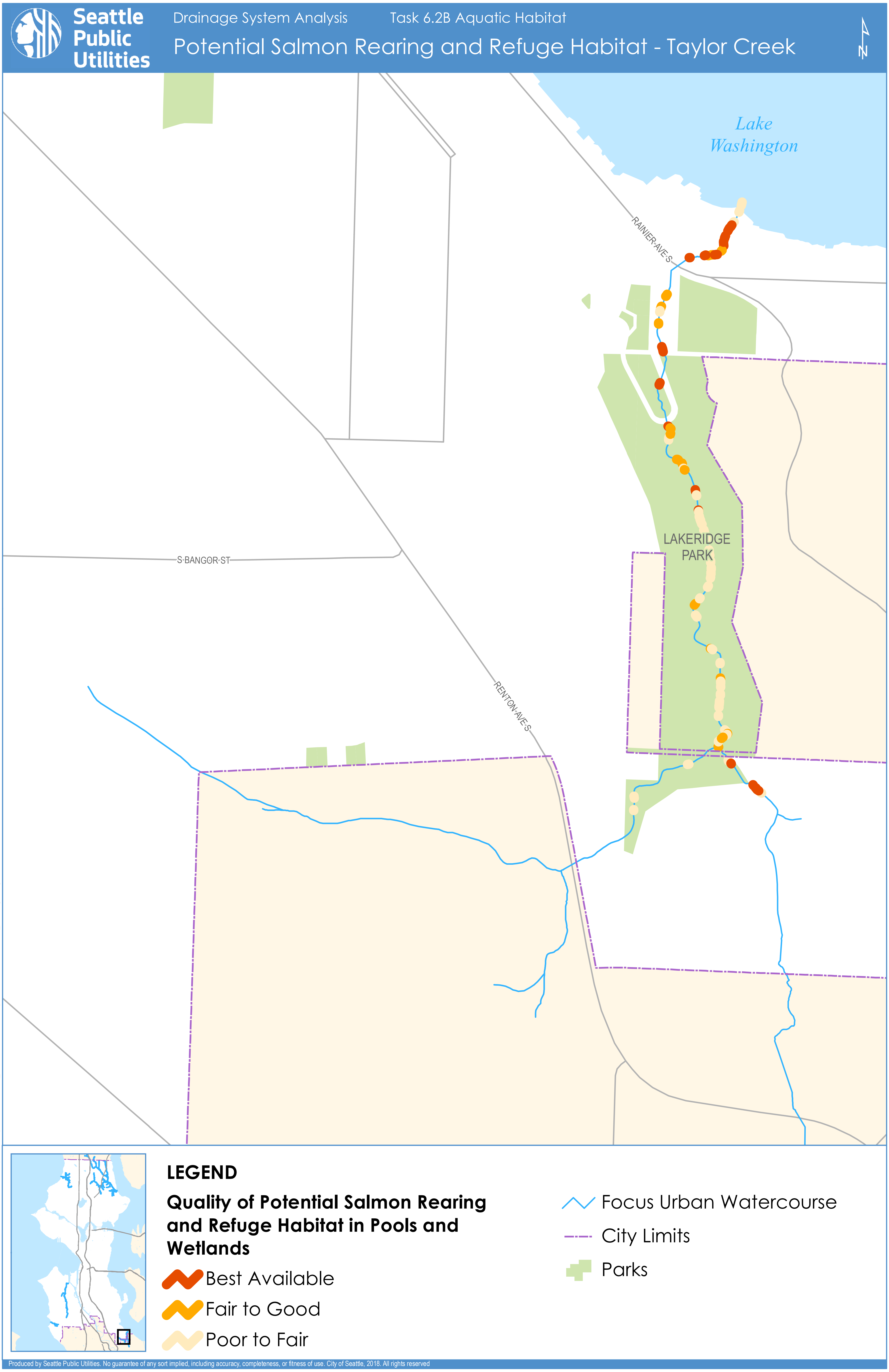
Drainage System Analysis Task 6.2B Aquatic Habitat

Potential Salmon Rearing and Refuge Habitat - Taylor Creek



LEGEND

Quality of Potential Salmon Rearing and Refuge Habitat in Pools and Wetlands

- 🟥 Best Available
- 🟧 Fair to Good
- 🟨 Poor to Fair
- Focus Urban Watercourse
- City Limits
- 🟩 Parks

Author: SPU Shin Date: 3/10/2020 File Path: X:\Separated Systems\Business_Areas\DSA\GIS\Library\MXD\Task 6\Task6-2B_RearingRefugeHabitat.mxd

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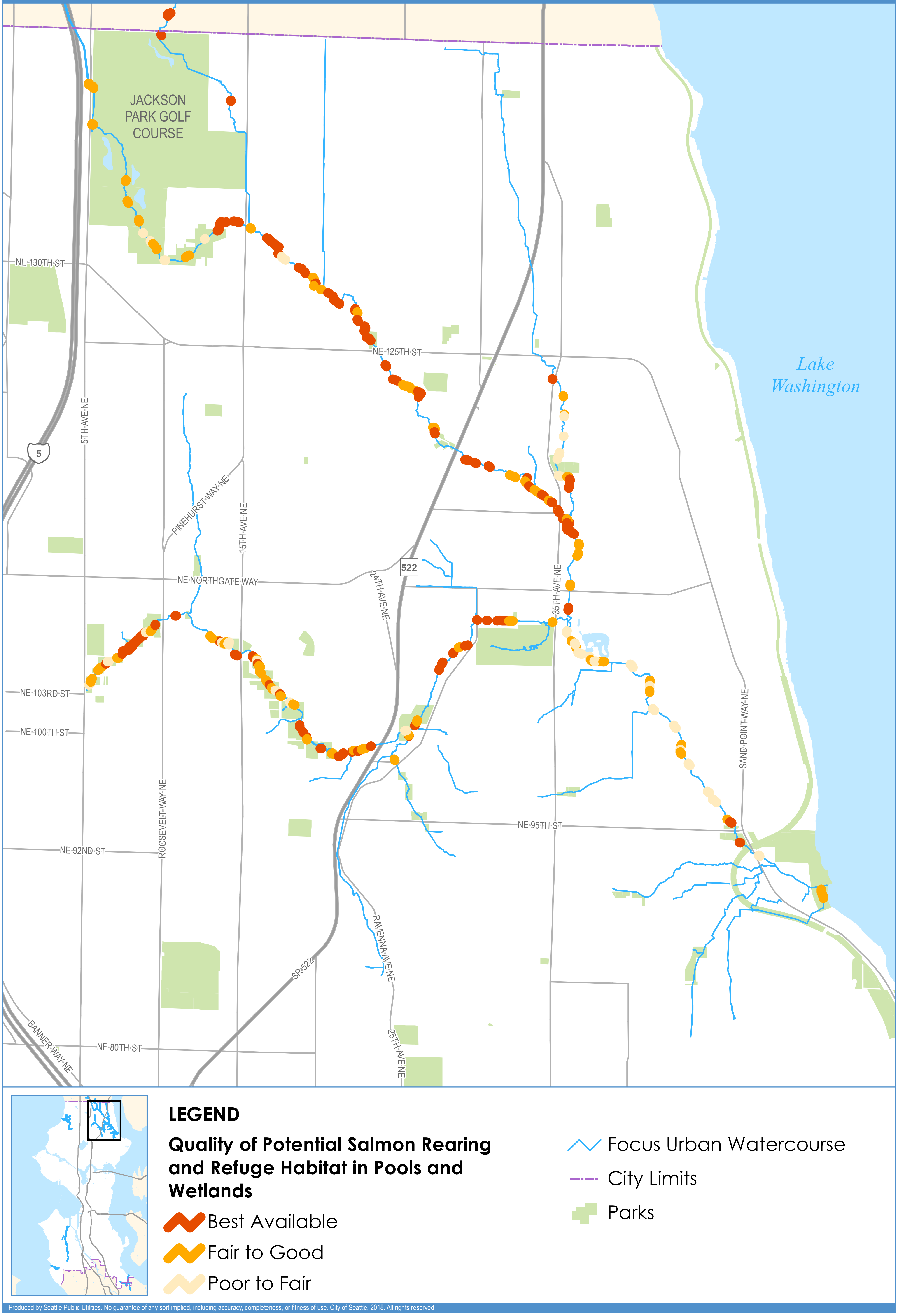
Drainage System Analysis Task 6.2B Aquatic Habitat

Potential Salmon Rearing and Refuge Habitat - Thornton Creek



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Appendix E: Summary of Seattle Stream Habitat Data Collection Efforts

Summary of Seattle Stream Habitat Data Collection Efforts

Data on creek habitat conditions were collected through a series of studies between 1999 and 2005. Following is a more detailed description of the data sources used to assess conditions of Seattle's five major streams for the *Seattle State of the Waters Report*.

- *Stream typing/water typing* (1999, 2005) was conducted to identify fish-bearing and non-fish bearing waters as the basis of state regulatory requirements for water bodies and their riparian areas (Washington Trout 2000). This analysis followed water typing protocol outlined in the State Forest Practices Rules (WAC 222-16-030 and WAC222-16-031). Presence of fish is the primary indicator of fish-bearing waters (types S and F, previously types 1 through 3), and the presence of natural barriers (particularly gradient changes) is the primary indicator of non-fish- bearing waters (types Np and Ns, previously types 4 and 5). The analysis also considers physical stream characteristics in systems with man-made barriers to classify water bodies. Basin size and gradient were recorded, and the results were mapped using a Geographic Information Systems (GIS). The results of this survey are currently being reassessed by the U.S. Fish and Wildlife Service to verify the accuracy of the stream typing determinations (Lantz et al. 2006). The stream-typing information was used in this report to assess fish access potential for each creek.
- *Culvert assessments* (1999-2000, updated 2001 and 2002) were conducted to identify barriers to fish passage within Seattle creeks associated with piped section of creek. The assessments followed protocols developed by Washington Trout and the WDFW. Culverts were inspected and measured for parameters, such as the height of the culvert outfall above the streambed (also called perch height), capacity (size/width relative to stream width), gradient, flow velocity through culvert, residual pool depth at outlet, and accessibility. Height and condition of weirs (a small dam in a creek to raise water levels) were also noted. Culverts were rated as passable to all species of fish or impassable for certain species or life stages (WDFW fish passage criteria), and supplemented with observations from spawning surveys. Data were mapped using a GIS. Data on culvert location and length was verified using the City of Seattle's GIS stream layer. This fish barrier information was used in this report.
- *Habitat assessments* (2000-2004) were conducted to inventory creek channel conditions within Seattle's five main creek watersheds (Thornton, Piper's, Longfellow, Fauntleroy, and Taylor). Data was collected continuously along the creeks and recorded instream habitat units (e.g., pools, riffles, glides), potential spawning and rearing habitat, substrate composition, and stream bank integrity (particularly location/type of stream bank armoring). The assessment used protocols from the Habitat Inventory Methods of Timber Fish and Wildlife, adapted slightly for urban conditions and low flow periods. Data were compiled in a Microsoft Access database and mapped using a GIS. Data was checked for accuracy on selected segments of each system following mapping and found to be accurate within 30 feet. Data on stream habitat units, substrate, bank armoring, and encroachment by urban development into the stream corridor were used in this report.
- *Channel condition assessments* (2001) examined the key factors affecting how creeks recruit, store, and transport sediment as the building blocks of instream habitat. These key factors include watershed geology, land form, creek valley shape and gradient of Seattle's five main creek watersheds.

These assessments identified instream sediment recruitment, transportation, and deposition rates/processes, and the land use practices affecting these processes. The protocol for this survey was adapted from Montgomery-Buffington channel-type classification**,** Henshaw bank stability class, Harvey and Watson/Simon stage of incised-channel evolution, Henshaw relative bed stability**,** and Rosgen entrenchment ratio**.** Channel confinement (ability of the creek valley walls to limit the size and floodplain of the creek) and width, bank height, erosion stage and activity and bank armoring were also recorded. Data were compiled in a Microsoft Access database and mapped using a GIS. Data was verified for accuracy on selected segments of each system following mapping, with accuracy determined to be +/- 50 feet. Detailed results and analysis of the channel condition surveys are summarized in a technical report (Stoker and Perkins 2005).

Data on channel confinement and width, bank height, erosion stage and bank armoring were used for this report.

- *Riparian assessments* (2003) were conducted to evaluate the condition of the riparian vegetation along Seattle's five main creek watersheds. The continuous survey collected data on riparian extent, canopy and understory composition, canopy density, stream shading, slope, and land use type. Data are compiled in a Microsoft Access database and mapped using a GIS. Data were checked for accuracy on selected segments of each system following mapping, with accuracy estimated at +/- 100 feet. Data from the assessment were used to analyze riparian conditions for this report.
- A *Subcatchment and Outfall Inventory* (2002) was conducted to identify the subbasins delivering stormwater to the five main creek watersheds. The inventory included delineation of all subcatchment boundaries, associated outfall locations, and outfall types. The data are based on existing information on SPU's drainage network and spot field checks, and compiled using a GIS. Data on subcatchment size and outfall point were used in the analysis for this report.
- *Permeability* data identifies the ability of subsurface soils to absorb water, or infiltrate, affecting the amount of water runoff that can be generated during a storm. Data were obtained from the Pacific Northwest Center for Geologic Mapping Studies at University of Washington and are based on direct translation of geologic data into permeability classes (Troost et al. 2005). These classes were then entered into a GIS to determine their size and location. The permeability data are accurate at a scale of 1:12,000 (1 inch=1,000 feet). Permeability data were used for an analysis of runoff production from Seattle's creek watersheds.
- *Seattle topography* data provides the relief of the land. This information was collected through Light Detection and Ranging (LiDAR) obtained through the Puget Sound LiDAR Consortium (Bare Earth DEM 2000). The topography surveys were collected in 2000 and converted to the City of Seattle's GIS and vertical datum. Conversion to Seattle's datum may have introduced about 1 foot of error into the elevations. This City of Seattle topography data has a positional tolerance of 3.3 feet and vertical accuracy on the order of one foot. These data were used to calculate slope and were accurate at a scale of 1:12,000 (1 inch=1,000 feet). This information was also used for an analysis of runoff production from Seattle's creek watersheds.
- *Flow monitoring* data is available in 4 of the 5 urban creeks (1999-2005), although flow information is not always continuous or available in consistent locations. The data was used to generate time series graphs of flow conditions and calculations of mean, peak and low flows, where such data was available.

- *Impervious surfaces* are surfaces that are impermeable to water and prevent water from reaching the soils beneath, such as concrete, asphalt and buildings. Impervious surface data is based on 2002 LANDSAT data from the University of Washington Urban Ecology Research laboratory (Alberti et al. In press). LANDSAT refers to multi-spectral data collected via satellite. These data are then interpreted for various land covers such as forests, grasses, and pavement. The LANDSAT data used in this study was interpreted specifically for the level of imperviousness. The impervious data was checked for accuracy through a random sample of 90-meter grid cells comprising 10% of the spatial extent of the data. The land cover classification of these grid cells was overlaid onto ortho-photography (a type of aerial photography). This analysis indicated good accuracy, however, this was based on rather large areas (90-meter cells). This information was used for an analysis of runoff production from Seattle's creek watersheds.
- *Fish presence/absence surveys* (1999, 2005) were conducted to identify creek areas that contained fish in Seattle' major creeks, in conjunction with stream typing surveys. Washington Trout spot-checked areas for the presence of fish (particularly higher in the tributaries) using electrofishing equipment. Captured fish were identified and their size, general condition, and relative abundance in the immediate area are recorded. Data were compiled using GIS. To update fish presence information, this survey is currently being repeated by the U.S. Fish and Wildlife Service. Data on the extent of fish use per system (from the 1999 data collection) was used in this report. Data on the fish species present in each stream were taken from 2005 work conducted by the U.S. Fish and Wildlife Service (Lantz et al. 2006).
- *Spawning surveys* (1999-present) occurred to record the numbers and locations of spawning salmon and trout, and their redds (egg nests). These surveys have been conducted on an annual basis in Thornton, Piper's, Fauntleroy, Taylor, and Longfellow creeks since the fall of 1999.

  Spring surveys have also been conducted in both Thornton and Piper's since 2000. Spawning survey data collected since 2000 were compiled in a Microsoft Access database and mapped using a GIS. Results and assessment of the spawning survey data were summarized in a series of technical reports (McMillan 2000, 2001, 2002, 2003, 2004; Glasgow 2005). Data was checked for accuracy by surveyors during subsequent surveys and in the process of data compilation.

  This data was used in this report to provide salmon redd locations and the upstream extent of creek use by various salmonid species.
- *Smolt trapping* (2001-present) was conducted to identify the types and numbers of juvenile salmon leaving Seattle's creeks. The trapping efforts have been conducted on an annual basis since 2001 in cooperation with WDFW. This effort is part of the State's annual smolt-trapping program for the Lake Washington and Green River systems. Traps were placed in Thornton and Longfellow for a one to two-week period in May, during the estimated peak out-migration period for coho smolts from Lake Washington tributaries. Smolt trapping data have been compiled in a Microsoft Access database. Results and assessment of the data were summarized in a series of technical reports (SPU 2004; Glasgow 2005). This data was used to assess instream conditions for juvenile salmon rearing in Thornton and Longfellow creeks.
- *Benthic macroinvertebrate sampling* (1994-present) identifies small insects, crustaceans, mollusks, and worms that inhabit Seattle creeks. The sampling has been conducted at sites in Thornton, Piper's, Longfellow, Fauntleroy, Taylor, Puget, and Schmitz creeks every other year. Collected invertebrates were sent to a taxonomic laboratory and examined under a microscope to determine which genus and

species are present and their abundance. Seattle Public Utilities uses the Benthic Index of Biotic Integrity (B-IBI) to interpret benthic macroinvertebrate data. B-IBI is a multi-metric index that indicates the degree of human impact on streams based on measurement of different factors, including number of species present and composition, tolerance and intolerance to disturbance, functional feeding groups, and life cycle length. There is a Puget Sound lowland stream version of the B-IBI that is calibrated for an area that includes all Seattle streams. Additional information about B-IBI can be found in Appendix C of the *Seattle State of the Waters Report*.

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Appendix F: Creek Instream Habitat Quality Assessment

Creek Instream Habitat Quality Assessment for the Seattle State of the Waters Report

Analysis of instream habitat conditions was based on channel reach types. These channel reach types were developed from those commonly found in the Puget Sound region, based on a review of the scientific literature (Montgomery and Buffington 1993; Montgomery and Buffington 1998; Scholz and Booth 2000; Montgomery and Macdonald 2002; Buffington et al. 2003).

These basic channel types are described in Table H-1 and were used for assessing the integrity of channel-forming processes in each creek (see also the overall report).

The existing channel conditions were compared to expected conditions to assess the integrity of habitat-forming processes (Table H-2). For each reach, several indicators were examined to score the process integrity. Processes and indicators included:

- *Channel morphology/channel shape*: Does the channel show signs of excessive degradation due to altered flow regime and/or encroachment?
  - *Indicators*: channel erosion stage, channel stability, bank erosion, bank armoring, channel encroachment, channel widths/depths, floodplain connection, habitat type distribution (e.g., pools, riffles), instream structure
- *Sediment transport and delivery*: Are there signs of significant disruption to the channel's expected sediment regime?
  - *Indicators*: channel and bank geology, dominant bed substrate, bank armoring
- *Biological function*: Does the channel currently support biological function OR does it offer the physical habitat conditions necessary to support biological function?
  - *Indicators*: habitat units, spawning habitat quality, pool quality, instream structure, salmonid spawning locations

Table H-2 summarizes the criteria used for the instream habitat quality scoring. The scores for each of the three habitat-forming processes were averaged to determine an overall score of Instream Habitat Condition for each reach. A summary table of rankings of individual factors and overall habitat condition by reach and creek is included in Table H-3. Maps illustrating the instream habitat rankings are provided for each creek in the map section of the report (Habitat Quality maps for each creek).

Table F-1: Basic Channel Types

- **Headwaters or alluvial delta (<1% stream gradient)**
  - Unconfined, sinuous, wide channel usually on plateau (headwaters) or in wide valley (delta) with extensive floodplain connection
  - Source reach for water and sediment inputs if headwater reach
  - Response/depositional reach dominated by sands which are easily mobilized if delta reach
  - Few pools
  - Side channel refugia
- **Pool-riffle channel (1-2% stream gradient)**
  - Unconfined, sinuous wide channel with extensive floodplain
  - Response/depositional reach dominated by gravel and some cobble
  - Bank erosion and sediment deposition in meander bends
  - Alternating pool and bar bedforms due to lateral flow, with short glides to connect pool and riffle habitats
  - Side channel refugia
- **Plane-bed channel (2-4% stream gradient)**
  - Unconfined to confined, sinuous, wide channel with variable floodplain connection and bank erosion
  - Response/depositional reach dominated by gravel/cobbles
  - Long reaches of riffles and glides with a few pools formed by instream structures (e.g., wood, boulders)
- **Confined step-pool channel (4-8% stream gradient)**
  - Confined channel usually in steep valley/canyon with little floodplain, significant channel incision, and little bank erosion
  - Transport reach dominated by cobbles
  - Steps and pools formed by large woody debris and boulders; few riffles and glides and no side channel refugia
  - Instream wood and boulders trap sediment and slow downcutting

Table F-2: Existing Channel Conditions Comparison

Channel morphology/channel shape: Does the reach show signs of excessive degradation due to altered flow regime and /or encroachment?

Indicators: erosion stage, channel stability, bank erosion, bank armoring and encroachment, channel widths/depths, floodplain connection, habitat unit distribution, instream structure.

Score	>1% headwaters or delta	1-2% pool-riffle	2-4% plane-bed	4-8% step-pool
10	Wide sinuous channel, delta aggrading and widening, mostly low banks with floodplain connection on one side, moderate erosion on one bank	Mostly low banks, good floodplain connection, little armoring, reach degrading and aggrading, very little severe erosion, good distribution of habitat units, high pool count, abundant in stream structure	Mostly low banks, good floodplain connection, little armoring, reach degrading and aggrading, very little severe erosion, good distribution of habitat units, high pool count, abundant in stream structure	Narrow channel degrading, little sinuosity, high pool count and lots of instream structure, slight bank erosion
7.5	N/A	Channel not completely entrenched, low bank heights and moderate to good floodplain connection, moderate bank erosion on alternating banks, good distribution of habitat units, moderate to high pool count, but little instream structure	Channel not completely entrenched, low bank heights and moderate to good floodplain connection, moderate bank erosion on alternating banks, good distribution of habitat units, moderate to high pool count, but little instream structure	N/A
5	~50% of the channel length is becoming entrenched with moderate to high banks. Channel losing sinuosity and connection to the surrounding floodplain.	50% degrading and widening or frozen, and 50% has some room to move, moderate amounts of floodplain connection, more bank erosion than expected, some pools but could be more	50% degrading and widening or frozen, and 50% has some room to move, moderate amounts of floodplain connection, more bank erosion than expected, some pools but could be more	Narrow channel more incised than expected, has a few pools, but little instream structure, significant bank erosion
2.5	N/A	Incised channel with <25% floodplain connection, reach degrading, degrading and widening, or frozen but some room to move = less encroachment than "1" moderate bank erosion on both sides	Incised channel with <25% floodplain connection, reach degrading, degrading and widening, or frozen but some room to move = less encroachment than "1" moderate bank erosion on both sides	N/A
1	Incised or frozen creek, single channel which lacks sinuosity, mostly high banks (=little floodplain connection), armoring and encroachment, >10% severe erosion both banks	Straight, narrow, incised channel, >75% reach degrading, degrading and widening, or frozen, <10% floodplain connection on either side, >50% encroachment (culverts/armoring), severe erosion both banks, few to no pools, long stretches of glide or riffle	Straight, narrow, incised channel, >75% reach degrading, degrading and widening, or frozen, <10% floodplain connection on either side, >50% encroachment (culverts/armoring), severe erosion both banks, few to no pools, long stretches of glide or riffle	Channel excessively degrading or has some degradation and widening, few pools, no instream structure, moderate to severe bank erosion for a lot of reach

Table F-2: Existing Channel Conditions Comparison

Sediment Transport and Delivery: Are there signs of significant disruption to the reach's expected sediment regime given the gradient and channel type?

Indicators: channel and bank geology, dominant bed substrate, bank armoring

Score	>1% headwaters or delta	1-2% pool-riffle	2-4% plane-bed	4-8% step-pool
10	Variable substrate composition, but high fine presence, no channel armoring	Mostly gravel, few fines, little bank armoring	Mostly gravel, few fines, little bank armoring	Primarily gravel and cobble substrate with little bank armoring
7.5	N/A	Good quality gravel, few fines, less than 50% bank armoring	Good quality gravel, few fines, less than 50% bank armoring	N/A
5	>50% bank armor	Some gravel but not great quality or more fines than expected, >50% bank armoring	Some gravel but not great quality or more fines than expected, >50% bank armoring	Presence of fines, >50% bank armor
2.5	N/A	Mostly fine sediment, and greater than 50% bank armoring	Mostly fine sediment, and greater than 50% bank armoring	N/A
1	Mostly fine sediment, and >75% bank armoring	Mostly fine sediment, and >75% bank armoring	Mostly fine sediment, and >75% bank armoring	Presence of fines, >75% bank armoring

Table F-2: Existing Channel Conditions Comparison

Biological Function: Does the reach support biological function OR does it offer the physical habitat conditions necessary to support biological function?

Indicators: habitat units, spawning habitat quality, pool quality, instream structure, salmonid spawning locations

Score	>1% headwaters or delta	1-2% pool-riffle	2-4% plane-bed	4-8% step-pool
10	High pool count and slow water habitat of good/high quality; high instream structure counts; extensive salmonid use if fish accessible	High pool count and riffles, few glides; good quality pool and spawning habitat; lots of instream structure throughout majority of reach; extensive salmonid use, if fish accessible	High habitat unit diversity; good quality pool and spawning habitat; high instream structure counts; extensive salmonid use, if fish accessible	Dominated by step-pool and/or cascade habitat; High instream structure counts
7.5	High pool count and slow water habitat of good/high quality; little instream structure in reach; moderate salmonid use if fish accessible	High pool count and riffles; few glides; good quality pool and spawning habitat but little instream structure in reach; moderate salmonid use if fish accessible	High habitat unit diversity; good quality pool and spawning habitat; little instream structure in reach; moderate salmonid use if fish accessible	N/A
5	Moderate pool count and low quality slow water habitat; little instream structure; little salmonid use if fish accessible	Good number of pools and riffles, but spatial distribution not optimal or not good quality spawning and pool habitat; little salmonid use if fish accessible	Good number of pools and riffles, but spatial distribution not optimal or not good quality spawning and pool habitat OR little salmonid use if fish accessible	Dominated by step-pool and/or cascade habitat; moderate to low instream structure counts
2.5	Long glides, few pools, little instream structure; little salmonid use if fish accessible	Long glides, few pools, little instream structure; 25% good quality pool or spawning habitat	Long glides, few pools, little instream structure, 25% good quality pool or spawning habitat	N/A
1	Long glides, no pools, little instream structure; no observed salmonid use	Long glides, no pools, little instream structure; <10% good quality pool or spawning habitat	Long glides, no pools, little instream structure, <10% good quality pool or spawning habitat	Dominated by riffle habitat; little to no instream structure

Table F-3: Summary Rankings of Factors and Overall Habitat Condition by Reach and Creek

Reach	Channel Type	Length	Morphology	Sediment	Habitat	Quality/Reach
Fauntleroy Creek						
FA01	Beach	35	N/A	N/A	N/A	N/A
FA02	Plane-bed/Step-pool	180	5	5	5	5.0
FA03	Plane-bed	2132	5	10	5	6.7
FA04	Plane-bed/Step-pool	700	10	7.5	5	7.5
FA05	Plane-bed/Step-pool	613	10	7.5	5	7.5
System Score - Fauntleroy						***6.8***
Longfellow Creek						
LF01	*Culvert*	*3258*	1	1	1	1.0
LF02	*Riffle: Pool*	*1391*	2.5	5	10	5.8
LF03	*Riffle: Pool*	*1051*	5	5	7.5	5.8
LF04	*Plane-bed/Riffle: Pool*	*4471*	7.5	7.5	7.5	7.5
LF04.GC01	*Riffle: Pool*	*894*	10	1	1	4.0
LF05a	*Plane-bed/Riffle: Pool*	*1773*	2.5	2.5	2.5	2.5
LF05b	*Plane-bed/Riffle: Pool*	*2045*	5	10	7.5	7.5
LF05c	*Plane-bed/Riffle: Pool*	*568*	2.5	2.5	2.5	2.5
LF05d	*Plane-bed/Riffle: Pool*	*21587*	5	7.5	7.5	6.7
LF06	*Culvert*	*1817*	1	1	1	1.0
LF07	*Plane-bed/Step-pool*	*589*	2.5	5	5	4.2
LF08	*Riffle: Pool*	*2057*	2.5	10	5	5.8
System Score - Longfellow						***4.8***
Piper's Creek						
PI01	*Riffle: Pool*	*2122*	7.5	7.5	10	8.3
P101.VE01	*Riffle: Pool*	*545*	7.5	5	7.5	6.7
PI01.VEO2	*Plane-bed/Step-pool*	*457*	5	5	7.5	5.8
PI01.VE02.MO01	*Plane-bed/Step-pool*	*803*	5	7.5	5	5.8
PI01.VE02.MO01.EF01	*Plane-bed/Step-pool*	*270*	2.5	7.5	5	5.0
PI01.VE02.MO01.EF02	*Plane-bed/Step-pool*	*642*	7.5	7.5	2.5	5.8
PI01.VE02.MO01.WF01	*Plane-bed/Step-pool*	*635*	5	10	5	6.7
PI01.VE02.MO01.WF02	*Plane-bed/Step-pool*	*175*	2.5	7.5	5	5.0
PI01.VEO3	*Plane-bed/Step-pool*	*578*	10	10	7.5	9.2
PI01.VEO4	*Plane-bed/Step-pool*	*518*	7.5	10	5	7.5
PI01.VEO5	*Plane-bed/Step-pool*	*1254*	7.5	7.5	5	6.6

Table F-3: Summary Rankings of Factors and Overall Habitat Condition by Reach and Creek

Reach	Channel Type	Length	Morphology	Sediment	Habitat	Quality/Reach
PI02	*Riffle: Pool*	*342*	1	1	1	1.0
PI03	*Riffle: Pool*	*2866*	7.5	10	7.5	8.3
PI04	*Plane-bed/Riffle: Pool*	*1633*	7.5	7.5	2.5	5.8
PI05	*Plane-bed*	*1725*	1	1	1	1.0
System Score - Piper's						***6.3***
Taylor Creek						
TA01	*Plane-bed/Delta*	*1194*	1	5	7.5	4.5
TA02	*Plane-bed/Riffle: Pool*	*661*	5	7.5	7.5	6.7
TA03	*Riffle: Pool*	*355*	10	10	10	10.0
TA04	*Plane-bed/Step-pool*	*399*	10	10	10	10.0
TA05	*Plane-bed/Step-pool*	*1357*	10	10	10	10.0
TA05.EF01	*Plane-bed/Step-pool*	*483*	1	7.5	7.5	5.3
TA05.WF01	*Plane-bed/Step-pool*	*743*	10	10	10	10.0
TA05.WF02	*Plane-bed/Step-pool*	*482*	10	10	7.5	9.2
TA05.WF03	*Plane-bed/Step-pool*	*2935*	7.5	10	10	9.2
System Score - Taylor						***8.5***
Thornton Creek						
TM01	*Delta/Plane-bed*	*1027*	2.5	2.5	5	3.3
TM02a	*Riffle: Pool*	*1287*	5	10	5	6.7
TM02b	*Plane-bed*	*772*	5	7.5	7.5	6.7
TM03	*Riffle: Pool*	*3314*	5	5	5	5
TM04	*Riffle: Pool*	*1077*	7.5	5	10	7.5
TN01	*Plane-bed*	*1706*	2.5	7.5	5	5
TN01.LB01	*Riffle: Pool*	*2998*	2.5	5	5	4.2
TN02a	*Plane-bed/Riffle: Pool*	*2546*	2.5	5	7.5	5
TN02b	*Plane-bed/Riffle: Pool*	*2694*	2.5	5	5	4.2
TN02c	*Plane-bed/Riffle: Pool*	*2584*	2.5	7.5	5	5
TN02d	*Plane-bed/Riffle: Pool*	*1322*	1	5	5	4.2
TN03a	*Riffle: Pool*	*703*	1	2.5	5	2.8
TN03b	*Riffle: Pool*	*1583*	10	10	7.5	9.2
TN03c	*Riffle: Pool*	*3304*	2.5	5	2.5	3.3
TN03.LI01	*Culvert*	*1648*	1	1	1	1.0
TN03.LI02	*Plane-bed*	*1183*	1	2.5	2.5	2.0

Table F-3: Summary Rankings of Factors and Overall Habitat Condition by Reach and Creek

Reach	Channel Type	Length	Morphology	Sediment	Habitat	Quality/Reach
TN03.LI03	*Riffle: Pool*	*1384*	2.5	2.5	5	3.3
TN04	*Culvert*	*2192*	1	1	1	1.0
TN05	*Plane-bed*	*8008*	1	2.5	2.5	2.0
TS01	*Riffle: Pool*	*1521*	2.5	5	5	4.2
TS01.KR01	*Plane-bed*	*966*	1	2.5	2.5	2.0
TS02a	*Riffle: Pool*	*1236*	2.5	7.5	7.5	5.8
TS02b	*Plane-bed/Riffle: Pool*	*1828*	5	5	7.5	5.8
TS02.WI01	*Plane-bed/Step-pool*	*693*	2.5	5	7.5	5.0
TS03	*Riffle: Pool*	*1563*	5	5	7.5	5.8
TS04a	*Riffle: Pool*	*2739*	7.5	7.5	7.5	7.5
TS04b	*Riffle: Pool*	*802*	5	7.5	5	5.8
TS05a	*Riffle: Pool*	*1749*	2.5	2.5	2.5	2.5
TS05b	*Riffle: Pool*	*920*	7.5	10	7.5	8.3
					System Score - Thornton	***4.2***

Ranking Key: Poor = 0 - 4.9 Moderate = 5.0 - 7.4 Good = 7.5 - 10.0

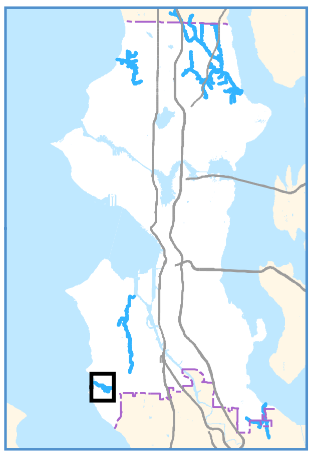
Appendix G: Channel Erosion Stage Maps

List of Maps

Seattle Public Utilities

Drainage System Analysis   Task 6.3 Aquatic Habitat

Channel Erosion - Fauntleroy Creek



LEGEND

Erosion Stage

- Pre-modified or Slight Downcut
- Constructed or Frozen
- Degradation; Degradation & Widening
- Aggradation
- Restablization

- Focus Urban Watercourse
- Parks

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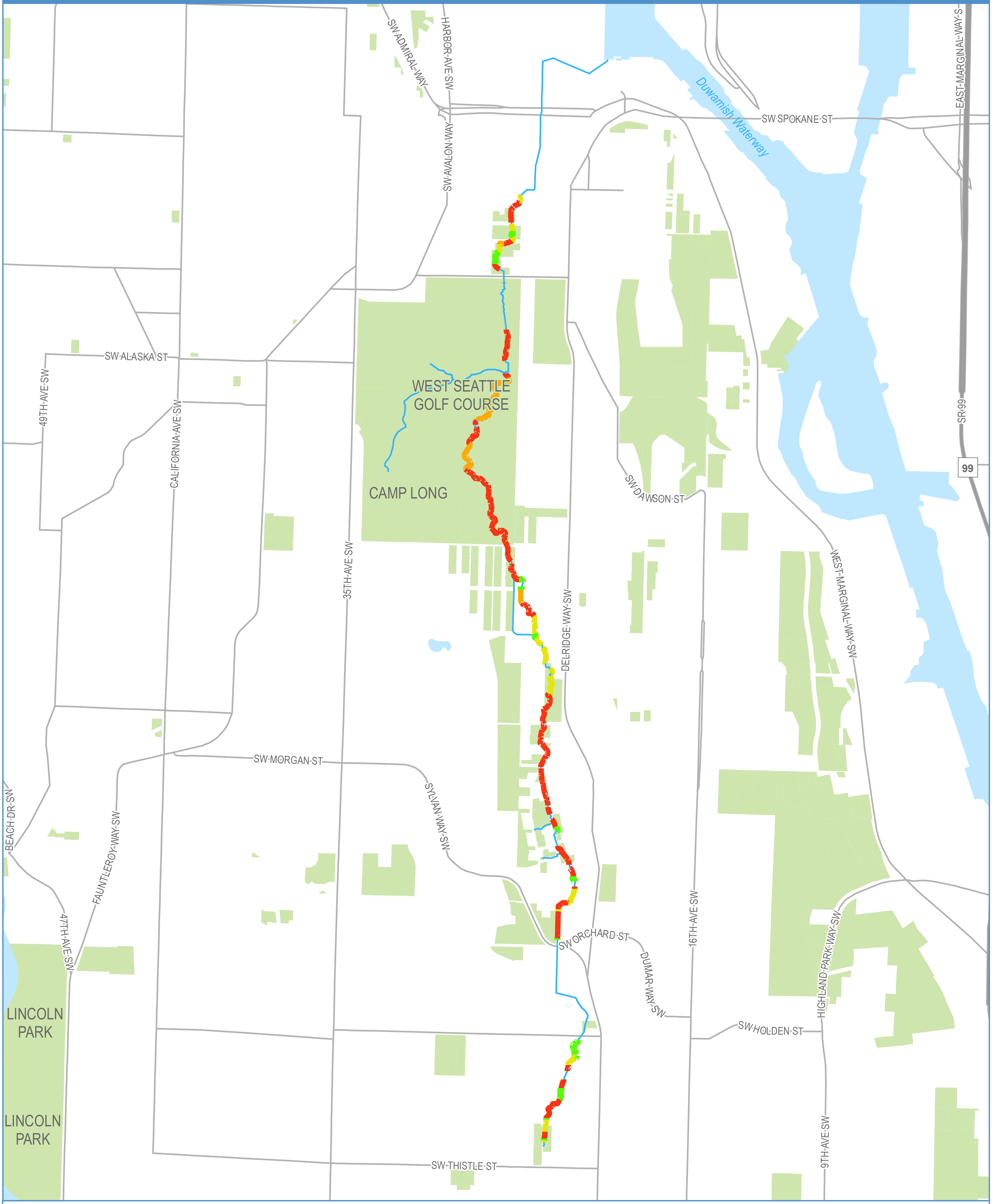
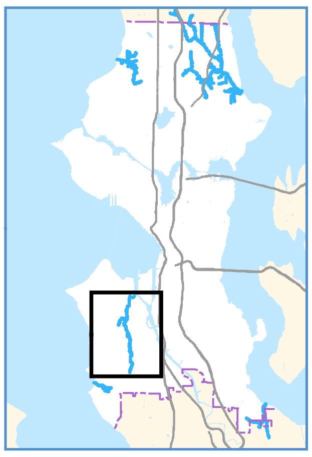
Seattle Public Utilities

Drainage System Analysis

Task 6.3 Aquatic Habitat

Channel Erosion - Longfellow Creek





LEGEND

Erosion Stage

- 🟩 Pre-modified or Slight Downcut
- 🟨 Constructed or Frozen
- 🟥 Degradation; Degradation & Widening
- 🟧 Aggradation
- 🟩 Restablization
- ~ Focus Urban Watercourse
- 🟩 Parks

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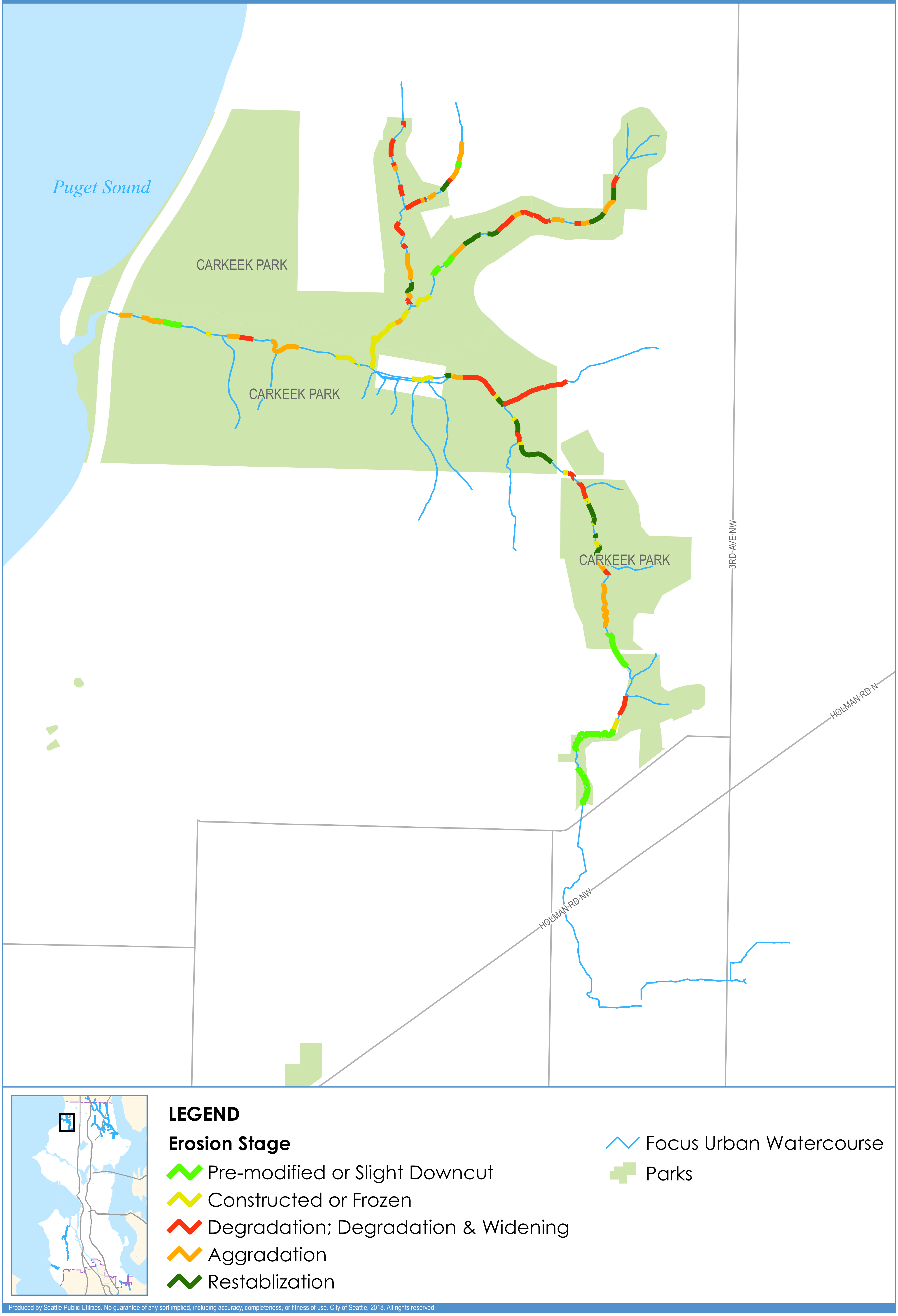
Drainage System Analysis

Task 6.3 Aquatic Habitat

Channel Erosion - Piper's Creek



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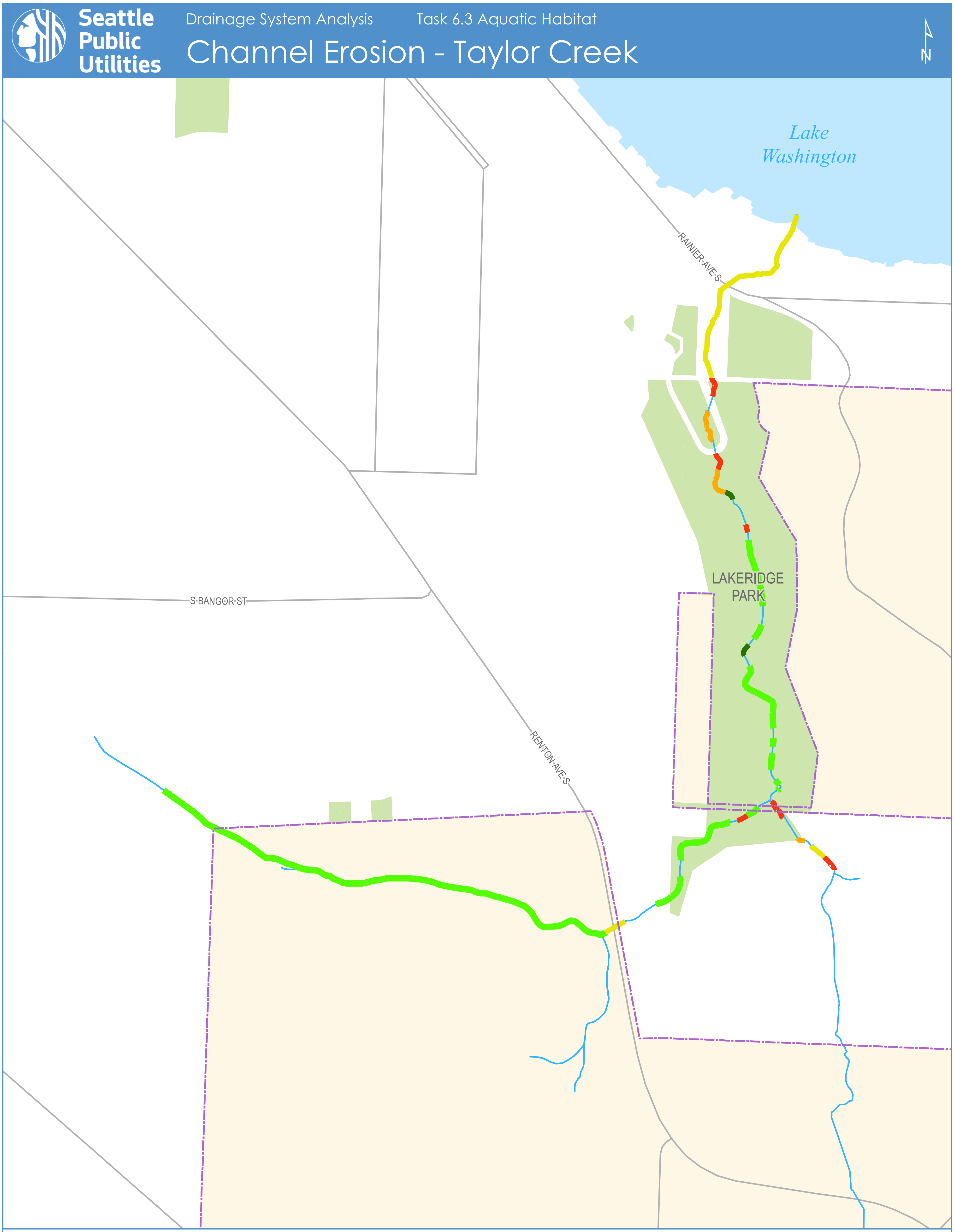
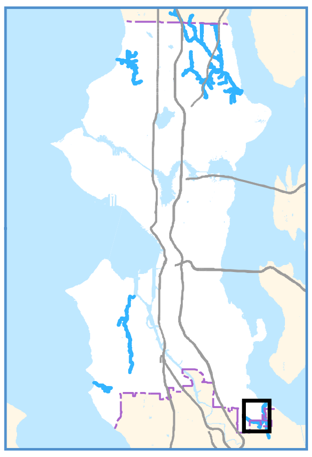
Drainage System Analysis   Task 6.3 Aquatic Habitat

Channel Erosion - Taylor Creek





LEGEND

Erosion Stage

- 🟩 Pre-modified or Slight Downcut
- 🟨 Constructed or Frozen
- 🟥 Degradation; Degradation & Widening
- 🟧 Aggradation
- 🟩 Restablization

- Focus Urban Watercourse
- City Limits
- Parks

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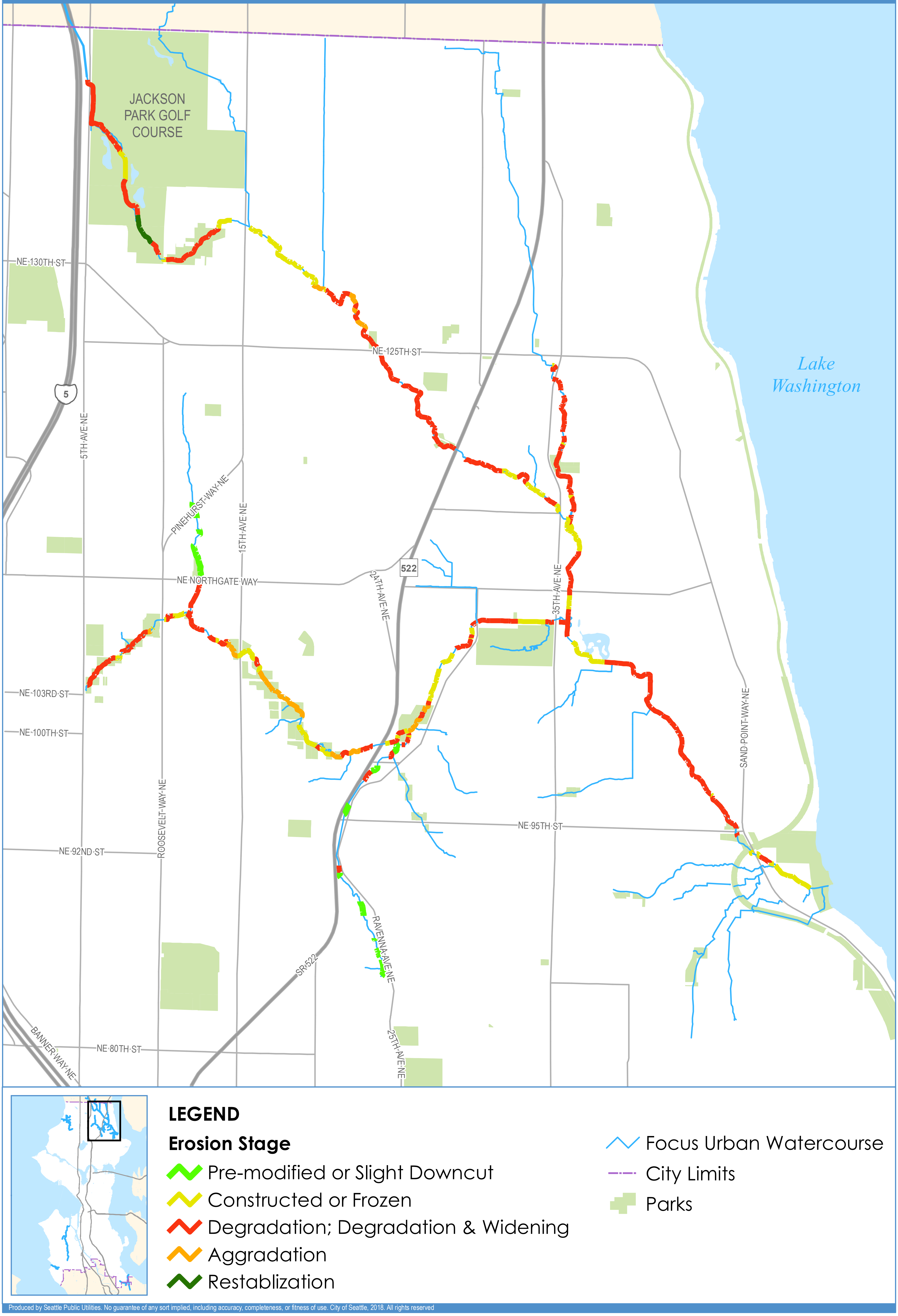
Drainage System Analysis   Task 6.3 Aquatic Habitat

Channel Erosion - Thornton Creek



LEGEND

Erosion Stage

- 🟩 Pre-modified or Slight Downcut
- 🟨 Constructed or Frozen
- 🟥 Degradation; Degradation & Widening
- 🟧 Aggradation
- 🟩 Restablization

- Focus Urban Watercourse
- City Limits
- Parks

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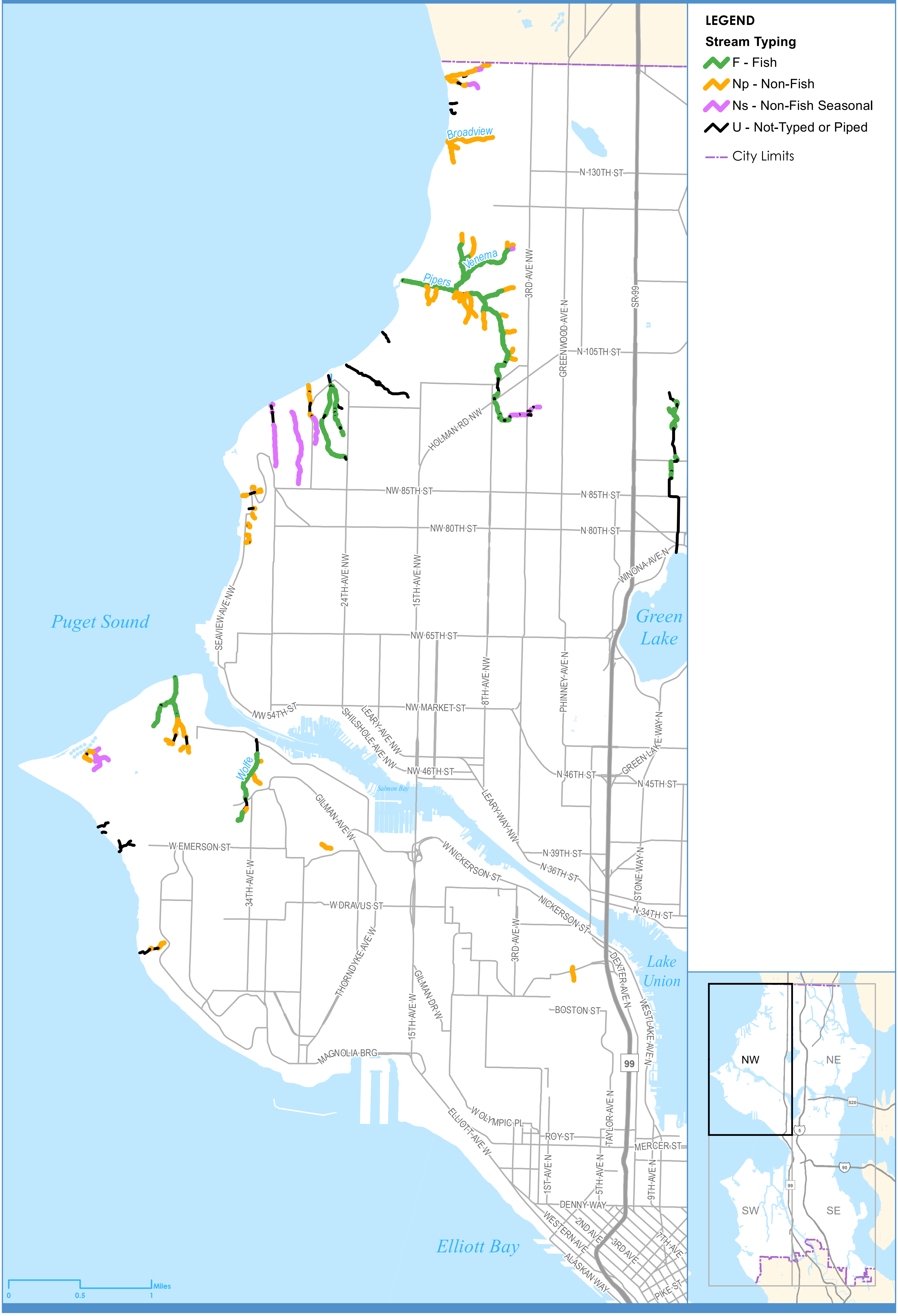
Appendix H: Stream Typing Maps

List of Maps

Seattle Public Utilities

Drainage System Analysis Task 6.4 Aquatic Habitat

Stream Typing - NW



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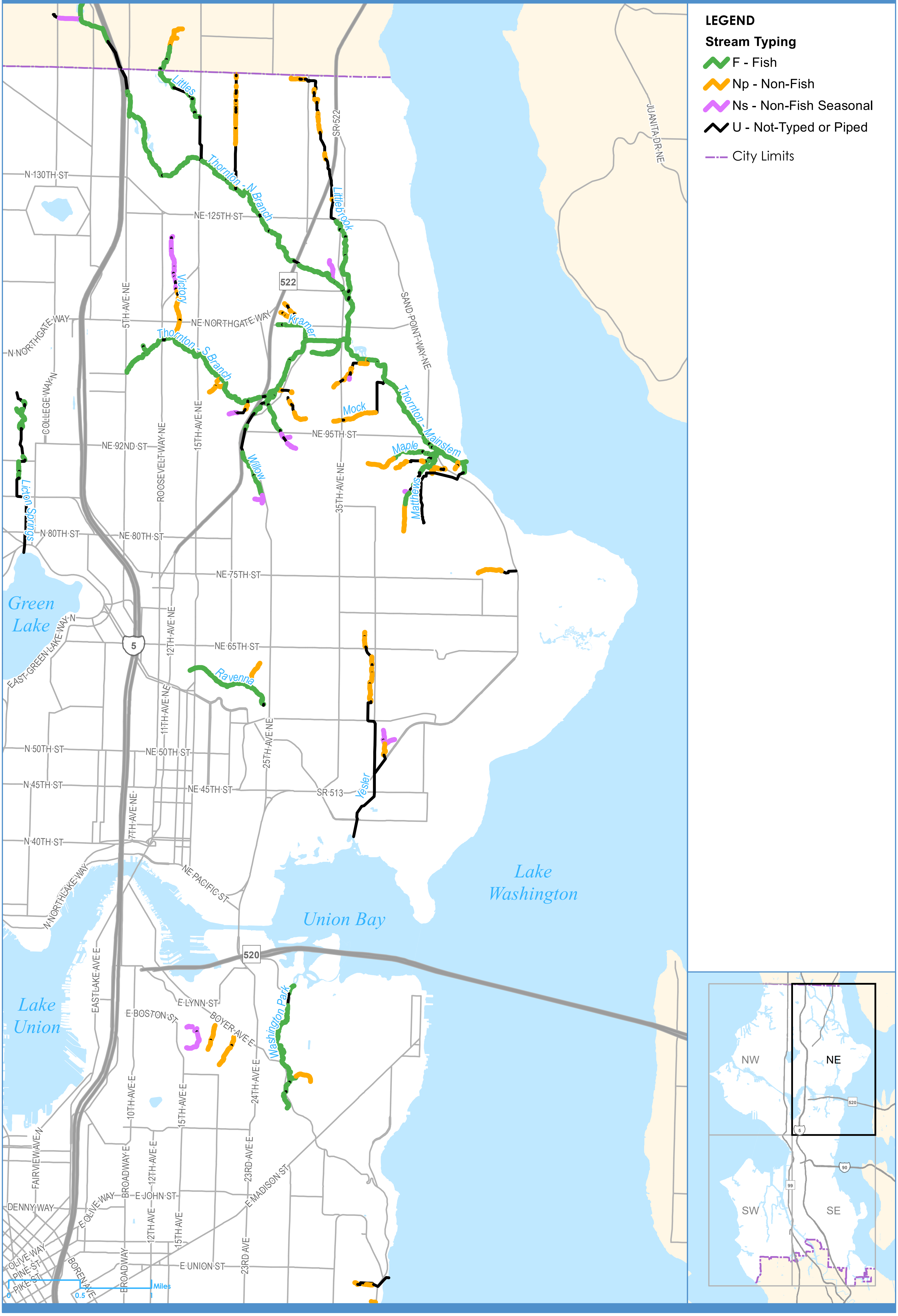
Drainage System Analysis Task 6.4 Aquatic Habitat

Stream Typing - NE



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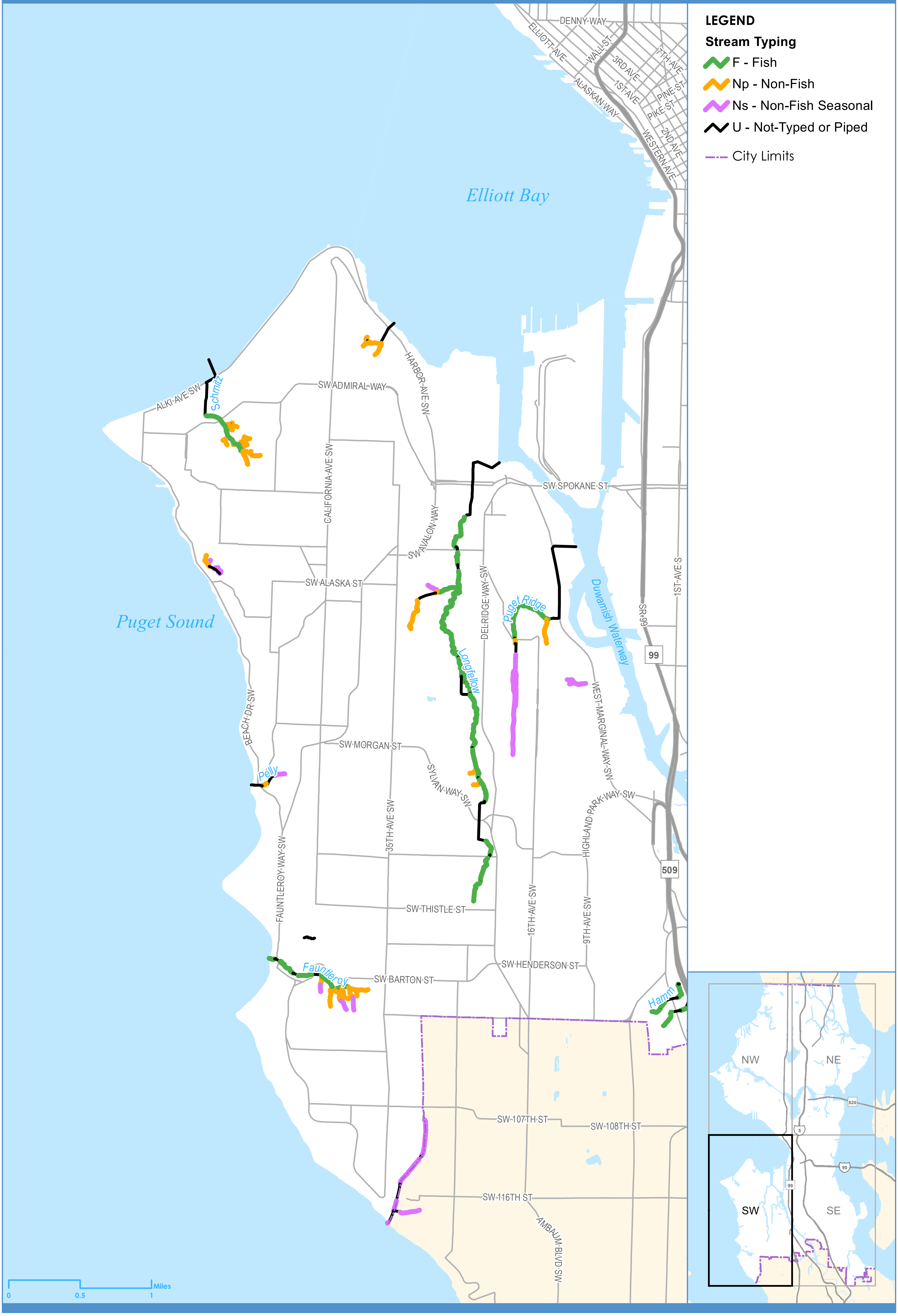
Drainage System Analysis   Task 6.4 Aquatic Habitat

Stream Typing - SW



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Date: 3/9/2020

Author: SPU Shin

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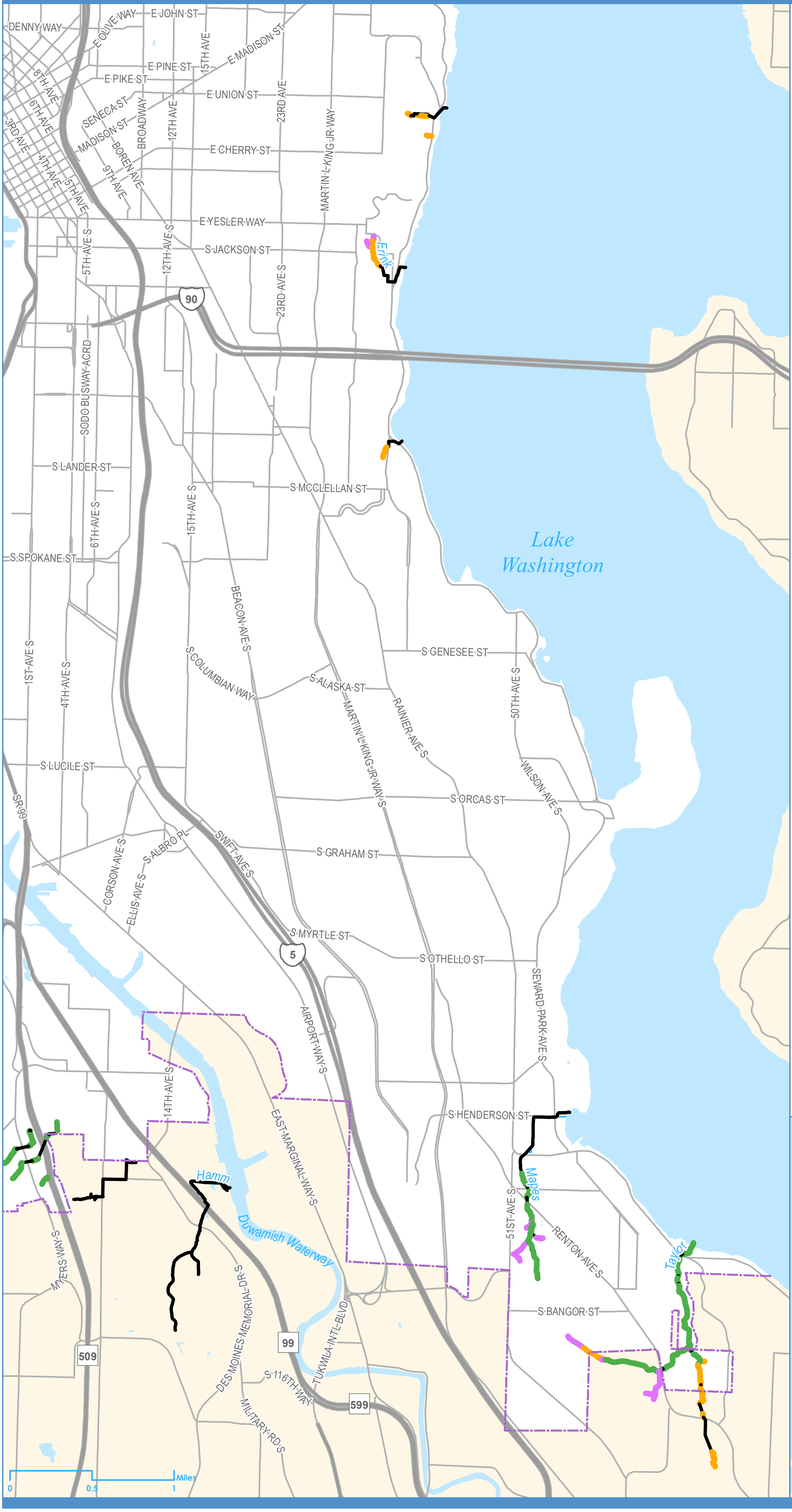
Drainage System Analysis   Task 6.4 Aquatic Habitat

Stream Typing - SE

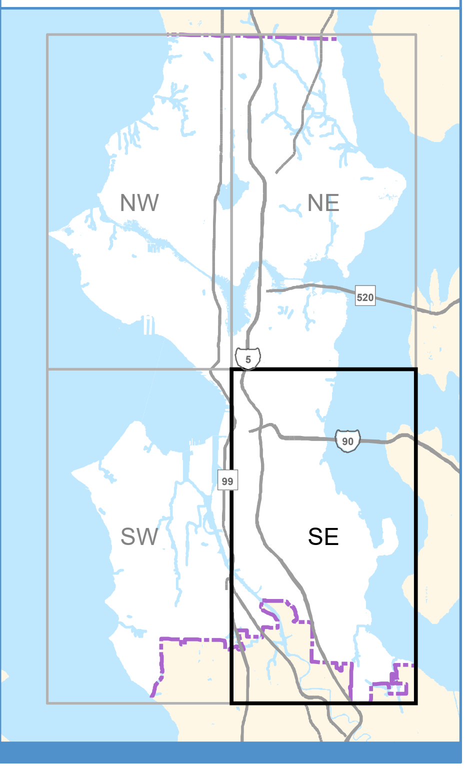


LEGEND

Stream Typing

- 🟩 F - Fish
- 🟧 Np - Non-Fish
- 🟪 Ns - Non-Fish Seasonal
- ⬛ U - Not-Typed or Piped

- -·- City Limits



Author: SPU Shin   Date: 3/9/2020   File Path: X:\Separated Systems\Business_Areas\DSA\GIS\Library\MXD\Task 6\Task6-4_StreamTyping.mxd

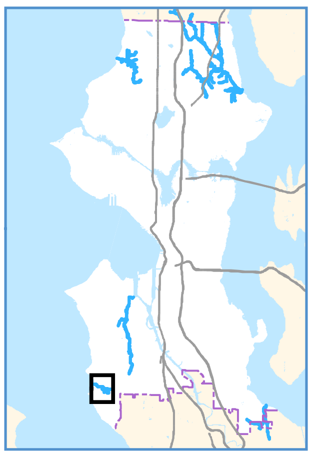
Appendix I: Fish Use Maps

List of Maps

Seattle Public Utilities

Drainage System Analysis   Task 6.5 Aquatic Habitat

Most Upstream Fish Sightings By Species - Fauntleroy Creek



LEGEND

Listed Salmon/Trout
- ● Chinook

Non-listed Salmon/Migratory Trout
- ● Chum
- ● Coho
- ● Migratory Cutthroat
- ● Pink
- ● Rainbow
- ● Sockeye

Resident Trout
- ● Resident Cutthroat

Other Fish
- ● 3-Spined Stickleback
- ● Bass
- ● Carp
- ● Peamouth
- ● Sculpin
- ● Sucker

- Focus Urban Watercourse
- Fish Path Trace
- 🟩 Parks

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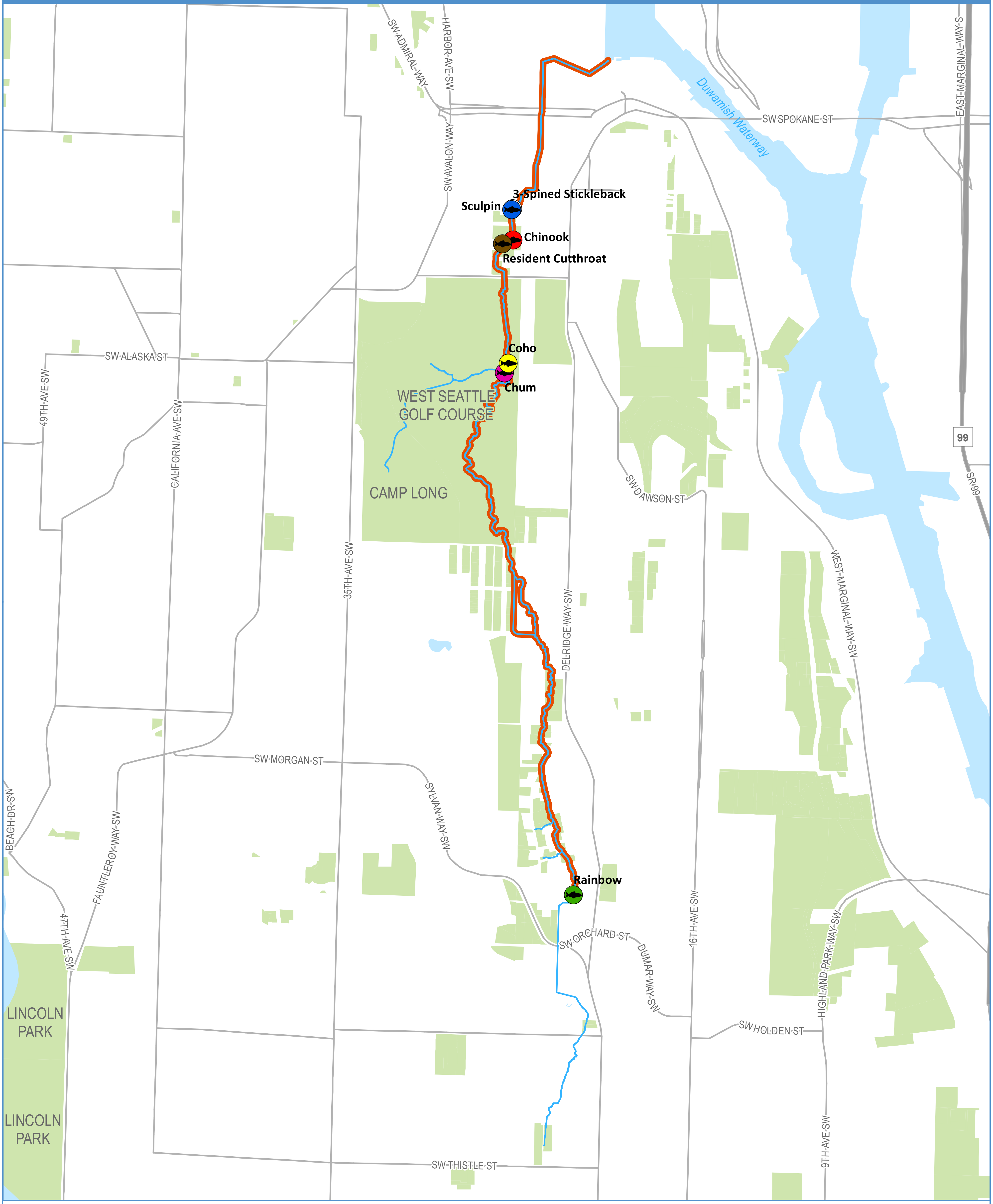
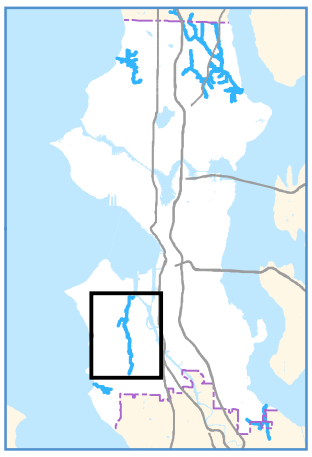
Drainage System Analysis Task 6.5 Aquatic Habitat

Most Upstream Fish Sightings By Species - Longfellow Creek





LEGEND

Listed Salmon/Trout

● Chinook

Non-listed Salmon/Migratory Trout

● Chum
● Coho
● Migratory Cutthroat
● Pink
● Rainbow
● Sockeye

Resident Trout

● Resident Cutthroat

Other Fish

● 3-Spined Stickleback
● Bass
● Carp
● Peamouth
● Sculpin
● Sucker

Focus Urban Watercourse
Fish Path Trace
Parks

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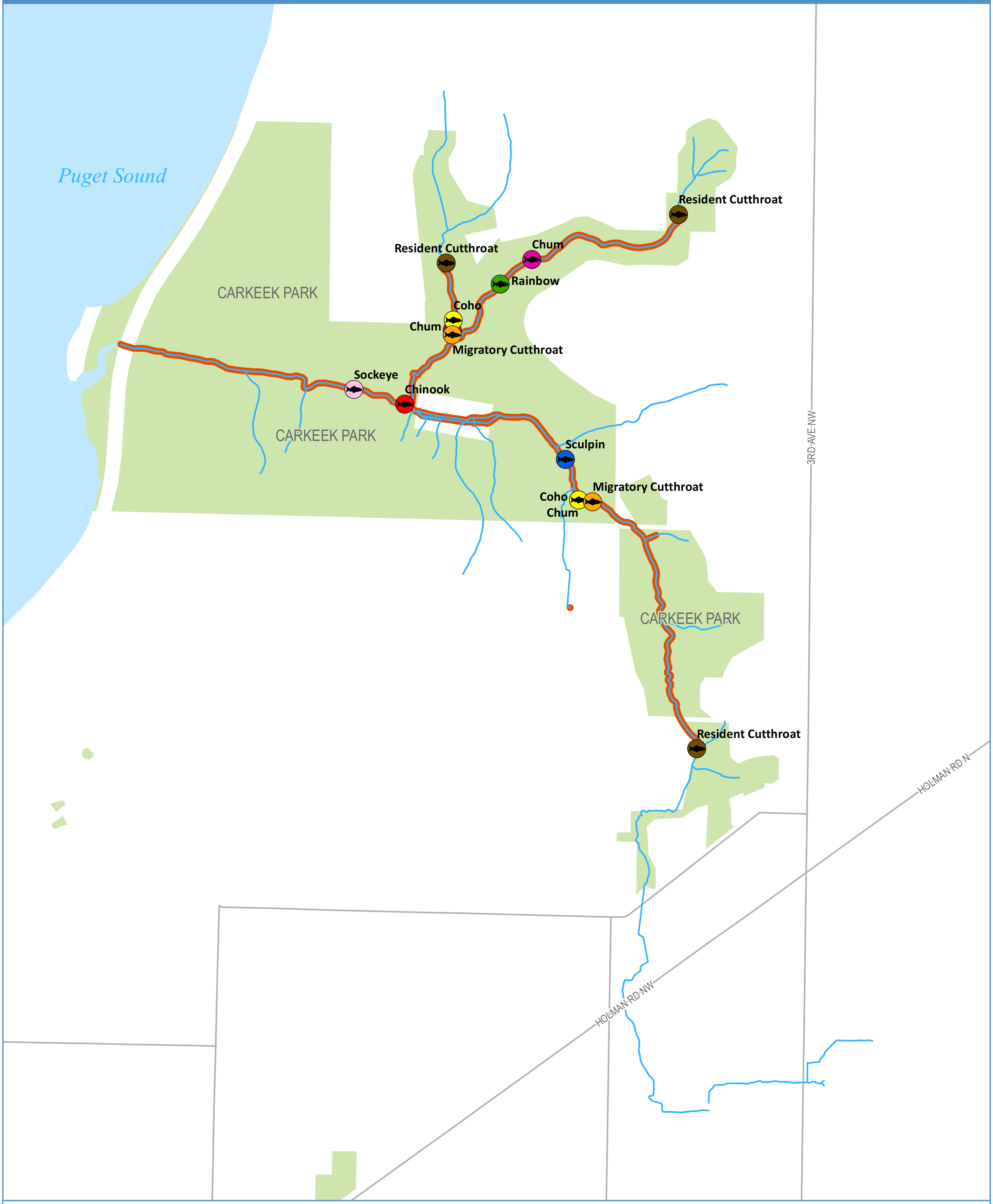
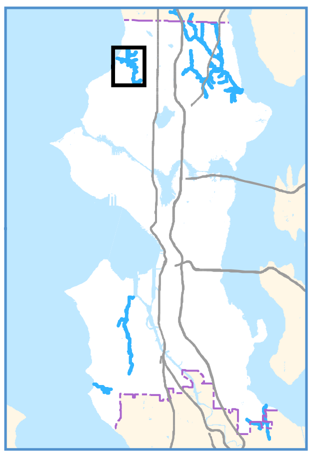
Drainage System Analysis   Task 6.5 Aquatic Habitat

Most Upstream Fish Sightings By Species - Piper's Creek





LEGEND

Listed Salmon/Trout
- ● Chinook

Non-listed Salmon/Migratory Trout
- ● Chum
- ● Coho
- ● Migratory Cutthroat
- ● Pink
- ● Rainbow
- ● Sockeye

Resident Trout
- ● Resident Cutthroat

Other Fish
- ● 3-Spined Stickleback
- ● Bass
- ● Carp
- ● Peamouth
- ● Sculpin
- ● Sucker

- Focus Urban Watercourse
- Fish Path Trace
- Parks

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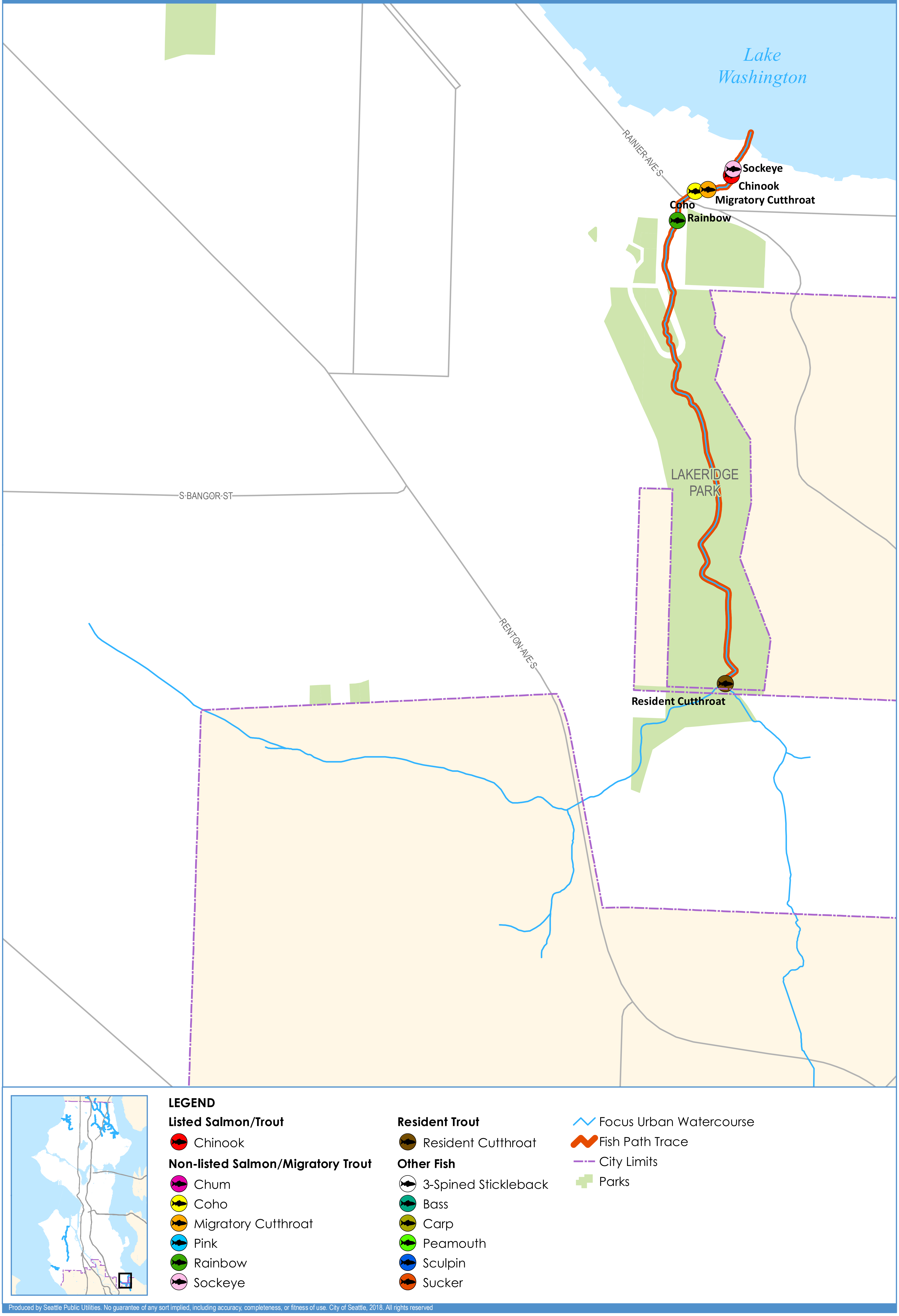
Most Upstream Fish Sightings By Species - Taylor Creek



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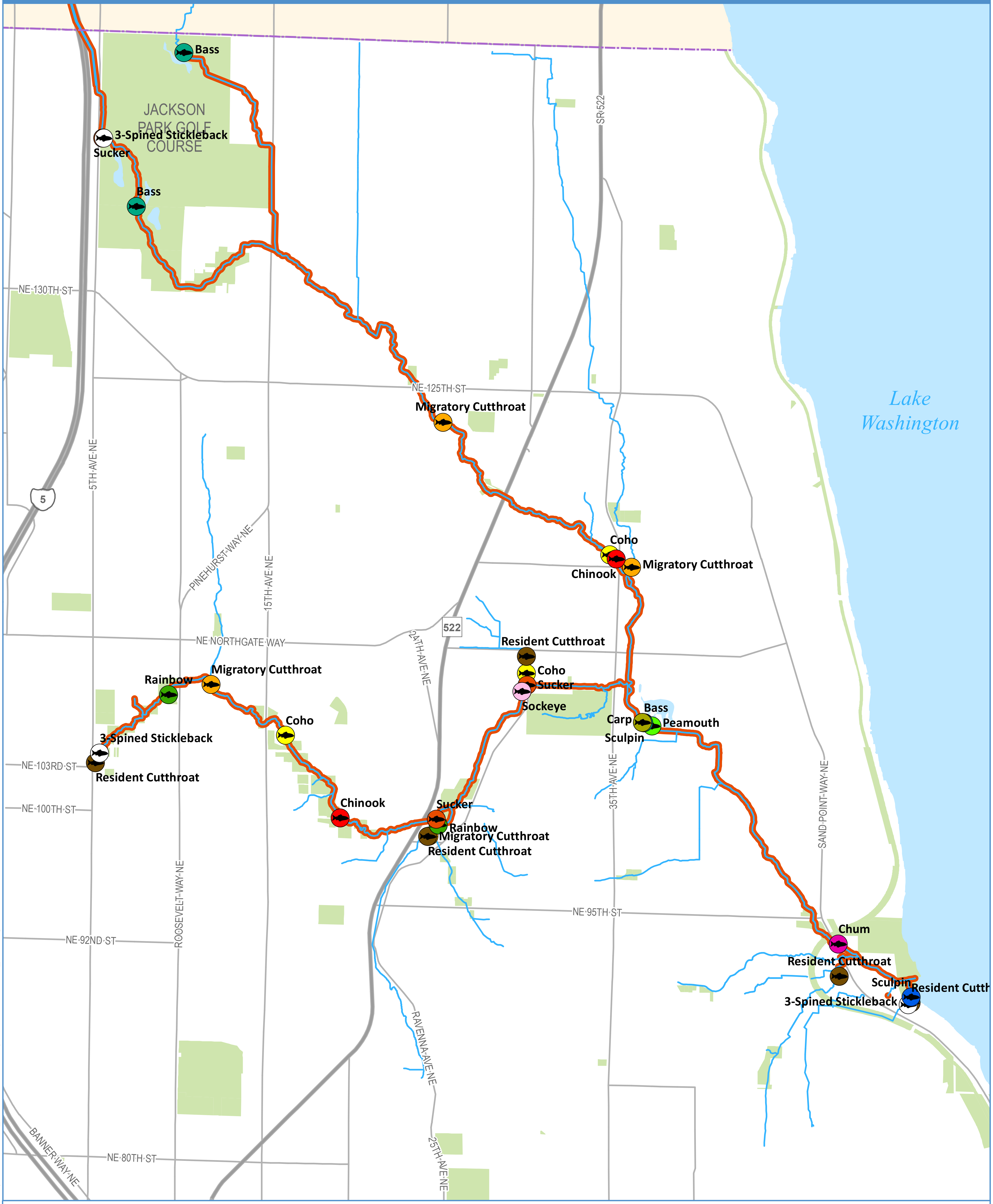
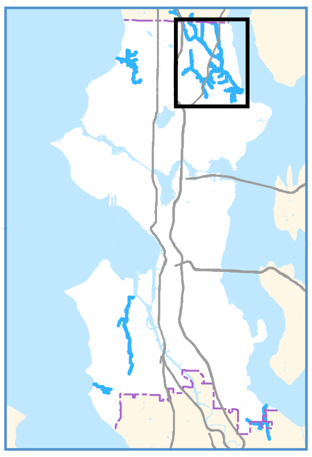
Drainage System Analysis Task 6.5 Aquatic Habitat

Most Upstream Fish Sightings By Species - Thornton Creek





LEGEND

Listed Salmon/Trout
- ● Chinook

Non-listed Salmon/Migratory Trout
- ● Chum
- ● Coho
- ● Migratory Cutthroat
- ● Pink
- ● Rainbow
- ● Sockeye

Resident Trout
- ● Resident Cutthroat

Other Fish
- ● 3-Spined Stickleback
- ● Bass
- ● Carp
- ● Peamouth
- ● Sculpin
- ● Sucker

- Focus Urban Watercourse
- Fish Path Trace
- City Limits
- Parks

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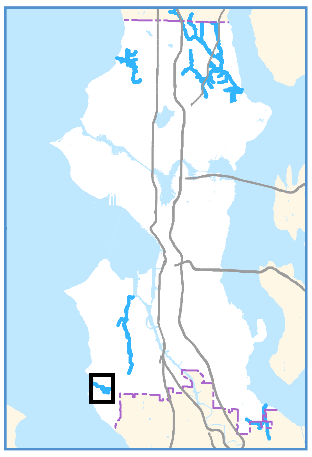
Drainage System Analysis   Task 6.5B Aquatic Habitat

Extent of Fish Habitat Use by Species Group - Fauntleroy Creek



LEGEND

Extent of Fish Sightings in Urban Watercourses

- Listed Salmon / Trout
- Non-listed Salmon / Migratory Trout
- Other Fish
- Potential Habitat (Type F)
- Non-Type-F or Unknown

- Focus Urban Watercourse
- 🟩 Parks

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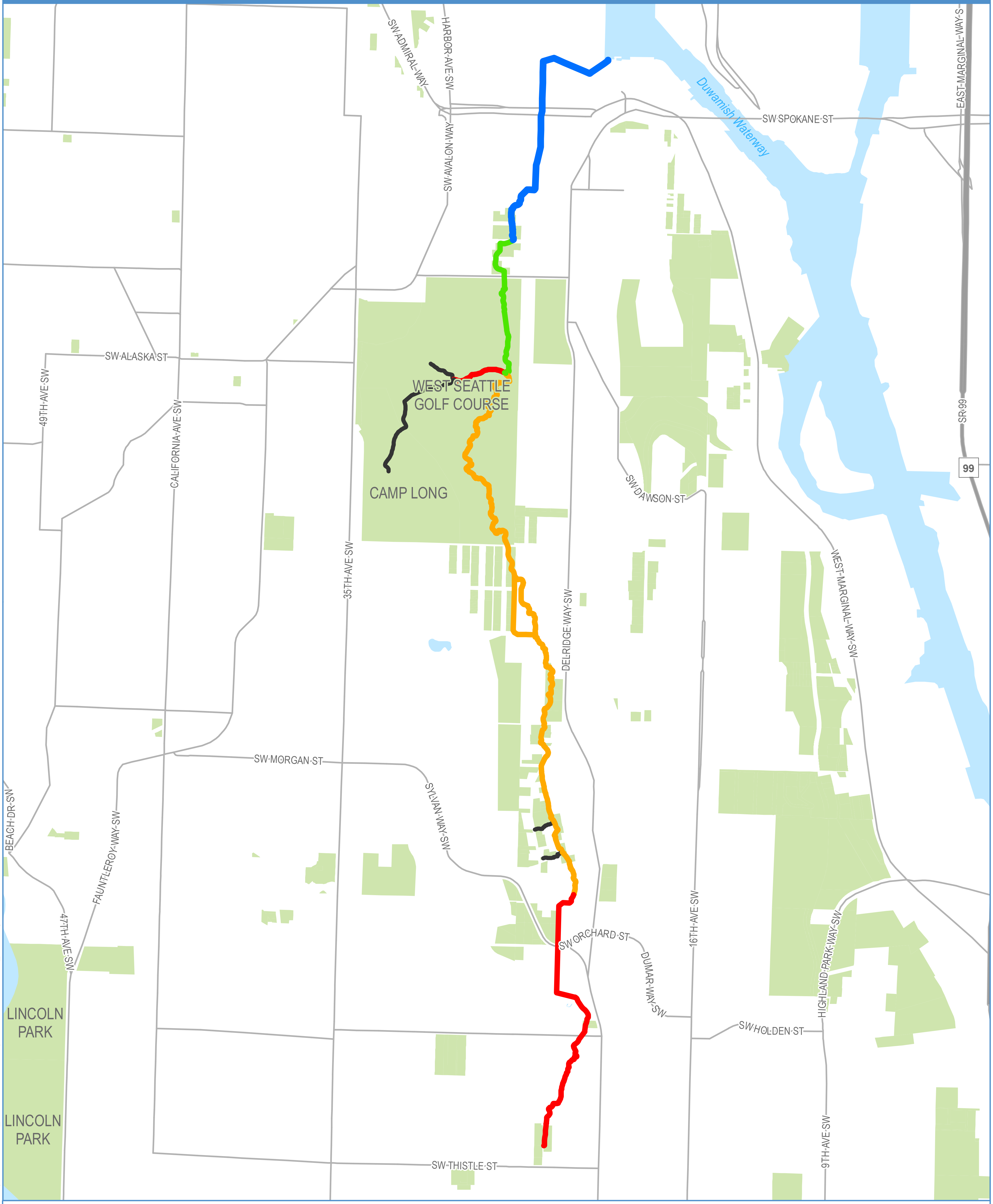
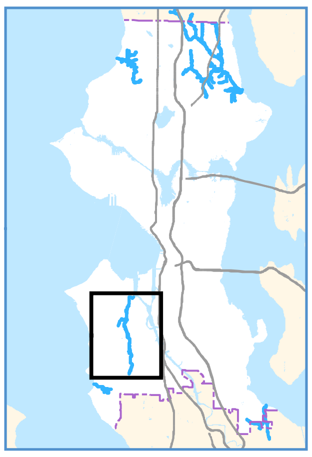
Drainage System Analysis Task 6.5B Aquatic Habitat

Extent of Fish Habitat Use by Species Group - Longfellow Creek





LEGEND

Extent of Fish Sightings in Urban Watercourses

- Listed Salmon / Trout
- Non-listed Salmon / Migratory Trout
- Other Fish
- Potential Habitat (Type F)
- Non-Type-F or Unknown
- Focus Urban Watercourse
- Parks

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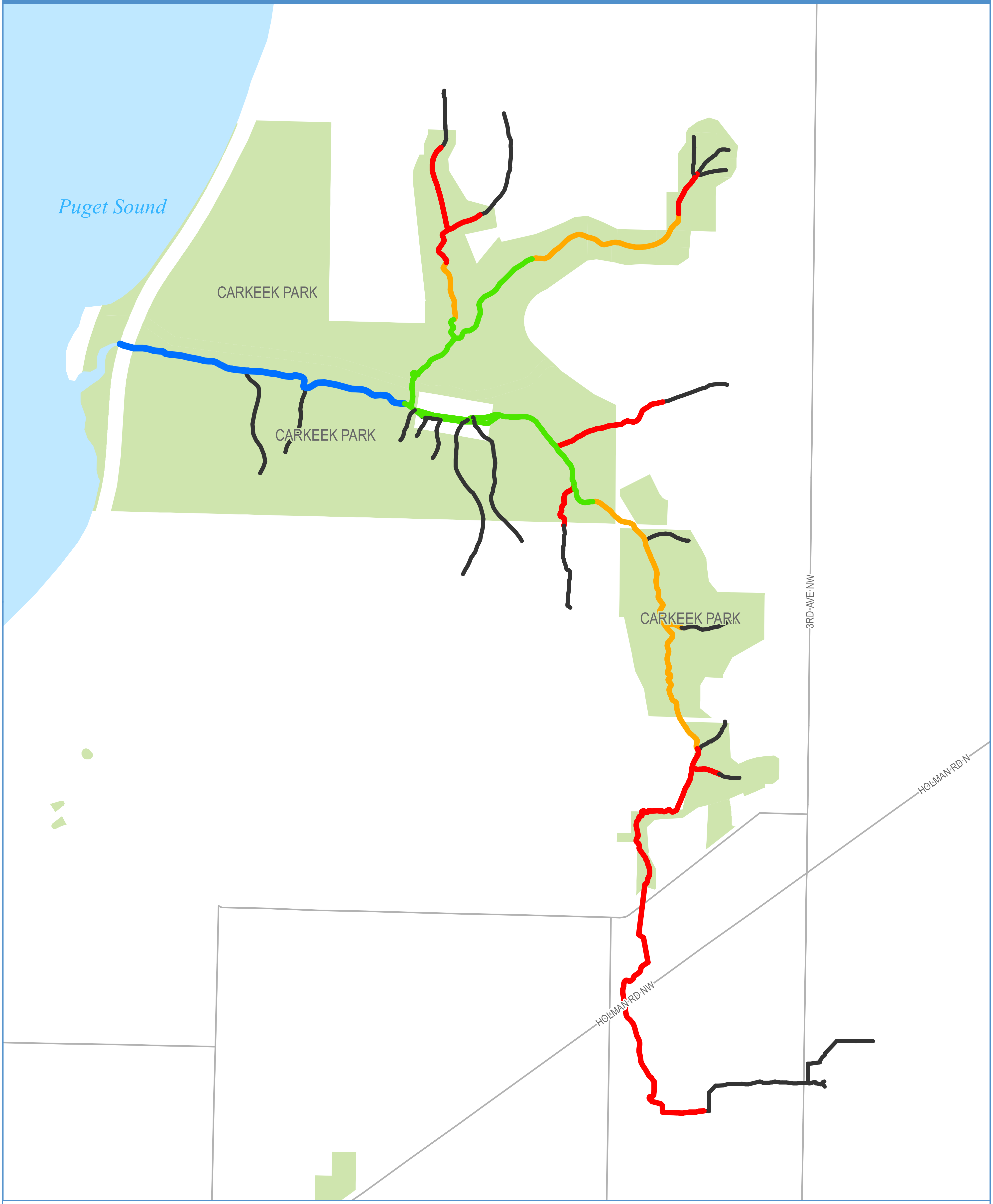
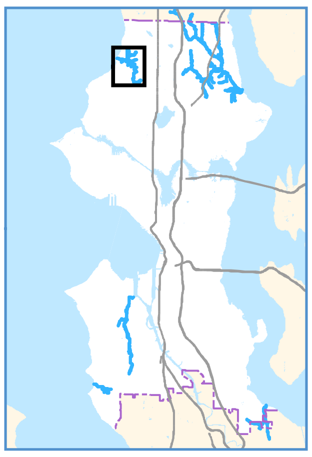
Drainage System Analysis   Task 6.5B Aquatic Habitat

Extent of Fish Habitat Use by Species Group - Piper's Creek





LEGEND

Extent of Fish Sightings in Urban Watercourses

- Listed Salmon / Trout
- Non-listed Salmon / Migratory Trout
- Other Fish
- Potential Habitat (Type F)
- Non-Type-F or Unknown
- Focus Urban Watercourse
- Parks

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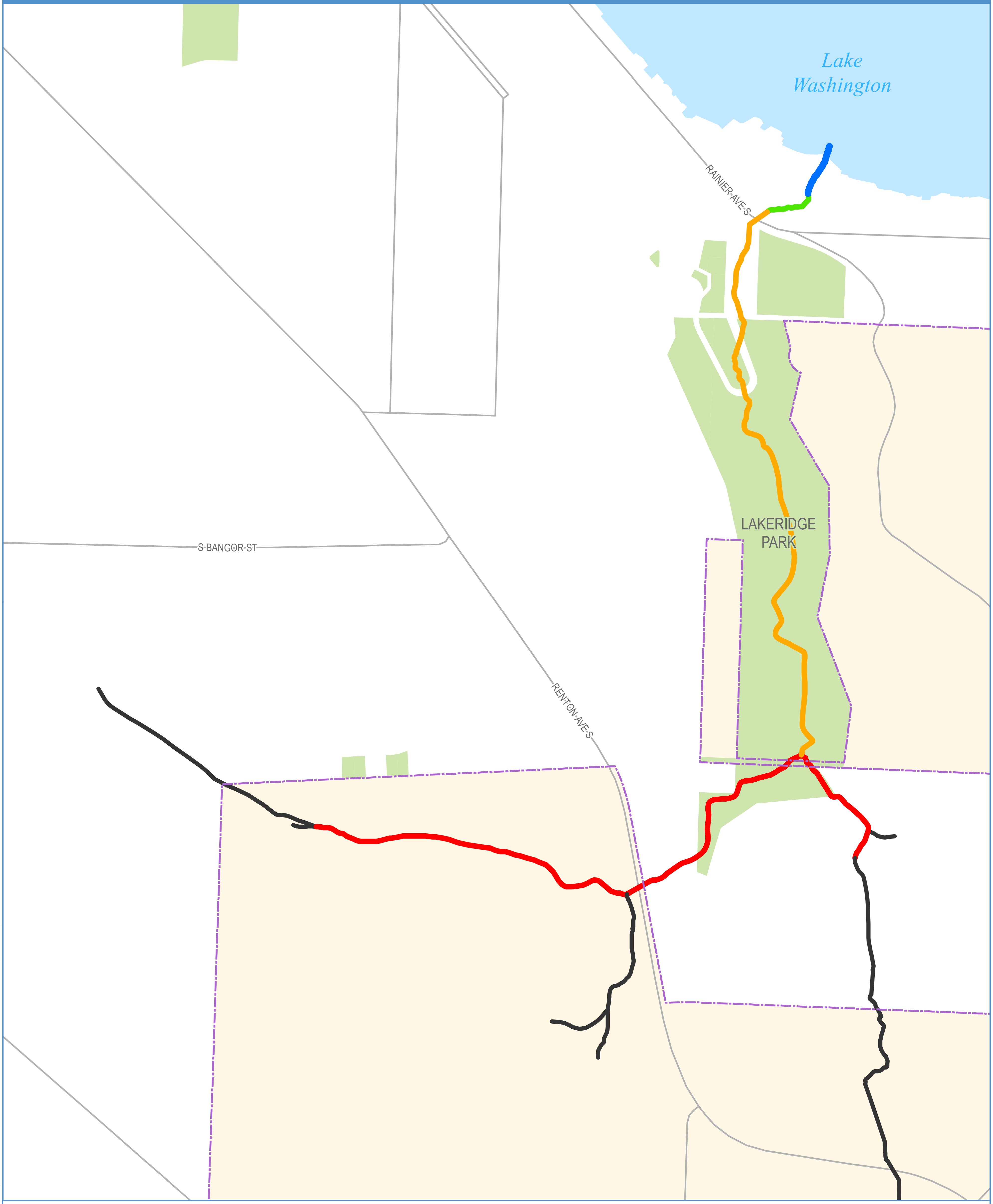
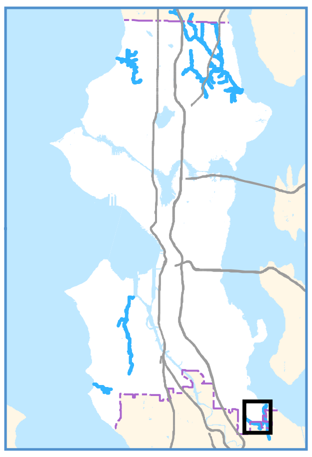
Drainage System Analysis Task 6.5B Aquatic Habitat

Extent of Fish Habitat Use by Species Group - Taylor Creek





LEGEND

Extent of Fish Sightings in Urban Watercourses

- 🟦 Listed Salmon / Trout
- 🟩 Non-listed Salmon / Migratory Trout
- 🟧 Other Fish
- 🟥 Potential Habitat (Type F)
- ⬛ Non-Type-F or Unknown

- Focus Urban Watercourse
- City Limits
- 🟩 Parks

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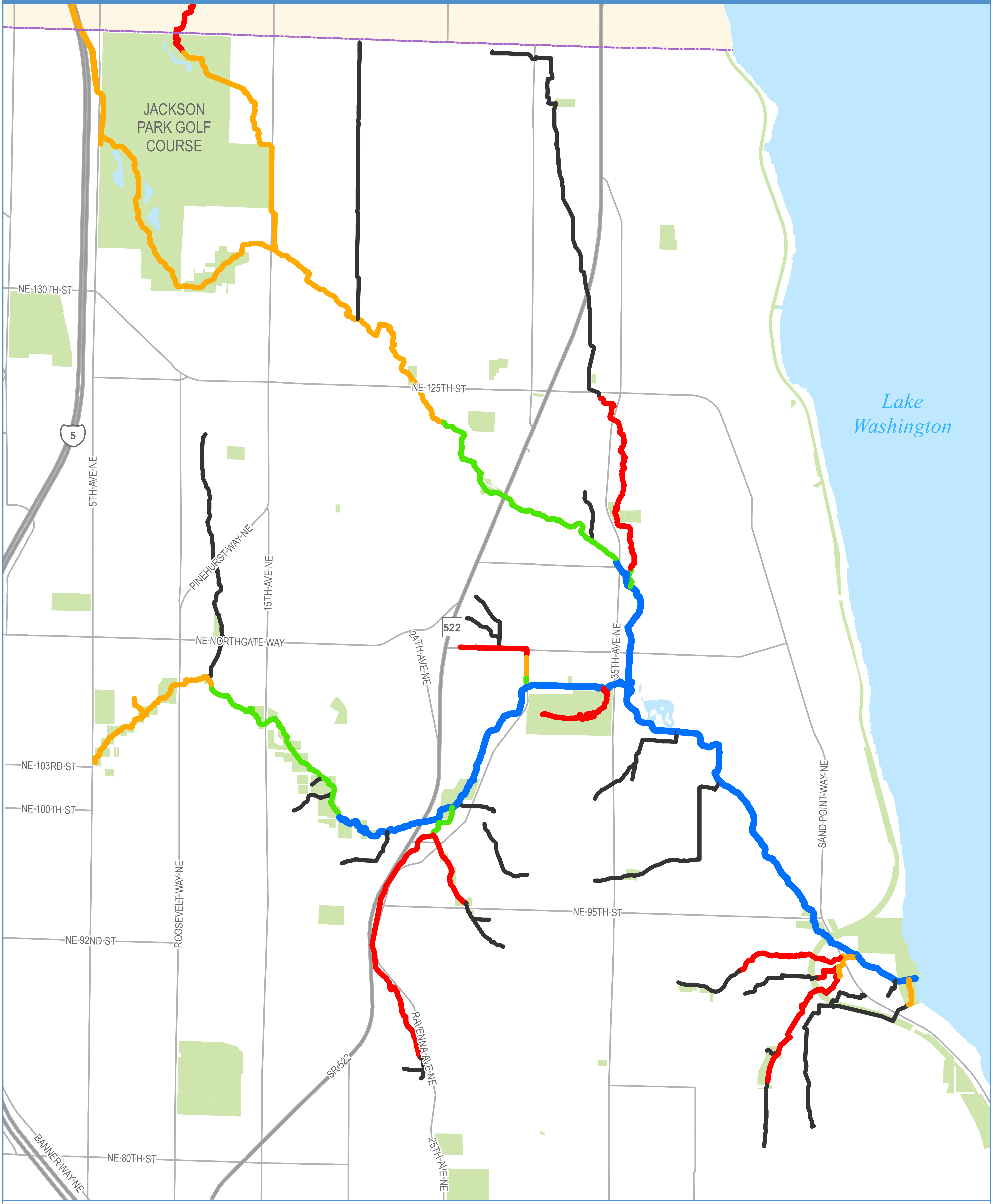
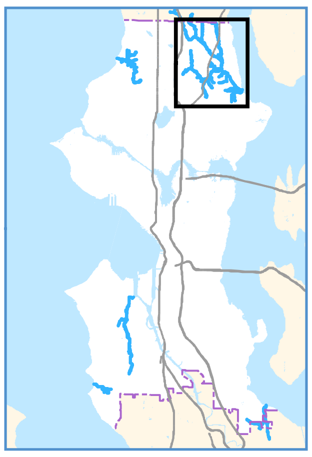
Drainage System Analysis Task 6.5B Aquatic Habitat

Extent of Fish Habitat Use by Species Group - Thornton Creek





LEGEND

Extent of Fish Sightings in Urban Watercourses

- Listed Salmon / Trout
- Non-listed Salmon / Migratory Trout
- Other Fish
- Potential Habitat (Type F)
- Non-Type-F or Unknown

- Focus Urban Watercourse
- City Limits
- Parks

Author: SPU Shin Date: 10/2/2020 File Path: X:\Separated Systems\Business_Areas\DSA\GISLibrary\MXD\Task 6\Task6-5B_FishUsageLn.mxd

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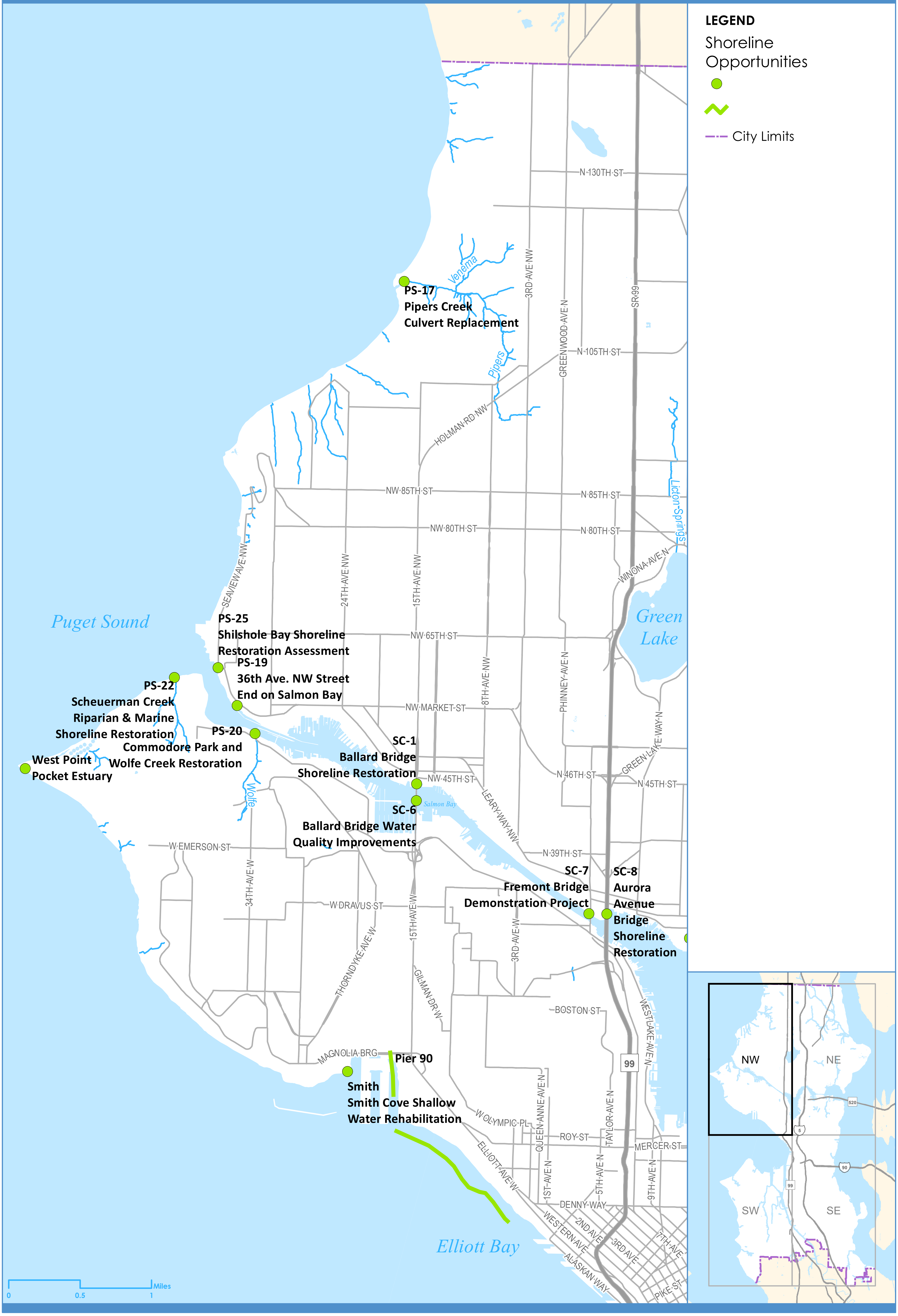
Appendix J: Shoreline Restoration Maps and Table

List of Maps and Table

Seattle Public Utilities

Drainage System Analysis Task 6.6B Aquatic Habitat

Shoreline and Creek Restoration Opportunities - NW



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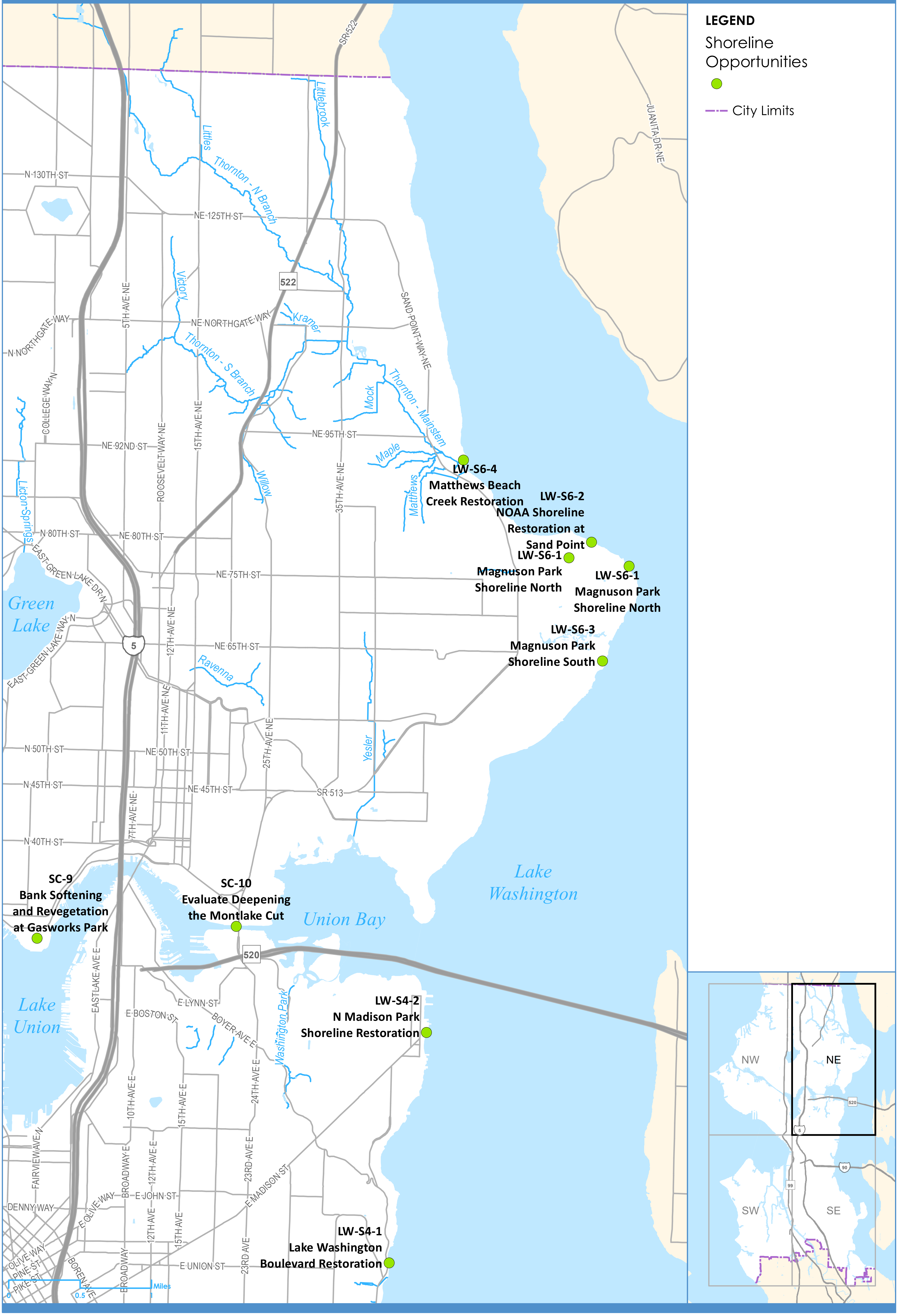
Date: 3/10/2020

Author: SPU Shin

Seattle Public Utilities

Drainage System Analysis Task 6.6B Aquatic Habitat

Shoreline and Creek Restoration Opportunities - NE

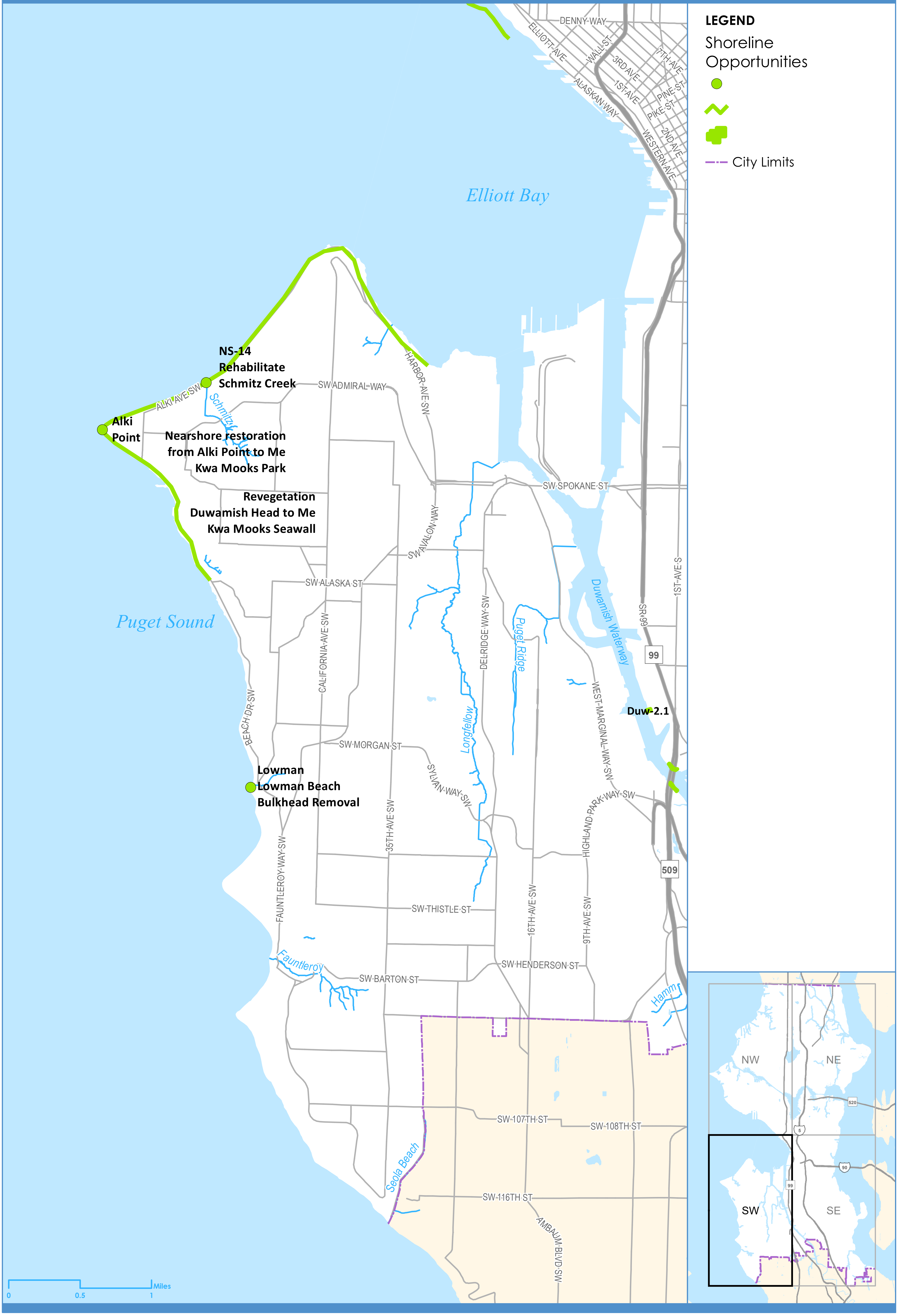


Author: SPU Shin Date: 3/10/2020 File Path: X:\Separated Systems\Business_Areas\DSA\GISLibrary\MXD\Task 6\Task6-6B_ShorelineOpportunities.mxd

Seattle Public Utilities

Drainage System Analysis   Task 6.6B Aquatic Habitat

Shoreline and Creek Restoration Opportunities - SW

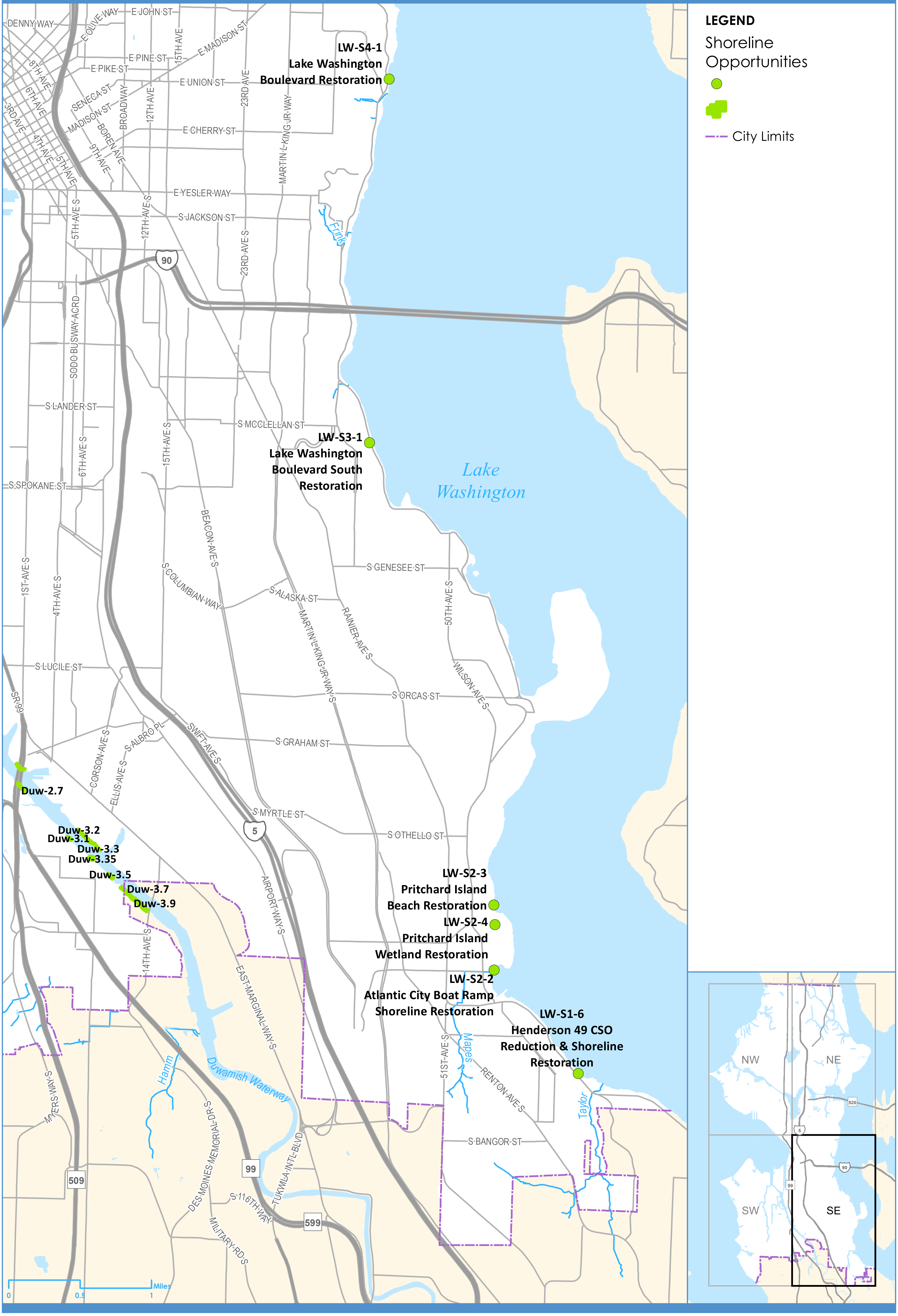


Author: SPU Shin   Date: 3/10/2020   File Path: X:\Separated Systems\Business_Areas\DSA\GIS\Library\MXD\Task 6\Task6-6B_ShorelineOpportunities.mxd

Seattle Public Utilities

Drainage System Analysis Task 6.6B Aquatic Habitat

Shoreline and Creek Restoration Opportunities - SE



LEGEND

Shoreline Opportunities

●

▨

City Limits

Author: SPU Shin Date: 3/10/2020 File Path: X:\Separated Systems\Business_Areas\DSA\GIS\Library\MXD\Task 6\Task6-6B_ShorelineOpportunities.mxd

Table J-1: Shoreline Restoration Opportunities

DSA Project #	Project Name	GIS Type	Plan	Links	Source Plan #
22	West Point Pocket Estuary	Point	WRIA 8	Puget Sound Nearshore	PS-21
28	Alki Point	Point	WRIA 9 Anchor Report	Download Section 5	Nearshore
27	Lowman Beach Bulkhead Removal	Point	WRIA 9	Four-Year Work Plan Project List - 2018	Lowman
18	Henderson 49 CSO Reduction and Shoreline Restoration	Point	WRIA 8	Lake Washington	LW-S1-6
17	Atlantic City Boat Ramp Shoreline Restoration	Point	WRIA 8	Lake Washington	LW-S2-2
1	Pritchard Island Beach Restoration	Point	WRIA 8	Lake Washington	LW-S2-3
2	Pritchard Island Wetland Restoration	Point	WRIA 8	Lake Washington	LW-S2-4
3	Lake Washington Boulevard South Restoration	Point	WRIA 8	Lake Washington	LW-S3-1
4	Lake Washington Boulevard Restoration	Point	WRIA 8	Lake Washington	LW-S4-1
19	N Madison Park Shoreline Restoration	Point	WRIA 8	Lake Washington	LW-S4-2
5	Magnuson Park Shoreline North	Point	WRIA 8	Lake Washington	LW-S6-1
20	Magnuson Park Shoreline North	Point	WRIA 8	Lake Washington	LW-S6-1
21	NOAA Shoreline Restoration at Sand Point	Point	WRIA 8	Lake Washington	LW-S6-2
6	Magnuson Park Shoreline South	Point	WRIA 8	Lake Washington	LW-S6-3
7	Matthews Beach Creek Restoration	Point	WRIA 8	Lake Washington	LW-S6-4
25	Rehabilitate Schmitz Creek	Point	WRIA 9 Anchor Report	Download Section 5	
14	Piper’s Creek Culvert Replacement	Point	WRIA 8	Puget Sound Nearshore	PS-17
15	36th Ave. NW Street End on Salmon Bay	Point	WRIA 8	Puget Sound Nearshore	PS-19
16	Commodore Park and Wolfe Creek Restoration	Point	WRIA 8	Puget Sound Nearshore	PS-20
23	Scheuerman Creek Riparian and Marine Shoreline Restoration	Point	WRIA 8	Puget Sound Nearshore	PS-22
24	Shilshole Bay Shoreline Restoration Assessment	Point	WRIA 8	Puget Sound Nearshore	PS-25
8	Ballard Bridge Shoreline Restoration	Point	WRIA 8	Lake Union/Ship Canal	SC-1
13	Evaluate Deepening the Montlake Cut	Point	WRIA 8	Lake Union/Ship Canal	SC-10

Table J-1: Shoreline Restoration Opportunities

DSA Project #	Project Name	GIS Type	Plan	Links	Source Plan #
9	Ballard Bridge Water Quality Improvements	Point	WRIA 8	Lake Union/Ship Canal	SC-6
10	Fremont Bridge Demonstration Project	Point	WRIA 8	Lake Union/Ship Canal	SC-7
11	Aurora Avenue Bridge Shoreline Restoration	Point	WRIA 8	Lake Union/Ship Canal	SC-8
12	Bank Softening and Revegetation at Gasworks Park	Point	WRIA 8	Lake Union/Ship Canal	SC-9
26	Smith Cove Shallow Water Rehabilitation	Point	WRIA 9	Four-Year Work Plan Project List - 2018	Smith
1	Pier 90	Polyline	WRIA 9	Marine Nearshore Subwatershed Actions and Policies	NS-1
2	Myrtle Edwards Park Small Pocket Beaches/Shallow Water Habitat	Polyline	WRIA 9	Marine Nearshore Subwatershed Actions and Policies	NS-2
3	Revegetation Duwamish Head to Me Kwa Mooks Seawall	Polyline	WRIA 9 Anchor Report	Download Section 5	Reveg
4	Nearshore restoration from Alki Point to Me Kwa Mooks Park	Polyline	WRIA 9 Anchor Report	Download Section 5	Nearshore
1	S Fidalgo Street – right bank	Polygon	Duwamish Blueprint	Project List	Duw-2.1
3	Project 9: North First Avenue South Bridge	Polygon	Duwamish Blueprint	Project List	Duw-2.5
4	Project 10: North 1st Ave South Bridge	Polygon	Duwamish Blueprint	Project List	Duw-2.7
5	Project 15: S Fontanelle St/5th Ave S	Polygon	Duwamish Blueprint	Project List	Duw-3.1
6	Project 16: South Othello St to 8th Ave S	Polygon	Duwamish Blueprint	Project List	Duw-3.2
7	Project 17: SW corner, 8th Ave S	Polygon	Duwamish Blueprint	Project List	Duw-3.3
8	S Riverside Dr	Polygon	Duwamish Blueprint	Project List	Duw-3.35
9	Project 19: S Chicago St to S Kenyon St/10th Ave S	Polygon	Duwamish Blueprint	Project List	Duw-3.5
10	12th and Elmgrove	Polygon	Duwamish Blueprint	Project List	Duw-3.7
11	South Park Bank Restoration and Shallow Water Habitat Creation	Polygon	Duwamish Blueprint	Project List	Duw-3.9

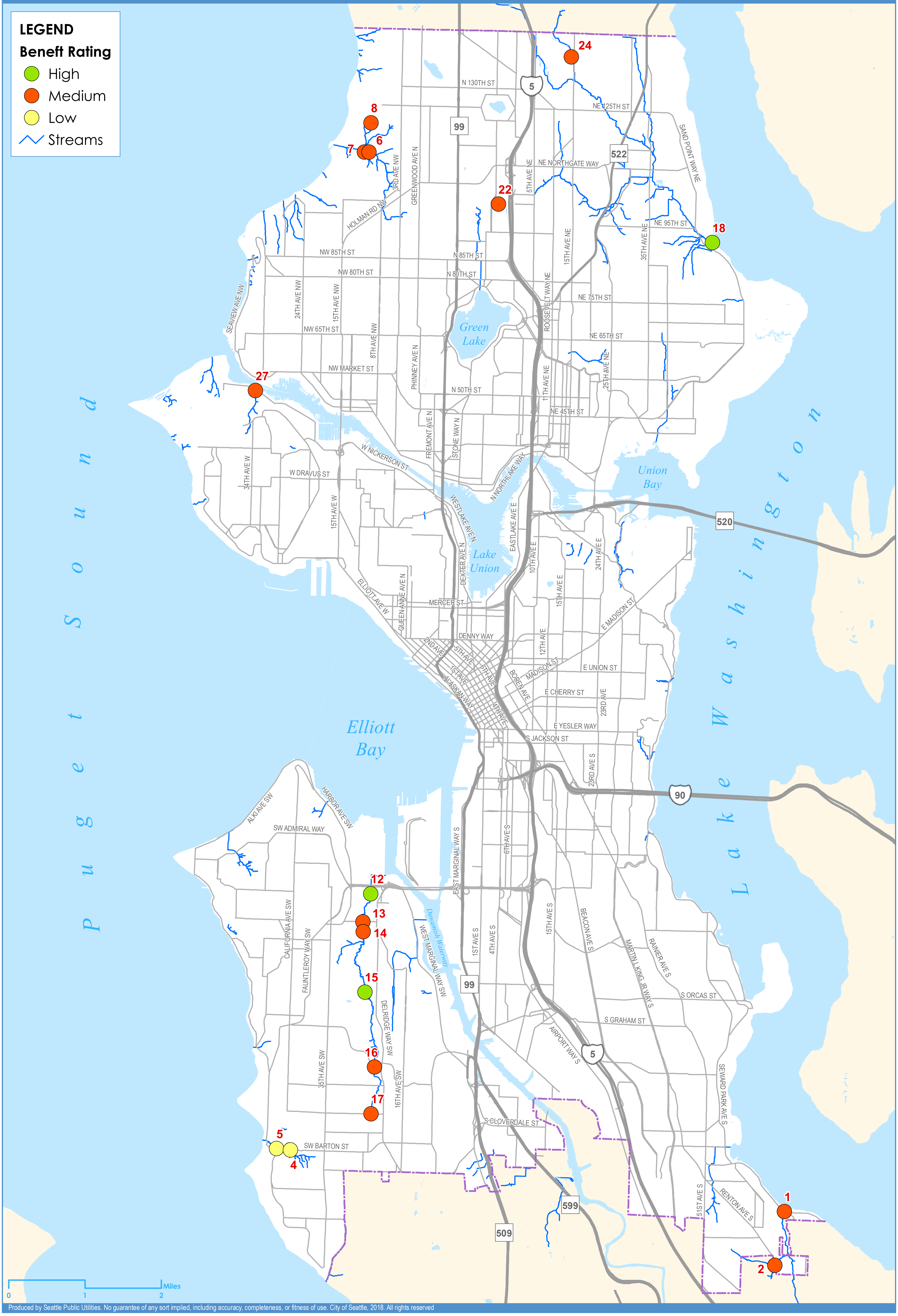
Appendix K: Creek Daylighting Opportunities Maps and Tables

List of Maps and Tables

Seattle Public Utilities

Drainage System Analysis Task 6-6C Aquatic Habitat

Creek Daylighting Opportunities



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Date: 3/9/2020

Author: SPU Shin

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Table K-1: Ranked List of Creek Daylighting Opportunities

1 Salmon downstream (20 pts)	2 Salmon upstream (25 pts)	3 Retain runoff (10 pts)	4 Water Quality (2 pts-neg 10 pts)	5 Floodplain connection (25 pts)	6 Barriers (15 pts)	7 Riparian condition (10 pts)	8 Adds light (5 pts)	9 Other? Size? (10 pts)	Total	Benefit Rating Low (0-39); M (40-79); H (80-120)	Proposed Activities
20	25	0	0	25	10	10	0	5	**95**	H	Remove bank armoring, replace lined channel with reconstructed stream channel and reconnect floodplain.
10	20	10	0	15	10	10	3	10	**88**	H	Re-align existing creek channel into bypass location and daylight the creek. Floodplain reconnection, stream channel improvements and improved fish passage.
20	25	5	-10	16	12	2	5	10	**85**	H	Daylight downstream section of mainline pipe and create an open channel through Port property to the Duwamish; restore shoreline at creek mouth.
19	22	0	0	3	15	10	2	5	**76**	M	Remove creek culvert and fish passage barrier; may need slope stabilization/lined channel
9	9	8	2	15	7	6	5	7	**68**	M	Remove culverts, separate creek from storm drain; re-create creek channel, reconnect floodplain.
7	13	10	2	15	2	3	5	10	**67**	M	Detain and treat water potentially using GSI.
16	25	0	0	4	13	2	2	5	**67**	M	Replace existing culvert with bridge, or shorter fish passable culvert; stream channel and floodplain reconnection opportunities.
3	13	10	2	15	1	8	5	10	**67**	M	Retain and treat water entering creek tributaries potentially using GSI.
15	25	0	0	2	13	2	2	5	**64**	M	Replace culvert with bridge or very wide culvert; floodplain reconnection and stream channel improvements.
5	5	6	2	15	5	10	4	10	**62**	M	Daylight and realign creek channel onto public property; stream channel improvements and floodplain reconnection.
10	15	0	2	5	13	10	1	5	**61**	M	Separate creek flow from combined sewer line; install culvert beneath W Commodore Way; create open channel to the Ship Canal and restore creek mouth.
1	10	10	2	15	1	10	5	6	**60**	M	Retain and treat water potentially using GSI; possible daylighting in/adjacent to wetlands.
0	11	10	2	15	0	5	5	10	**58**	M	Remove abandoned creek culvert and fill; reconnect floodplain; possible supplement with GSI in upper basin.
0	10	10	2	15	3	3	5	10	**58**	M	Retain and treat water entering creek tributaries potentially using GSI.
0	10	10	2	15	2	3	5	10	**57**	M	Daylight piped stormwater and replace with GSI to retain and treat water.
18	22	0	-5	2	15	0	1	1	**54**	M	Remove buildings in delta; replace and shorten roadway creek culvert; reconnect floodplain; reconfigure creek channel.
8	8	0	-5	2	12	0	2	5	**32**	L	Replace stream culverts; channel grading and widening; floodplain restoration.

Scores were on based on how well a daylighting project would help address limiting factors (to fish and stream health), including the following: hydrology, water quality, horizontal connectivity (floodplain connection), longitudinal connectivity (barriers to fish, sediment, and water movement), sediment (coarse for habitat & fine for impacts to habitat), instream structure (hydraulic and aquatic habitat diversity) and riparian condition.

Table K-2: Creek Daylighting Opportunities and Ecological Benefits

Proposed Work	Description and Ecological Benefits *Limiting factors addressed as per Grebe 2006.*	Daylighting Creek from pipe	Create or reconnect floodplain	Fish Passage	Stream Restoration	Other Water Quality	Reach Length (minimum, in feet)	Reach Length (maximum, in feet)	Property Owner	Headwater potential (retain and treat stormwater)
Remove buildings in delta; replace and shorten roadway creek culvert; reconnect floodplain; reconfigure creek channel	**Taylor Creek Fish Passage** - This project has the potential of opening up most of the system to salmon by replacing the creek culvert, removing homes in the floodplain, reconfiguring the creek channel and possibly addressing fish passage barriers upstream of Rainier Avenue. It is currently in design phase. Benefit to coho salmon by restoring access to up to 85% of potential salmon-bearing habitat in creek. The project would also address significant flooding problems.									
Remove abandoned creek culvert and fill; reconnect floodplain; possible supplement with GSI in upper basin	**Taylor Creek East Fork Stormwater Retention/Treatment** - This project would remove a defunct creek culvert in Lakeridge near the confluence with mainstem (and potentially, pipes upstream of 116th Ave S in unincorporated King County). The creek culvert was originally put in to direct flows around a small sewage treatment plant. The treatment plant is gone so there is no longer a need for the culvert. The culvert slowly filled in, and sometime in the early 2000s, the creek starting cutting a new channel around the culvert. Benefits include: restoring floodplain connectivity and some of the ecological functions of former headwater wetlands. Additional water quality benefits could be achieved if GSI were feasible along 116th Ave S.	x	x	no	no	x	200	1200	Parks & King County	x
Retain and treat water entering creek tributaries potentially using GSI	**Fauntleroy Creek Stormwater Retention/Treatment** - This site is in the headwaters of Fauntleroy Creek where there is an opportunity to retain and treat stormwater before it enters the small tributaries to Fauntleroy Creek. The project was expected to score higher because of its potential to begin addressing altered hydrology and water quality in Fauntleroy Creek. Benefits include potentially restoring some of the ecological functions of former headwater wetlands (retain and treat stormwater runoff) in a subcatchment with one of highest runoff potentials in the basin.	no	x	no	no	x	200	1000	Parks & SDOT	x
Replace stream culverts; channel grading and widening; floodplain restoration	**Fauntleroy Fish Passage** - The culverts are 200-400 ft. in length. Options Analysis is currently underway to replace these culverts with much larger (14' wide) and somewhat shorter culverts which are designed for required fish passage standards. **This project is in the options analysis phase (C316078).**	x	x	x	x		600		Parks & SDOT	no
Remove creek culvert and fish passage barrier; may need slope stabilization/lined channel	**Piper's Creek Pumping Station Fish Passage** - Located on King County pump station property, this project could restore access to as much as 62% of the potential salmon-bearing habitat in mainstem Piper's (assuming the Twin Pipes outfall marks the upper limit of useable salmon habitat). Benefits include: improving coho and chum salmon access. This is the most downstream barrier, and it blocks all of upper Piper's Creek, which has both spawning and rearing habitat. Salmon currently access about 2100 feet of the mainstem, and there is some indication that spawning habitat is limited (spawning survey results suggest that in high return years, there is insufficient space for the number of redds, and superimposition occurs). Daylighting would provide little, if any, floodplain connection because the pipes (culvert and bypass) are helping to stabilize a steep, sandy slope on the left bank. Daylighting would most likely require a replacement structure to stabilize the toe of the slope. Could gain WQ treatment with addition of constructed hyporheic zone.	?	no	x	x	x	600		King County	no
Detain and treat water potentially using GSI.	**Piper's Creek Stormwater Retention/Treatment** - The subcatchment to Twin Pipes has the highest runoff potential in the Piper's Creek basin (Greve 2006, former headwater area), and therefore it has a very high potential for water treatment benefits, if bioswales/GSI were added along the road ROW to detain and treat stormwater runoff that that feeds Twin Pipes. Currently there is no room to reconnect floodplain. Benefits include: potentially restoring some ecological functions of former headwater wetlands to improve retention/treatment of stormwater runoff. These improvements could benefit coho and chum salmon spawning and rearing downstream of the outfall. Direct benefits to salmon, benthic invertebrates, and instream flows may be easier to measure than in some of the other systems because there is only one high runoff potential outfall upstream of the Twin Pipes outfall, and this subcatchment already contains a natural drainage system (Viewlands Cascade).	no	x	no	no	x				x

Table K-2: Creek Daylighting Opportunities and Ecological Benefits

Proposed Work	**Description and Ecological Benefits** *Limiting factors addressed as per Grebe 2006.*	**Daylighting Creek from pipe**	**Create or reconnect floodplain**	**Fish Passage**	**Stream Restoration**	**Other Water Quality**	**Reach Length (minimum, in feet)**	**Reach Length (maximum, in feet)**	**Property Owner**	**Headwater potential (retain and treat stormwater)**
Daylight piped stormwater and replace with GSI to retain and treat water.	**Mohlendorph Creek Stormwater Retention/Treatment** - Benefits include: potentially restoring some of the ecological functions of former headwater wetlands to improve retention/treatment of stormwater runoff from a subcatchment with one of highest runoff potentials in the basin. This would involve daylighting drainage mainline in former headwater area, upstream of existing creek channel. Mohlendorph base flows have been decreasing over the last couple of decades, which has impacted spawning in the lower channel (insufficient flow). This could benefit coho and chum salmon that spawn and rear in the lower Venema Creek tributary system. However, GSI (infiltration) is not feasible west of 3rd Ave.	x	x	no	no?	x			SPU & SDOT	x
Daylight downstream section of mainline pipe and create an open channel through Port property to the Duwamish; restore shoreline at creek mouth.	**Longfellow Creek Mouth Daylighting, and Transition Habitat Restoration** - This project could contribute 1900-4700 feet of transition habitat for coho and chum salmon entering & leaving Longfellow Creek, depending on the location of the daylighted channel. The area was formerly mostly mudflats, which is desirable habitat for juvenile Chinook salmon out-migrating from the Duwamish/Green River watershed (WRIA 9). The challenge will be to find a suitable corridor for the daylighted channel through Port property (one area scouted out was under the West Seattle Freeway). In addition, there would be water quality concerns associated with protecting an open channel, which runs through commercial and industrial property. Note: the 3250' culvert at the mouth does not appear to be a barrier. The pipe is up to 90" in diameter and is set at a zero degree gradient (flat).	x	x	x	x		1900	4700	Port, Private & SDOT	no
Replace culvert with bridge or very wide culvert; floodplain reconnection and stream channel improvements.	**Genesee Street Fish Passage** - The culvert is a partial fish passage barrier, but the energy dissipater at the outlet of the culvert is usually blocked with sediment (high maintenance infrastructure). Benefit includes improved access for coho and chum salmon to as much as ~ 75% of the potential salmon-bearing habitat in creek. Limitations on ecological benefits include: (1) there are barriers immediately upstream (12th fairway culvert and the WPA dam), and (2) improving access will not address coho pre-spawn mortality (a water quality issue), which may be a bigger issue, at least for coho (chum do not appear to be affected). If culvert were ever to be replaced with a bridge (i.e., daylighted) or wide culvert, the channel could support a constructed hyporheic zone, which has demonstrated water treatment benefits.	x	no	x	x	x	250'		Parks & SDOT	no
Replace existing culvert with bridge, or shorter fish passable culvert; stream channel and floodplain reconnection opportunities.	**Longfellow Creek 12th Fairway Fish Passage** - This project has the potential to open up Longfellow Creek to salmon. Benefit includes improved access for coho and chum salmon to as much as ~75% of the potential salmon-bearing habitat in creek. This is the most downstream barrier in Longfellow besides the extensive mainline at the mouth. Most of the highest quality spawning and rearing habitat for salmonids in Longfellow Creek is located in the West Seattle Golf Course, immediately upstream of this barrier. Limitations on ecological benefits include: (1) the WPA dam immediately upstream of the 12th fairway would need to be made fish passable to fully realize the project's access potential, and (2) improving access will not address coho pre-spawn mortality, which may be a bigger issue, at least for coho (chum do not appear to be affected). Floodplain reconnection may be challenging because the culvert is located within a fairway (and would likely need to be replaced by a bridge suitable for golf carts). There is potential to add a constructed hyporheic zone along the length of the channel which would provide water treatment potential in a stream where water quality is a limiting factor (Longfellow and Thornton have the highest coho pre-spawn mortality rates in Seattle, approaching 90%). This site is being evaluated as part of the Longfellow Creek Flood Storage (C600490).	x	x	x	x	x	250	350	Parks	no
Re-align existing creek channel into bypass location and daylight the creek. Floodplain reconnection, stream channel improvements and improved fish passage.	**Longfellow Creek Juneau Street Fish Passage and Floodplain Connection** - Remove sections of the high flow bypass pipe and realign the channel onto adjacent public property (Parks, SPU, and SCL). Note: ~800 ft of the bypass is already located on the Parks property. This project could significantly improve floodplain connection, and habitat quality along almost 1000 ft of channel, and to open an additional 42% of potential coho habitat upstream of the barrier. This is one of the top rated floodplain reconnection sites in salmon-bearing watersheds in Seattle because of the potential amount of existing floodplain available, and could eliminate a fish passage barrier on Longfellow (the bypass and Juneau culvert are fish passage barriers). Benefits include hydrologic, water quality, and riparian benefits by providing a channel with greater capacity than the exiting pipes, and space to re-establish riparian wetlands and vegetation. The site has potential to retain and treat some of the runoff from High Point. This site is being evaluated as part of the Longfellow Creek Flood Storage (C600490).	x	x	x	x	x	1000	1200	Parks	no
Daylight and realign creek channel onto public property; stream channel improvements and floodplain reconnection.	**Myrtle Street Floodplain Connection** - Daylight creek and re-aligning an estimated 300 ft. of channel onto public property (Parks); reconnection the floodplain and restore riparian habitat. There would be hydrologic, & water quality benefits (reduced flooding & bank erosion, improved water treatment). This site is being evaluated as part of the Longfellow Creek Flood Storage (C600490).	x	x	x	x	x	300	1200	Parks & Private	no

Table K-2: Creek Daylighting Opportunities and Ecological Benefits

Proposed Work	Description and Ecological Benefits *Limiting factors addressed as per Grebe 2006.*	Daylighting Creek from pipe	Create or reconnect floodplain	Fish Passage	Stream Restoration	Other Water Quality	Reach Length (minimum, in feet)	Reach Length (maximum, in feet)	Property Owner	Headwater potential (retain and treat stormwater)
Retain and treat water entering creek tributaries potentially using GSI.	**Upper Longfellow Creek Stormwater Retention & Treatment** - The subcatchments feeding this drainage pipe have some of the highest runoff potential in the Longfellow Creek basin (Greve 2006, pipe is located in former headwater area). There is a very high potential for water treatment benefits. However, there is very limited room for floodplain reconnection. If bioswales/GSI were added along the road ROW to detain and treat stormwater runoff wherever possible. The lower 300' of Parks property, upstream of that would mostly be in SDOT ROW. Benefits include: potentially restoring some of the ecological functions of former headwater wetlands to improve retention/treatment of stormwater runoff from the upper watershed. These improvements could benefit coho and chum salmon spawning and rearing downstream. Direct benefits to benthic invertebrates, instream flows, and channel condition may be easier to measure than in some of the other systems because this is the most upstream outfall in the open channel. There are several stormwater discharge outfalls from highly developed areas upstream. This upstream area is slated for redevelopment as part of an Urban Village.	?	x	x	x	x	300	1000	Parks & SDOT	x
Remove bank armoring, replace lined channel with reconstructed stream channel and reconnect floodplain.	**Thornton Delta & Floodplain Connection** - This is more of a channel widening project (remove bank armoring and reconnect floodplain), rather than strictly a daylighting opportunity because it is a lined channel, not a pipe. This site is similar to Thornton Confluence pre-project. It is among the top floodplain reconnection sites in salmon-bearing watersheds in Seattle. The benefits to humans would be reduced flooding and bank erosion. The benefits to salmon and other fish would be reduced instream flow velocities (through better floodplain connection), improved habitat diversity (through the addition of more shoreline and delta habitat and room to add instream structure), as well as water treatment (hyporheic and/or riparian wetlands). Benefits to Chinook would be uncertain because it is not known whether juveniles use the delta areas in the north end of Lake Washington (deltas are known to be refuge areas in the south end). The project would be adversely impacted by the limited sediment supply downstream of Meadowbrook Pond, potentially downgrading the project to a medium rating. Channel length would be 300' in current alignment, >1000' if channel realigned onto adjacent Parks property.	no	x	no	x	x	300	1100	Parks	no
Retain and treat water potentially using GSI; possible daylighting in/adjacent to wetlands.	**Meridian Avenue Stormwater Retention /Treatment** - This project would be in addition to existing improvements: restored wetlands and detention pond. The site is located high in Thornton S Branch system (former headwater) and therefore has higher potential for source control benefits (water quality and surface runoff retention) by detaining and treating runoff from subcatchment with one of highest runoff potentials in the watershed. This is the Drainage Main line that runs from the Seattle Police N Precinct wetland, under College Way NE to the NSCC wetlands. There are wetlands adjacent to the pipe on NSCC property. There is little to no room for floodplain reconnection, but the area would provide water quality and stormwater runoff retention benefits by adding bioswales/GSI along the College Way NE (a boulevard), and daylighting pipes within NSCC wetlands.	no?	x	no	no	x	400	1200	NSCC & SDOT	x
Remove culverts, separate creek from storm drain; re-create creek channel, reconnect floodplain.	**Thornton North Branch Floodplain Connection and Habitat Improvements** - The site is located in the former headwater wetland of Little's Creek and therefore has higher potential for source control benefits (water quality and surface runoff retention). Benefits include: improved floodplain connection, peak flow velocity, bank protection, habitat quality, water quality, and fish access in lower Littles Creek and Thornton Creek N Branch. The challenge will be to find sufficient room to realign and daylight the channel onto Parks property, adjacent to the golf course. Direct benefits to salmon would not be apparent to Chinook and coho salmon in the North Branch, until barriers downstream of Little's Creek, are removed.	x	x	x	x	x	1000		Parks & SDOT	x
Separate creek flow from combined sewer line; install culvert beneath W Commodore Way; create open channel to the Ship Canal and restore creek mouth.	**Kiwanis/Wolfe Creek Mouth Daylighting** - This project could recreate shallow estuarine habitat for juvenile Chinook salmon use as refuge habitat along the marine nearshore in of the Ship Canal. It would also provide some water quality benefit by separating creek from the sewer system. Daylighting would involve separating the creek from the sewer pipe, culverting it under W Commodore Way, and creating a channel through Commodore Park, along with a creek mouth and delta in the Ship Canal. This project would mostly likely have strong WRIA 8 support (and SRFB/PSAR funding potential because of potential benefits for ESA-listed juvenile Chinook salmon). Could also have community support based on past advocacy efforts. If needed, potential value as mitigation project for Ship Canal Tunnel.	x	x	x	x	yes	200		Parks & SDOT	no

Appendix L: Limiting Factors Analysis and Critical Needs Assessment

FAUNTLEROY CREEK - CRITICAL NEEDS LIST
1st step in prioritizing system critical needs - prioritize reach needs

Critical Needs Assessed:
- Flow Volume & Velocity (indirectly)
- Water Quality (indirectly)
- Connectivity-Floodplain
- Connectivity-Barriers
- Sediment-Gravel & Fines
- Channel Complexity
- Riparian Vegetation
- Fish Habitat & Use

Priority:

High	🟨
Med	🟩
Low	🟦

General Comments: Fauntleroy Creek is in fair to good condition. Most of the channel is free of artificial confinement, has some floodplain connection, moderate instream structure/complexity and good quality riparian habitat (especially in the park). The exceptions are reach FA02, which is encroached and confined, and much of reach FA03, which has extensive filing. The primary changes to Fauntleroy are extensive valley filling in the lower reaches and altered hydrology. Much of FA03 has been filled for roads and culverts. Outfalls feed stormwater directly into the upper mainstem and tributaries in the upper watershed, which were probably forested swales with limited flow prior to development. In addition, Fauntleroy Creek has a high volume of fines (sand). Sand dominates the channel substrate because it is the main source of sediment, originating from the erosion of the advance outwash deposit that dominates the upper valley walls. Most of the sediment supply to Fauntleroy Creek is from mass wasting (sliding) of steep valley walls of the upper basin. Other concerns of note are fish passage barriers at the 45th Avenue SW and California Avenue SW culverts in FA03, and potential water quality problems. Coho pre-spawn mortality is occurring at a lower rate in Fauntleroy Creek (25% for females), and benthic invertebrate communities are of higher quality than either of these conditions is in other Seattle salmon-bearing creeks.

Critical needs:
- Protection of steep valley walls in upper watershed to reduce erosion and failure rates
- Access @ 45th Avenue SW and California Avenue SW culverts (probably not feasible – too costly to fix), monitor beach channel access
- Channel widening downstream of Fauntleroy Way SW
- More instream structure/complexity
- Water quality is probably of concern

Critical Needs in Fauntleroy Creek Watershed

Reach	Problems	Information
FA01: Fauntleroy Beach (30-140 feet, depending upon path that channel cuts through beach, 2001 path was 140' under ferry dock) Mouth @ Puget Sound to beach perimeter @ private property Overall Condition: Fair 1-2% average gradient (max 5.5% for straight path across beach)	• Access at low tide	• Fish passage impeded at lower tidal elevations by build up of logs U/S from wharf pilings, driftwood, sand, shallow/subsurface flow • Channel is naturally unconfined (5'), braided to plane bed • Sediment (sand) from U/S sources and longshore current
FA02: Lower Fauntleroy Uplifted Beach (189 ft) Beach perimeter @ private property to outlet of Fauntleroy Way culvert Overall Condition: Poor 2.2%	• Loss of channel capacity - channel is encroached, confined, incised, straightened, armored • Limited instream structure/complexity • Water quality likely a concern for coho • High fines	• Severely encroached by armoring (52%), bldgs and yards • Loss of channel capacity - confined (W/H ratio 2.3), active width 4.5' • Channel is in degraded erosion stage, but "not entrenched" (banks 2'), armored, straightened, 35% glide, plane-bed • 25-50% coho PSM • Limited instream structure-rock weirs acting as grade controls but needs more structure • Poor riparian condition -continuous yards, some invasives • 6 pools (12% of reach length) median residual pool depth 0.7' (0.5-1.1') • 26% spawning (53% riffle), higher quality (used by coho) • Does have gravel substrate, but high fines

FA03: Middle Fauntleroy Recessional Outwash (2124 ft) Outlet Fauntleroy Way culvert to inlet of California Street culvert (inc. Fish Ladder) Overall Condition: Good 4.1%	• Access • Water quality likely a concern for coho • High fines • Would benefit from more instream structure/complexity • Riparian vegetation – high invasives, needs more mature native veg	• Fish passage barriers a@ 45th (FAMA-BA02) and CA (FAMA-BA03) • B-IBI = 31, 26-36, n= 2. Sampled 8 yrs, avg=25, 20-36, but most samples did not meet threshold no. of 400 bugs (Sta. FA02 @ Pickens' property) • Encroached by culverts, roads & fill (39% of reach length is culverted inc. Fauntleroy Way, 45th, & California culverts), remaining 60% slightly to moderately encroached, confined (active channel width 4-7') but "not entrenched",. Channel type is pool-riffle • Armoring (5%) @ Fish Ladder • Good instream structure-lots of wood & weirs, but could use more • 20 pools (6%) mostly associated w/ Fish Ladder + side pools (U/S), median residual pool depth 0.8' (0.5-1.6') • 36% spawning (55% riffle), mostly higher quality – mostly gravel substrate w/ fines • Poor quality riparian vegetation – high invasives, needs more mature native veg
FA04: Lower Fauntleroy Park Lawton Clay (652 ft) Inlet of California Street to confluence w/ second tributary Overall Condition: Good, best available in Fauntleroy 2.8%	• High fines • Riparian vegetation – high invasives, needs more mature native veg • Would benefit from more instream structure/complexity	• B-IBI = 31, 26-36, n= 2. Sampled 8 yrs, avg=25, 20-36, but most samples did not meet threshold no. of 400 bugs (Sta. FA01 @ U/S of YMCA) • Potential partial barriers FAMA-BA04&05 (log jams) may provide U/S access • Erosion stages are split 50:50 widening and incising. Long-term knickpoint @ 2nd trib. controlled by dense glacial lake bottom sed • Channel is in fairly good condition pool-riffle – mostly unconfined (active channel width 4', W/H ratio 4.8) and not entrenched/some local incision (banks<1'). Valley widens in lower section • Moderate erosion activity – banks are a source of fines • Good instream structure-lots of wood, log jams, islands (2), but could use more • 1 – two ft-long pool • 59% spawning (100% riffle), mostly fair (high fines?) • Poor quality riparian vegetation – high invasives, needs more mature native veg
FA05: Upper Fauntleroy Park Advanced Outwash (739 ft) Confluence w/ second tributary to 5th Tributary @ 39th Ave SW (gradient increase @ upper valley walls) Overall Condition: 9.4%	• Steep valley walls prone to sliding (mass wasting) – protect from storm runoff, yard waste dumping, trail erosion • High fines • Altered hydrology – outfalls feed directly into upper mainstem and tribs • Limited instream structure for grade controls	• Landslide (5+ years old) on right bank. Erosive outwash deposits dominate steep valley walls (U/S of 2nd trib). Contact zone between sand and underlying clay prone to mass wasting when saturated w/ groundwater • Sand is dominant substrate in channel because of erosion of advance outwash deposit that dominates valley walls • Altered hydrology – outfalls feed directly into upper mainstem & tribs of upper watershed. Mainstem & tribs were probably forested swales with limited flow prior to development • Few gravel sources – glacial till cap in upper watershed (now main source of gravel) delivers minimal gravel to creek • Potential partial barrier FAMA-BA06 (log jams) may provide U/S access • Some instream structure wood & log jams – needs more for grade controls • Channel is in fairly good condition step-pool – moderately confined to unconfined and widening (active channel width 3', W/H ratio 3.6) and not entrenched (banks<1') • Active and potential floodplain connection throughout reach • No pools except for step-pools • Wetland created by contact between lake bed & advance outwash (@ 2nd trib) • 40% spawning (100% riffle), mostly fair (fines)

LONGFELLOW CREEK - CRITICAL NEEDS LIST
1st step in prioritizing system critical needs - prioritize reach needs

Critical Needs Assessed:
- Flow Volume & Velocity (indirectly)
- Water Quality (indirectly)
- Connectivity-Floodplain
- Connectivity-Barriers
- Sediment-Gravel & Fines
- Channel Complexity
- Riparian Vegetation
- Fish Habitat & Use

Priority:

High	🟨
Med	🟩
Low	🟦

Overview of watershed condition: Topographically, Longfellow Creek Watershed is an area of 4.4 square miles (2810 acres), but the actual drainage area, as defined by the existing infrastructure, is about 60% of that area (2.6 square miles, 1677 acres). The narrow, straight, elongated shape of the basin requires much of the system's energy from flow to be dissipated within the channel. The dominant land use is residential (31%), but Longfellow Creek has a high proportion (44%) of land use dedicated to industrial, commercial and transportation (roads, parking and right-of-way). About one fifth of the watershed is park/open space, and much of it occurs along the channel (42% of the area within 100 feet of the creek). The primary changes to Longfellow Creek are the increased frequency, magnitude and duration of flood runoff, and encroachment into the channel migration zone. The valley floor and channel migration zone were about 75-150 feet wide upstream of SW Dakota, and 200-400 feet wide downstream pre-development, except in L06 and L07 which are characterized by a steeper, more confined inner valley. Channel encroachment/confinement has reduced conveyance capacity of the channel, as well as its ability to recruit materials (sediment, wood) that create and maintain good aquatic habitat (Stoker, Draft 2002). The channel had become confined to the point where flood flow conveyance is reduced, the channel is incised and has higher flow velocities to the point of scouring the bed onto a smoother profile (plane-bed) with more glide habitat. The areas in the creek which are wide enough to pass flood flows with lower velocities (parts of L04), sediment has formed into bars and shape the bed into riffle:pool pattern important to habitat.

Critical needs, limiting factors and areas of concern:

- Altered hydrology – is one of primary changes in Longfellow Creek and includes increased frequency, magnitude and duration of stormwater runoff (Stoker, Draft April 2002). Longfellow Watershed has outfalls with large sub-catchment areas (>150 acres) located in upper and mid-channel reaches (@ Barton, Myrtle, Juneau). The monitoring and evaluation of Highpoint Redevelopment Project will help to determine the potential of natural drainage systems to reduce stormwater runoff from residential areas to the creek (the project targets the Juneau outfall subcatchment area). SPU is beginning to research the question of how much area would need to be converted to natural drainage before we can begin detecting a noticeable reduction in stormwater runoff to the creek (beginning with SEA Streets in Piper's WS).
- Water quality/toxicity - is likely a concern, especially for coho. The evidence is indirect: high coho pre-spawn mortality rates (54-88%) and low B-IBI scores (12-18). SPU has been supporting research led by NOAA Fisheries to determine the causes of coho pre-spawn mortality, and Longfellow Creek is one of the study areas (2000 to present). No underlying biological factor was found (2000-2001), and some environmental factors are being investigated in 2003 (heavy metals, PAH's).
- The reduction in horizontal connectivity to the floodplain, which has resulted from encroachment into the channel migration zone, is another primary change that has occurred in Longfellow Watershed (Stoker, Draft April 2002). Over one-third of the channel has been piped including the lower 3258 feet, and the upper mile of former plateau wetlands (30% of open channel is piped). Buildings, roads, yards and armoring (12% of open channel) confine much of the remaining open channel. The channel migration zone was about 75-150 feet wide upstream of Dakota, and 200-400 wide downstream before development. The delta at the mouth has been lost, and the channel has been artificially confined to an average active width of <12 feet. By contrast, unconfined sections in the golf course canyon reach are as wide as 30 feet within the channel, and 100 feet within in-channel wetlands. The there is physical evidence of reduced channel capacity and high flow velocities (bank erosion/armoring, incision (average 3.5-foot bank height), constructed sections of channel, a bypass, sections of thin substrate layer and long sections of feature-less channel (no instream structure, plane-bed channel type, e.g.,17% of length of open channel is glide habitat).
- Longitudinal connectivity – The downstream-most fish passage barrier is located in the Golf Course at the 12th fairway culvert, and it limits anadromous fish access to the lower 2400 feet of open channel. Superimposition of salmon redds suggests that there may not be sufficient spawning habitat (<800 linear feet) available for the existing numbers of fish (up to an estimated 500 coho and 90 chum), despite 60-88% pre-spawn mortality of coho. Barriers in the upstream end of the Golf Course and at Juneau are the remaining barriers that block the majority of the remaining open channel habitat in Longfellow Creek.
- Gravel – Longfellow appears to have limited gravel recruitment and retention. Isolated pockets of gravel-dominated substrate are found primarily in the Golf course and in restored areas. Most of the gravely sand sediment supply is from the erosion of the bed and banks. Landslides and tributary inflows do not appear to add significant amounts of bed load sediment to the channel (Stoker, Draft April 2002). The channel alluvium is very thin to nonexistent in many channel segments. Stoker (Draft April 2002) recommended adding gravel to selected sites, such as, upper L08, and adding weirs and other instream structure to trap and hold sediment.
- Fines – Sediment supply in Longfellow is mostly gravely sands. Loose sand or silt tends to be the dominant bed substrate.
- Channel complexity – Most of the instream structure in Longfellow Creek has been artificially placed in restored sections of the creek (Yancy/L02, Delridge/L05). The limited pool habitat (18% of open channel length) and pockets of gravel are usually associated with these structures, and reaches without much structure have long uniform channel/habitat types, e.g., long sections of riffle in the Golf Course reach (L04). Most of the confined, incised sections of Longfellow Creek (lower L02, L03, L05, L07 and L08) probably would not have sufficient channel capacity to incorporate the addition of anything but low-profile structures in the channel without adverse effects (flooding, bank erosion). Channel widening may be needed required before adding structure in confined sections.

- Riparian vegetation – Restored areas (L02 and L05) have been replanted, but the vegetation is immature and needs continued monitoring/maintenance. The Golf Course offers good canopy cover, but lacks mature conifers. Parts of L02, L03, L05 and L08 have yard encroachment, and lack an adequate canopy to protect the creek from high temperatures. Invasives are found long sections of reaches L05 and L08.

Critical Needs in Longfellow Creek Watershed

Reach	Critical Needs	Rationale
LF01: Andover Culvert - Estuary Fill (3258 feet) Outlet to inlet of Andover St culvert 0% gradient Overall Condition: poor, 100% culverted	• Loss of delta, and loss of estuary habitat • Water quality is likely a concern • Access (temporary blockages @ SW Andover Street culvert inlet rack)	• Severely encroached and artificially confined by culvert and fill. Has resulted in loss of delta. Would have had a sediment fan of sandy deposits and multiple backwater channels in tidal zone (200 to 400' wide channel migration zone) • High coho pre-spawn mortality and low B-IBI score immediately U/S • High use migration route for anadromous fish (up to an estimated 500 coho & 90 chum adults/year)
LF02: Genesee/Yancy - Lower Inner Canyon Alluvium (1391 ft) Inlet of SW Andover Street culvert to outlet of SW Genesee Street culvert 1% median gradient, fill geology Overall Condition: Fair	• Water quality is likely a concern, especially for coho • Refuge/high flow velocities • Spawning habitat does not meet need • Likely to be Rearing habitat limited (?) • Constraints for on-site improvements • Riparian vegetation is replanted and still maturing. Has patches of invasives	• 72% (54-89%) coho pre-spawn mortality, B-IBI = 15.3 (14-18), n=3 @ LF04/LF05 U/S & D/S SW Adams Street) • Little room for instream structure in lower 200 feet, which is severely encroached by fill, into which the channel has incised (banks 6-7'). Active channel width is confined to 6-15', (formerly 200-400') and channel type is plane-bed (21% glide) • Few coho juveniles (observed on spawning surveys) or smolts (trapped average of 0.3-1/day) despite being a high use area (up to an estimated 500 coho adults in a single spawning season). More research needed to determine if the low number of juveniles is a function of poor water quality or lack of sufficient rearing habitat, or both (&/or other factors) • Insufficient spawning habitat (506', 36% of reach length, equals ~ 2000 ft ^{2}, room for about 250 coho redds or 110 chum redds). 2001 was a high fish-use year (up to 500 coho plus 90 chum). Although 60% of coho died before spawning, chum redds were superimposed on coho redds in 2001 • Active width U/S of SW Dakota (15-20') is a better fit for flows. Along w/ weirs has helped pool:riffle bed to form • Overall the reach is artificially confined (W/H ratio 2.2), average active width 15', bk ht 5.5', 17% armored, 2% culverted • 19+ (55%) pools, res pool depth 1.7', (1-8.3') • Instream structure is all artifically placed log weirs, LWD and rootwads • Channel is mostly degraded and widening • Gravel substrate mostly associated with restoration work, except @ SW Adams St bend (U/S Fishbone Bridge) – otherwise high % fines, with potential sources from bks • Most of riparian has been replanted but is immature, invasives U/S Andover
LF03: North Golf Course - Middle Inner Canyon Alluvium (1051 ft) Outlet of SW Genesee Street culvert to base of WPA dam 1% median gradient Overall Condition: Poor	• Water quality is likely a concern, especially for coho • Refuge/high flow velocities • Spawning habitat does not meet need • Lack of in-stream structure (diversity) • Access (temporary blockages @ culvert) • Lacks mature trees for shade	• 72% (54-89%) coho pre-spawn mortality • Few juveniles seen on spawning surveys • Limited spawning habitat (276 ft, 17%, ~1000 ft ^{2}). Chum superimposed redds over coho redds in 2001 • Severely encroached by culverts (47%), 5% armoring • Channel is narrow (average active width 14', w/o culverts, 9.3' w/),mostly incised (bk ht 4') • Artificially and naturally moderately confined (W/H ratio 3.4) • glide (3%) • Very little instream structure. ~ 4 pools (35%) pools, res. pool depth 1.2', (1-8.3') • Limited gravel, w/ little recruitment, but high fines w/ bank sources

		• Grass field w/ invasives U/S of Genesee
LF04: South Golf Course – Upper Inner Canyon Alluvium (4471 ft) Base of WPA dam to outlet of SW Brandon Street culvert 1% median gradient, mostly higher gradient, unconfined channel Overall Condition: Best available in system. Fair to good	• Access • Evidence of high flow velocities – lacks structure • Water quality (likely a concern) • Riparian predominately deciduous	• 3 barriers: 12th fairway culvert (LFMA-BA06) and WPA dam (LFMA-BA07) prevent anadromous access to entire reach, and LFMA-BA09 prevents access U/S of Brandon. Removal of first 2 barriers opens up to 850' of potential rearing habitat in wetland (19% of reach length), and almost quadruples amount of available spawning habitat (1885 ft /42% of reach length of which 40% is higher quality) • Coho & chum are trying to move into the area (trying to enter 12th fairway culvert each year, but it is a velocity barrier) • 66% riffle) • Although naturally confined in canyon, it is mostly an unconfined channel (W/H ratio 9). Average active width 19' (max 30' in canyon and up to 100' in wetland). • Evidence of high flows – channel has incised (average bank height 2.7') and widened, and there are some remnants of armoring • Little structure, does have some wood. 66% riffle, ~24 pools (14%), residual pool depth 1.2', (1-3.8') • Represents some of best habitat in system but still needs improvement (more structure) • Some encroachment from culverts (7%), fairways and trails, armoring (2%) • Riparian forest lacks mature conifers but offers good canopy • Has pockets of gravel and bank sources, but also high fines w/ bank sources throughout
LF05: Delridge- Recessional Outwash Valley (6217 ft) Outlet of SW Brandon Street culvert to outlet of Kmark culvert 1% median gradient, confined channel Overall Condition: Poor to fair	• Evidence of high flow velocities and reduced channel capacity • Access • Water quality is likely a concern • More instream structure @ lower flow levels • Limited gravel • High fines	• Evidence of high flow velocities and reduced channel capacity - channel is incised (bk ht 4') or constructed (U/S of Juneau to D/S or Findlay), 20% armored, 36% glide • About 75% is severely encroached by buildings, bypass, armoring (20%), roads, yards, culverts (9%). Exceptions are green spaces U/S of Brandon, between Raymond and Graham street, and @ Willow. Channel artificially confined (W/H ratio 2.5), average active width 9' • Full barrier (LFMA-BA15) @ Juneau • B-IBI = 14.8 (14-18), n=5 @ LF01, SW Brandon Street • Structure is all artificially placed LWD, root wads, and weirs. Some of the LWD is placed so high on banks that it would only create habitat @ higher flows • 35+ (29%) pools, residual pool depth 1.3', (1-32.2') • 34% spawning habitat (2120') • Little gravel except in restored areas (potential bank source at Willow St trib) • High fines w/ bank sources throughout reach • Mostly yards except for forested green space adjacent to Louisa Boren Jr high (S of Graham)
LF06: Kmart Culvert (1817 ft) Outlet to inlet of Kmark culvert 2% median gradient Overall Condition: culvert	• High flow velocities • Access • Water quality (likely a concern)	• Unknown if passable • Severely encroached and artificially confined (100% culverted) • Culvert is upper limit of fish distribution • Culvert confines channel width to 4' (of~16') • High stormwater input at Sylvan (outfall #42)

LF07: Webster Step-pool (589 ft) Inlet of Kmark culvert to outlet of SW Holden Street culvert 2% median gradient, steep gradient, confined valley bottom Overall Condition:	- Water quality (likely a concern)	- 4 barriers LFMA-BA25-BA28 – series of weirs - Can detain stormwater but not treat it - Severely encroached (44% armoring through Detention Pond) to slightly encroached (park/green space) - Channel is frozen, incised or not incised (in detention pond) - mostly glide 43% - Channel artificially & naturally moderately confined (W/H ratio 4), average active width 13.6’, bk ht 4.5’ - B-IBI = 12, n=2 @ LF03, SW Willow Street) - 24% pool, residual pool depth 1.1’, (1-1.8’) - 10% (61’) spawning habitat (32% riffle) - Instream structure is confined to wweirs located within the detention pond section of the channel, otherwise lacks structure - Gravel substrate U/S of detention pond, sand substrate in detention pond
LF08: Thistle (1995 ft) Outlet of SW Holden St. culvert To outlet of SW Thistle Street culvert 1% median gradient, thin alluvium Overall Condition:	- High flow velocities - Water quality (likely a concern)	- Barrier LFMA-BA30 - High flow stormwater input at Henderson – 61 - Channel artificially confined (W/H ratio 2.4), average active width 8’, bk ht 3.4’ - Channel is incised or constructed - Habitat mostly glide 46%, few pools (13%) - B-IBI = 13 (12-14), n=2 @ LF02 D/S SW Thistle Street) - 5+ (13%) pools, residual pool depth 1.3’, (1-1.8’) - Severely encroached by culverts to not encroached (green space adjacent to Chief Sealth HS) - Instream structure is limited to log weirs and an island in D/S end, otherwise lacks structure - Gravel substrate U/S SW Kenyon, sand substrate D/S
LF04.GC01: Golf course Tributary (838 ft) Outlet of SW Holden St. culvert To outlet of SW Thistle Street culvert Overall Condition:	-	- Channel naturally moderately confined (W/H ratio 4), average active width 4.3’, bk ht 2.0’ - Only 9% spawning habitat despite being mostly riffle (99%), glide 1%, no pools (0%) - 7% culverted (56’), no armoring

Data Analysis Summary: LONGFELLOW CRITICAL NEEDS ASSESSMENT

🟩 **Protect**
🟨 **Improve**
🟧 **Low Priority**

Data Indicators

- Gradient
- Channel Width
- Bank Height
- Armoring
- In-stream Structure
- Erosion Activity
- Erosion Type
- Channel Substrate
- Bank Geology
- Drainage Area
- Habitat Units
- Spawning Gravel Rating
- Pool Complexity
- Barriers
- Prespawning Mortality
- B-IBI Scores

Priority Areas – currently have habitat that supports or is needed to support aquatic life

Critical Needs – existing conditions which threaten or limit potential of priority areas

Data Indicators

- Streamtyping
- Redd locations
- Fish Counts (adults, redds, smolts, juveniles)

		Highest Potential	EXISTING PHYSICAL HABITAT + STORMWATER FLOWS		
			Good (Current Best Available)	Fair	Poor
EXISTING/POTENTIAL FISH USE	High	🟩	🟩 **South Golf Course L4** (4641 ft) • Width unconfined (avg=13 ft, max 30 ft) • Floodplain connection (<2% armor, bk ht≤2 ft) • Pool every 6 channel widths, 40% high quality (forest std. for pool frequency = at least 1 pool for every 5 to 7 channel widths (CW)) • Existing resident use, high potential anad. use • 41% spawning habitat (1885 ft, 40% high qual) • High rearing potential (850 ft of wetland, ~20%) • Almost no glide habitat (1%) • Adequate riparian, but lacks mature conifers • Good gravel quality & recruitment • Water quality likely a concern (monitor coho) **Needs: Access. In-stream structure (diversity). More conifers in riparian.**	🟩🟨 **Genesee/Yancy L2** (1446 ft) • High anad. use, but 72% coho pre-spawn mort. WQ pblm • Width moderate (avg=13 ft, max 24 ft), but incised areas • Ltd. floodplain potential (16% armor, bank ht avg>3') • 53% pools, pool every 4 CW (but none high quality) • Lots of structure, but still 20% glide • Good spawning (506 ft,172' high quality), but not enough • Limited rearing habitat (high adult / low juvenile use) **Needs: WQ. Refuge. Habitat/access** **North Golf Course L3** (1066 ft) • High anad. use, but 72% coho pre-spawn mort. WQ pblm • Width moderately confined (avg=10.5 ft, max 12 ft) • Some floodplain potential (11% armor, bank ht avg>3') • 58% pools, pool every 6 CW but none of high quality • Lots of structure, but still 13% glide • 276 ft spawning habitat (164 ft excellent) **Needs: WQ. Diversity, width, refuge, floodplain**	🟨 **Andover Culvert L1** (3258 ft) • High anadromous fish use, but 72% coho pre-spawn mortality. WQ problem. • Culvert – no habitat • Migration only **Needs: WQ. Access (keep culvert passable for fish migration)** ☐
	Medium	🟩	🟩	🟨 **Delridge L5** (6671 ft) • Rehabilitated but still confined (avg=8 ft, max 16 ft) • Ltd floodplain potential (42% armor + encroachment) • Existing resident use, potential anadromous use • 26% pools, but 1/9 CW & none of high quality • Some spawning habitat (276 ft, 60% high quality) • Lots of structure, but still high (39%) glide • Water quality likely a concern (monitor if coho access) **Needs: Access. Width. High flow velocities.WQ?**	🟨
	Low	🟩	🟩	🟨🟧 **Webster L7** (589 ft) • Banks low (<3'), but confined (7'), armor 30% • Some structure but 43% glide • No existing fish use & limited future potential • 24% pool (1/8 CW) but 61 ft poor spawning **Needs: Width, floodplain, high flow velocities** **Thistle L8** (2117 ft) • Banks low (3') & no armor, but confined (8') • No existing fish use & limited future potential • Little habitat: 46% glide; 415 ft spwn hab; 13% pools-1/18 CW **Needs: Width, floodplain, high flow velocities**	🟧 **Kmart L6** (1817 ft) • Culvert – no habitat • Migration only • Some potential for fish use (resident) **Needs: Access (resident fish), lower flows**

PIPER’S CREEK - CRITICAL NEEDS LIST
1st step in prioritizing system critical needs - prioritize reach needs

Critical Needs Assessed:

- Flow Volume & Velocity (indirectly)
- Water Quality (indirectly)
- Connectivity-Floodplain
- Connectivity-Barriers
- Sediment-Gravel & Fines
- Channel Complexity
- Riparian Vegetation
- Fish Habitat & Use

Priority:

High 🟨
Med 🟩
Low 🟦

General comments - Piper’s Creek channel is evolving in response to increased flow. Weirs have largely succeeded in stabilizing the channels vertically, reversing much of the channel incision, and in locations of Upper Piper’s, in succeeding to re-establishing a floodplain. However, in the lower reaches of Piper’s and Venema, bank armoring requires ongoing maintenance because the narrow channel concentrates the stream energy from increased runoff and the armoring prevents the channel from widening. In addition, Venema and Mohlendorph creeks lack effective structures to provide grade control and dissipate energy from increased water runoff.

Critical needs:

- Altered hydrology – increased runoff in combination with confined channels is resulting in channel widening and re-connection to floodplain (where possible), but amoring is preventing channel from adjusting (widening) in lower reaches of Piper’s and Venema. These sections rely on maintenance of armoring and weirs to control downcutting & bank erosion.
- Water quality is likely to be a problem – Variable but high coho pre-spawn mortaltiy, low B-IBI scores
- Access (for fish and sediment movement) – Treatment Plant culvert (Metro) limits access to Upper Piper’s
- Spawning habitat occurs mostly in the lower mainstem, and may be insufficient quantity for the numbers of spawning adults. High fines and small channel/lower flow may limit the quantity of spawning habitat available to anadromous fish in Venema system
- Gravels contain a high proportion of fines particularly in Upper Piper’s and in Venema
- Limited rearing and refuge habitat (mostly associated with weirs)

Critical Needs in Pipers Creek Watershed

Reach	Problems	Rationale
PI01: Lower Piper’s Alluvium (2159 feet) Outlet of railroad culvert to outlet of Treatment Plant culvert Overall Condition: Fair 1-1.5% average gradient	• Water quality likely a concern, especially for coho • Rearing habitat limited to pools associated with weirs (17 pools, max ~4000 ft^2 for coho & cutthroat juveniles) • Insufficient spawning habitat – quality & quantity (max 2200 ft^2 which provides room for about 150-300 salmon redds). Especially a concern for coho because chum spawn in the same areas shortly after the coho have constructed redds • Likely high flow velocities • Fines	• 20-90% coho pre-spawn mortality (PSM) • B-IBI @ mouth=10, n=3 and U/S of K-weirs B-IBI 12, n=2 and @ confluence w/ Venema + Plant culvert outlet B-IBI=10-16, avg=13, n=4 • Instream structure mostly weirs (95’ bet weirs) & some boulders – refuge habitat ltd to pools • 17 pools (15% of length, 327’) associated w/ weirs, med. residual pool depth 1.25’(1-2.75’) • Superimposition of redds in high return years; e.g., 400+ chum & 100+ coho • 35% (750’) spawning habitat (68% riffle), most only fair quality, best is located where channel widening occurring @ bend Sta. 1400-1500 (total ~2200 ft^2 max) • Evidence of high flow velocities – channel mostly entrenched, degraded & widening, 26% armored + constructed in lower and uppermost sections, plane-bed with forced pool riffle @ weirs, bank erosion @ weir logs • Armoring prevents channel from widening to est. new floodplain & meander • Channel is unconfined to moderately confined, median active width 16’ (10-18’) • Fines from U/S and from tributaries
PI02: Treatment Plant culvert 342’ Overall Condition: Poor 1.5%	• Access-Barriers PIMA-BA04 & bypass	• Treatment Plant culvert is a barrier (PIMA-BA04) and there no screen to prevent fish from entering bypass which is a dead end • Limited spawning habitat as indicated by superimposition of redds in high return years
PI03: Middle Piper’s (2866 ft) Treatment Plant culvert inlet to Twin pipes outlet @ NW 105th St Overall Condition: Good 3%	• Water quality likely a concern • Access (8 full, 10 partial barriers) • High delivery of fines and high % fines in substrate • Needs more instream structure to reverse remaining incision, and to create pools & refuge habitat	• D/S Twin Pipes B-IBI =14, n-=1 or 10-14, avg=12, n=2 (1 sample just <400 threshold) and 20-90% coho PSM immediately D/S • Barrier @ Treatment Plant culvert (PIMA-BA04) plus partial barriers (PIMA-BA06& 07) limit fish access (only 3 fish U/S in 4 yrs). Many barriers (7partial and 7 full) limit /S access • 35% spawning (88% riffle), most poor quality,

		high % of fines in substrate • Steep, eroding tributaries and landslides from upper valley walls supply large amounts of sand and gravel to the channel (estimated erosion rate (all types) 1600 yd^3/decade. Note: Barton's estimate (2002) was reduced by 50% to reflect sediment storage away from MS channel • Evidence of high flow velocities - grade controls are needed in 2 locations to dissipate energy & reverse incision. Also - 19% armored, and plane-bed w/ cascades @ weirs • Evidence that structure and floodplain potential are helping to stabilize the channel. Weirs (14 rock weirs & 4 log) have succeeded in reversing most of the incision and formed new floodplain connections • Needs more instream structure/complexity. Spacing is 22'-430' bet. structures, averaging 145'. Target spacing is closer to every 5-7 channel widths (CW). At a current median active channel width of 12' (10-18'), this would be structure at least every 60-84' • 12 pools (6%) median depth 1.1' (1-2.2')
PI04: Upper Piper's (1633 ft) Twin pipes outlet @ NW 105th St To NW 100th St culvert outlet Overall Condition: Poor 2.9%	• High delivery of fines and high % fines in substrate • Barrier is U/S limit of resident trout • Water quality is probably a concern - B-IBI is low (high flows may be not a contributing factor to low score because flows are much lower U/S of Twin Pipes) • Needs more instream structure to provide pool habitat (for resident fish & other aquatic biota) • Invasives	• Steep tributaries supply abundant sand from landslides and gullies (esp. during large flood events e.g., 1990, 1996). Also high % fines in substrate (dominant throughout reach) • Barrier (PIMA-BA21) @ 103rd Camel's Hump is upper limit of resident cutthroat trout • U/S Twin Pipes B-IBI=22-24, but counts were <400 threshold (thus may be too low to be reliable) • Little instream structure (spacing 273') & little hydraulic diversity (no pools and no spawning habitat although depositional floodplain w/ wetland just U/S of 103rd St culvert inlet) • High flow velocities do not appear to be an issue – median active channel width 5.6', not incised (1.6'), mostly unconfined W/H ratio 3.5 • Riparian vegetation is mostly invasive
PI05: Piper's Headwaters (1725 ft) surveyed 1575' (91%) NW 100th St culvert outlet to 1st Ave NW Overall Condition: Poor 2.5%	• Access (4 full, 1 partial) • Lacks instream structure • Lacks floodplain connection	• Severely encroached by 14% armoring, culverts (52%), yards (overlap w/ armoring), bldgs, roads - straightened & armored through residential area • No instream structure – 1 pool backwatered area U/S of Holman culvert (5% 2.4'), no spawning habitat and 10% glide • Active channel width 6.7', bk ht 1.2, but confined by undersized culvert (dia 2.5') • Barriers (4 full PIMA-BA22, 23, 24, 30 and one partial PIMA-BA29)
PI01.VE01: Lower Venema Alluvium (573 ft) Mouth to confluence with Mohlendorph Overall Condition: Fair 3%	• High flow velocities • Confined channel • Water quality likely a concern, especially for coho • Insufficient spawning habitat in Piper's Creek system for existing returns (Venema has lower densities of chum and coho than mainstem Piper's, which may reflect lower potential spawning habitat) • Limited floodplain connection, although potential exists	• Evidence of high flood flow velocities & confinement – channel is entrenched despite some floodplain potential, 35% armoring (mostly constructed riprapped banks), plane-bed with forced step-pools (constructed weirs). Armoring prevents widening • 20-90% coho PSM (variable) • @ mouth of Venema B-IBI=20-24, avg=22, n=3, and @ rearing pond B-IBI=22, n=1 • 71% (407') spawning (80% riffle), much of it good, but low normal flows, small channel size, limited holding areas and high % fines (from U/S sources) in substrate probably limit its potential as a spawning area (800 ft^2 max – room for 60+ redds). It is currently used by chum & coho • Active channel width 8.4' (5-14') unconfined to moderately confined, W/H ratio 4.3, bks 2' • 9 pools (16%), median depth 1', 1-1.75' limited to weirs (avg 64' spacing)
PI01.VE02: Venema Lower Canyon (457ft) Gradient break to base of LWD	• High flow velocities • Confined channel • High delivery of fines and high % fines in substrate	• Evidence of high flow velocities – entrenched, 40% armored, constructed lower section, plane bed with forced steps (lots of weirs) • Has floodplain connection potential (banks <

Overall Condition: Good 5.8%	• Limited floodplain connection, although potential exists	1') - but confined (active channel width 4', W/H ratio 4.9) • Lots of instream structure weirs & especially wood & log jams (26' spacing) • Head walls from U/S reaches supply lots of fines - high % fines in substrate • 7 pools (10%) as step pools, high gradient • 82% spawning (90% riffle), much of it good, some very good, accessible to, but not used by salmon (one partial barrier PIVE-BA02)
PI01.VE03: Venema LWD Jams (578 ft) Base of LWD jam to geologic (clay) break Overall Condition: Good to Best available in Venema 7% overall	• None listed	• Abundant instream structure especially wood & log jams in lower 230' (11% gradient) • Depositional zone U/S of jams (5.3%) • Large gravel bars, meandering channel, a few side channels, step pools in jams, sinuous plane bed U/S • Aggrading & widening, sections have restabilized • Not entrenched (bks 1.5'), moderately confined (7', W/H ratio 4.4) • Valley wall landslide bowl along the right bank • 0 pools – 100% riffle, steep gradient • 100% spawning potential mostly med. quality
PI01.VE04: Venema Slot Canyon (518 ft) Geologic break to 6' high silt/clay knickpoint Overall Condition: Fair 7.8%	• Lacks sufficient instream structure to prevent failure and headcutting	• Needs more instream structure (LWD steps limited to downstream 70') to protect knickpoint – channel is downcutting & widening • Highly confined (naturally) and entrenched through the slot canyon with a degrading channel structure • Continuous bank erosion • Median active channel width is 9', 7.5' med bk ht, W/H ratio 1.2 • 0 pools – 100% riffle, steep gradient • 100% spawning potential mostly med quality
PI01.VE05: Upper Venema (538 ft) Knickpoint to headwaters Overall Condition: Fair 4-11%	• Lacks sufficient instream structure to prevent failure and headcutting • Major source of fines (naturally, but impacted by land use and drainage)	• Needs more grade controls to prevent failure and headcutting (infrequent LWD jams and steps, spacing >100') • Major source of sand - extensive erosion of advance outwash sand in canyon walls. Tightlining outfalls greatly reduced delivery of sand to creek. Biostabilization projects at toes of landslides have had partial success. • Evidence of high flow velocities – 25% of channel is confined (W/H ratio 1.9), incising and widening (lower section), remaining 75% is aggrading and widening (& re-estabilishing a floodplain) • 0% armoring, 0% culverted, median channel width 11', bank ht < 2', • 0 pools – 100% riffle, steep gradient • Lacks instrm. structure • 100% spawning potential (100%-riffle) of primarily low quality due to sediment distribution
PI01.VE02.MO01: Lower Mohlendorph Alluvium (803 ft) Confluence w/ Venema to Mohlendorph forks Overall Condition: Fair 5.4% (1-2% between LWD jams 7 steps)	• Lacks sufficient instream structure to prevent failure and headcutting • High flow velocities in confined sections	• Limited instream structure (mostly weirs) - reach lacks effective structures to provide grade control and dissipate energy from increased water runoff • Evidence of high flows– coir 'logs' placed at toes of eroding 5-10' banks throughout reach, moderately confined (7.4') and entrenched (banks 3.6'), limited floodplain potential in this reach, but aggraded & widening – starting to restabilize • 90% spawning much of it good used mostly by chum & resident trout • 1 pool (1%), 99% riffle, steep gradient • Lower sediment load than Venema – substrate has less fines
PI01.VE02.MO01.WF01: Lower WF Mohlendorph Clay (635 ft) Mohlendodrph forks to geologic break (till to clay)	• Lacks sufficient instream structure to prevent failure and headcutting	• Limited instream structure - reach lacks effective structures to provide grade control and dissipate energy from increased water runoff • Channel is confined (W/H ratio 1.3) in canyon bottom (active channel width is 9.3'), avg bk

Overall Condition: 8.7%		ht 7.4’), no armoring • 0 pools, 100% riffle, steep gradient • 100% spawning potential prob mostly for trout • Good riparian canopy and understory exists • Upper WF Mohlendorph has slow erosion rates due to glacial till
PI01.VE02.MO01.WF02: Upper WF Mohlendorph Till (175 ft) Geologic break (till to clay) to headwaters Overall Condition: 17%	• Lacks sufficient instream structure to prevent failure and headcutting	• Limited instream structure - reach lacks effective structures to provide grade control & dissipate energy from increased water runoff • Unstable banks and downcutting channel - channel is very confined (W/H ratio 0.6) in canyon bottom (active channel width is 6.6’), avg bk ht 11’), • 0 pools, 100% riffle, steep gradient • 23% spawning potential prob mostly for trout • Good riparian canopy and understory exists • Upper WF Mohlendorph has slow erosion rates due to glacial till
PI01.VE02.MO02.EF01: Lower EF Mohlendorph (270 ft) Mohlendorph forks to LWD jam Overall Condition: 4-6%	• Lacks sufficient instream structure to prevent failure and headcutting	• Channel is downcutting, entrenched and moderately unstable - confined channel (W/H ratio 1.5), active width 9’, bk ht. 6’ • Limited instm structure l(LWD jams & logs) • Active bank erosion – silt, some sand. U/S fines not a problem due to till • 89% spawning (100% riffle), no pools
PI01.VE02.MO02.EF02: Upper EF Mohlendorph (642 ft) Mohlendorph forks to LWD jam Overall Condition: 17%	• Needs additional grade controls to prevent future failure and headcutting	• 2 LWD jams provide grade control but need reinforcement • Channel less incised than Lower EF, entrenched, altho very confined channel (W/H ratio 0.7), active width 7’, bk ht. 10’ • Limited instm structure l(LWD jams & logs) • Less bank erosion due to till • 24% spawning (100% riffle), no pools

TAYLOR CREEK - CRITICAL NEEDS LIST
1st step in prioritizing system critical needs - prioritize reach needs

Critical Needs Assessed:

- Flow Volume & Velocity (indirectly)
- Water Quality (indirectly)
- Connectivity-Floodplain
- Connectivity-Barriers
- Sediment-Gravel & Fines
- Channel Complexity
- Riparian Vegetation
- Fish Habitat & Use

Priority:

High	🟨
Med	🟩
Low	🟦

General Comments: Taylor Creek has some of the most promising stream habitat in the City. The reaches through the park are remarkably stable given the level of urbanization in the basin. There are several reasons for this relative stability compared to other urban streams. The fairly dense substrate resists erosion. The glacial material is older, more consolidated and has very little outwash sand. There are abundant large boulders and wood that creates grade controls to prevent downcutting (although spacing is generally not as close as it would be in a forested system). The wetlands in the West Fork moderate flood peaks flows by providing detention and storage. There is very little encroachment due to the steep canyon walls and its location in a park. Hydrology is altered, but the channel appears to have sufficient room to handle higher storm flows. Development in the West Fork wetland is expected to continue altering hydrology and may remove some of the buffering effects offered by the wetland.

Critical needs:

- Access (for fish and sediment movement) – starting with Rainier culvert
- Protection from possible future increase in storm flows (development adjacent to wetland)
- Channel widening and the addition of structure, especially in downstream of Rainier
- Research why wetland vegetation is dying, remove invasives in wetland

Critical Needs in Taylor Creek Watershed

Reach	Problems	Information
TA01: Rainier Alluvium/Riprap (1187 feet) Mouth @ Lake WA to beginning of natural channel (75' D/S 68th Ave SW culvert outlet) Overall Condition: Poor 2-2.5% average gradient	• Access -2 full & 3 partial barriers • Severely confined channel-high flow velocities/gravel scour • Lacks sufficient structure to create holding pools and refuge/ rearing habitat or to retain gravel • limited floodplain connection-although creek does flood yards U/S of Rainier • Poor riparian habitat	• Anadromous fish blocked @ Rainier (TAMA-BA05) & on private property (TAMA-BA06/dam also blocks sed. transport), partial (BA04 driveway culvert), U/S of 68th Ave SW culvert inlet (TAMA-BA10 & (BA11) • Coho currently access up to inlet Rainier culvert, and enter culvert • Evidence of high flow velocities -channel is highly confined (7.5', W/H ratio 2.6), entrenched, straightened, 100% constructed, 80% armored, plane bed, 3% glide, and 2% avg. gradient is sufficient to transport 2" dia. gravel into lake • Severely encroached with bank armoring (80%), buildings, roads, 28% culverted, yards • Flooding because channel & driveway culverts are undersized • Riparian condition – mostly yards • Instm structure limited to weirs. No LWD • No active erosion (armored & constructed) – all gravel recruitment from U/S, but does have delta that extends 100' into lake • 19 pools (22% of reach length) inc side pools, 0.5-1.25' residual pool depth, 0.8' med depth • 52% (622') spawning (56% riffle) mostly med quality – used by 3-4 coho/yr & 25-28 sockeye/yr max of 1244 ft^2 – room for about 130+ redds, enough for current level of return
TA02: (667 ft) Lakeridge Alluvial Fan beginning of natural channel (75' D/S 68th Ave SW culvert outlet) to 504' U/S of Holyoke culvert inlet Overall Condition: Good 4-4.9%	• Water quality likely a problem	• B-IBI scores: Bet 68th & Holyoke culverts (TA03) B-IBI=20-22, avg=21, n=2, and U/S Holyoke (TA01) B-IBI=10-18, avg=16.5, n=4 • Partial barrier (TAMA-BA14) LWD jam (natural)-but may still provide U/S access • Moderately encroached by culverts D/S park (24% culverted), armoring (10%) • Good instm structure-lots of wood & weirs – although currently buried under ~2' of sediment which had been stored U/S of old culvert (replaced 1999), 80-150 cu yd/yr • Active channel width 14-18', mod confined, not entrenched, W/H ratio 4.4

		• Plane bed, forced pool-riffle, some braiding above knickpoint (migrated 100’ U/S in ’99, + 65’ U/S in larger water year ’02), channel downcut 2-3’ since culverts removed • Channel is widening throughout reach w/ active bank erosion • Undersized Holyoke culvert replaced in 1999 is allowing sediment to move D/S, reach has become new deposition zone despite steepness because channel now wider, shallower, more complex (gtr. roughness). • 8 pools (12% of reach length) inc side pools – probably limited by gradient & by sediment formerly stored U/S replaced culverts, 0.8-1.1’ residual pool depth, median 0.8’ • 73% spawning (63% riffle), good to best available, large gravel, small cobble • Good shade
TMA03: (355 ft) Lower Canyon 504’ U/S of Holyoke culvert inlet to start of narrow canyon Overall Condition: Good (best available in system/possibly in city) B-IBI 10-22, avg = 17.6, n=5 3-5%	• Protection from possible future increase in storm flows (development in wetland reach) • Water quality likely a problem	• Channel is handling current flows, but development adjacent to West Fork wetland may reduce its ability to detain storm flows • B-IBI score @ Cascadia Quest footbridge B-IBI=10-22, avg = 17.6, n=5 • Partial barrier U/S Holyoke (TAMA-BA15) LWD jam (natural)-but may still provide U/S access • Good instm structure-lots of wood (good spacing 85’), weirs, island, boulder steps • Active channel width 17’, unconfined by encroachment (altho some armoring-14%), but moderately confined & entrenched naturally by canyon, W/H ratio 5.4 • Narrow floodplain & bars have formed in chan • Episodic supply of sed from valley-wall landslides • Forced pool-riffle, plane-bed, no glide • Channel has restabilized, lower area • 4 pools (10%) + side pools, 0.6-1.25 residual pool depth, median depth 1.1’ • 69% spawning (90% riffle)
TA04: (399 ft) Middle Canyon Start of narrow canyon to LWD jam Overall Condition: Good (best available in system/possibly in city) 4-7%	• Protection from possible future increase in storm flows (development in wetland reach)	• Channel is handling current flows, but development adjacent to West Fork wetland may reduce its ability to detain storm flows • Potential partial barriers TAMA-BA15&BA16 (log jams) – may still provide U/S access • Good instm structure-lots of wood & weirs, island, boulder steps, although could be spaced more closely (currently avg. 133’)-ideally every 5-7 channel widths (75-105’) • Active channel width 15’, moderately confined, naturally by canyon, W/H ratio 4.8 • Step-pool morphology prevents incision, numerous steps mostly lg boulder/log combos • Channel has restabilized in lower area • Altho vertically stable, lateral erosion of valley walls causes signif. landslides & bank erosion • 10 pools (21%) + lots side pools, 0.5-1.75’ residual pool depth, median depth 0.8’ • 69% spawning (79% riffle), no glide
TA05: (1357 ft) Upper Canyon LWD jam to confluence East & West forks Overall Condition: Good (some of best available in system/possibly in city) 4%	• Protection from possible future increase in storm flows (development in wetland reach)	• Channel is handling current flows, but development adjacent to West Fork wetland may reduce its ability to detain storm flows • Potential partial barriers TAMA-BA17-BA21 (log jams) - may still provide U/S access • No armoring, 0% culverted • Good instream structure lots of wood & island (103’ spacing is good, every 6 CW) • Active channel width 18’, unconfined, altho moderately confined naturally by canyon, W/H ratio 5.9. Wide valley perched U/S grade control (boulder steps) • No incision or entrenchment, channel has restabilized, step pool + forced pool-riffle, no glide • Lower section stable banks, middle & upper moderately to actively eroding banks

		• 24 pools (17%) + lots of side pools, 0.5-1.25’, median depth 1’ • 70% spawning (83% riffle)
TA05.WF01: (743’) Taylor West Fork Lower Canyon Confluence East & West forks to LWD jam Overall Condition: Good 6-8%	• Protection from possible future increase in storm flows (development in wetland reach)	• Channel is handling current flows, but development adjacent to West Fork wetland may reduce its ability to detain storm flows • Potential partial barrier TAWF-BA01 boulder cascade (natural)- may still provide U/S access • Good instm structure lots of wood, boulders, island, complex channel w/ LWD steps (132’ spacing, every 60-70’ would be better) • Active channel width 12.5’, unconfined, altho moderately confined naturally by canyon, W/H ratio 4.3 • Step-pool & plane bed, no glide • Channel has restabilized, some widening, locally entrenched w/ minor incision (no armoring) • Mostly stable banks, minor landslides & bank erosion, transport reach for sed from U/S • 3 pools (4%) plus side pools,0.5-.09’ depth, median depth 0.5’ • 86% spawning (96% riffle)
TA05.WF02: (482’) Taylor West Fork Upper Canyon Only 90’ surveyed (19%) LWD jam to road Overall Condition: Fair 3-5%	• Protection from possible future increase in storm flows (development in wetland reach)	• Channel is handling current flows, but development adjacent to West Fork wetland may reduce its ability to detain storm flows • No armoring, 0% culvert in 90’ • Less structure esp. in lower section, upper section has wood, weirs, island, a few LWD (cedar logs) steps & jams (79’ spacing) • Active channel width 13’ (9’ in 90’ surveyed section), unconfined, altho moderately confined naturally by canyon, W/H ratio 5.1 • Plane bed channel types, little complexity • Meandering channel 2-3% (upper) • Channel has restabilized, lower area • Primary source of fines – from channel & from landslides, gullies upper valley wall • Transport reach • 12 pools (13%) a couple side pools and • 87% spawning, 87% riffle in 90’ surveyed sec
TA05.WF03: (2935’) Taylor Upper Plateau Wetland B-IBI = 18-22, avg = 20, n=2 <1%	• Protection from possible future increase in storm flows (development in wetland reach) • Access (1 full barrier @ Rention culvert) • Invasives	• Wetland may not be handling altered hydrology (vegetation is dying/high density of invasives) and development adjacent to West Fork wetland may reduce its ability to detain storm flows • Barrier @ Renton culvert (TAWR-BA02) • No armoring, 4% culverted • Active channel width 3’, unconfined, W/H ratio 4, bank ht <1’ • Channel has restabilized, lower area • Active bank erosion • 96% wetland, 0% spawning
TA05.EF01: (484’) Taylor East Fork Canyon Confluence East & West forks to steep cascade Overall Condition: Good 4-8%	• Access (1 partial barrier)	• Partial barrier TAEF-BA01 (culvert). Very disturbed reach @culvert. Culvert plugs w/ 3’ of gravel, requires frequent maintenance. Bypass channel conveys overflow • Moderately encroached -2% armoring, 30% culverted, entrenched, active channel width 8’ • Eroding banks source of fines • U/S of culvert channel steepens, but bed is stabilized w/ logs & concrete slabs • Upper end is steep cascade, transitions to wide valley floor U/S, active channel width 11’ • Step pool + plane bed, no glide (upper) • Channel has restabilized, lower area • Landslides + bank erosion, debris flow in 1984 delivered lg volume of ourwash sand & gravel to U/S end of reach • 5 pools (21%) + side pools, 0.6-1’ depth, median depth 0.7’ • 30% spawning (49% riffle)

THORNTON CREEK - CRITICAL NEEDS ASSESSMENT

1st step in prioritizing critical needs for a watershed :
identify & rank needs for each reach using supporting data

High – Highly likely to be limiting factor for fish & habitat OR feature/function wld be lost if no intervention
Medium – Probably a limiting factor/contributing factor for fish & habitat
Low – May be limiting factor for either fish or habitat OR unknown (need more info)
Uses avg active channel width

Critical Needs Assessed:

- Flow Volume & Velocity (indirectly)
- Water Quality (indirectly)
- Connectivity-Floodplain
- Connectivity-Barriers
- Sediment-Gravel & Fines
- Channel Complexity
- Riparian Vegetation
- Fish Habitat & Use

Priority:

High 🟨
Med 🟩
Low 🟦

General Comments: Mainstem Thornton Creek has been altered by the cumulative effect of increased runoff, loss of channel complexity, encroachment, extensive bank armoring, lowering of Lake Washington, and installation of a flood bypass. Historically it would have been a low gradient stream which meandered across an alluvial valley bottom, unconfined (except for valley constriction between 45th and 46th), and often braided, ending in a 450+ foot wide delta at the mouth. Now the channel averages 9 to 10 feet wide, the floodplain is 3-4 feet above the channel, the banks are heavily armored, and houses, roads, yards are within 5 to 15 ft of the creek. Meadowbrook Pond traps much of the bedload, although fines can move downstream.

Summary of Critical Problems in Thornton Watershed:

- Altered hydrology, especially high peak flows
- Water quality likely a problem (low B-IBI, high coho pre-spawn mortality)
- Reduced channel capacity/high flow velocities–channel is confined & incised – offers no room for gravel bars and meanders to form or for adding structure to form habitat, dissipate energy, retain gravel, or provide hydraulic diversity
- Much of creek is an "armored trough" with almost no gravel recruitment or retention. M.Pond traps gravel, can pass fines.
- Little floodplain connection. Encroachment limits potential. Loss of delta, alluvial fans & wetlands to reduce flood levels
- Barriers on NB & SB (secondary). Degraded riparian habitat – yards, invasives.

Critical Problems in Thornton Creek Watershed - MAINSTEM

Reach	Problems	Rationale
TM01: Mainstem-Delta Alluvium (1027 feet) Mouth @ Matthews Beach to Maple Ck confluence Overall Condition: Poor 0.3-1.7%, median 0.7%	• Loss of delta refuge & feeding areas • Loss of channel capacity/High flow velocities – channel is severely encroached, confined, constructed, incised, & armored (banks & streambed) • No refuge from high flows (few pools, no instream structure or room to place it) • Water quality likely a concern, especially for coho • No gravel recruitment or retention • No floodplain connection but has potential (could help provide room for re-establishing delta) • Invasives RB U/S Park	• Loss of delta – straightened & confined, lost sediment sources, would be ~450' wide • Severely encroached w/ bank armoring (99%), buildings, roads & bridges • 50% constructed (concrete chute) forces spawning gravel D/S – redd scour • ~50% length of channel is highly confined (ratio 1.6, 7-10'), incised 3', no instm structure • Compacted substrate, 76% glide, plane bed • No gravel recruitment-U/S trapped by M.Pond • Few coho, sockeye & cutt redds in upper part • 83% coho pre-spawn mortality, • Heavy metals detected in storm water samples (copper, zinc, cadmium, chromium, arsenic, silver), and detected in sed. samples (copper, lead, zinc, nickel, chromium, w/nickel & lead > guidelines) - from Minton 1998 - King Co 93-97 data, City 91 data • No spawning habitat, although 17% riffle • Very few pools (2) 7% of length, 48 channel widths/pool (CW/pool) • Potential floodplain connection in park
TM02: Mainstem - Sand Pt Wy alluvium (1772 ft) Maple Ck confluence to 45th Ave & 97th St. Overall Condition: Good - Best Available in Mainstem (MS) because only area in MS w/ small channel migration zone (CMZ) due to open space, setback of bldgs., & minimal bank armoring 1%	• Water quality likely a concern, especially for coho • Protect/enlarge CMZ • Poor rearing habitat –- high % glide, few pools, limited structure • Limited gravel recruitment/retention • Limited floodplain connection but has potential – may be able to extend CMZ • High flow velocities – some incision, channel widening • Invasives U/S 45th & 96th	• Highest density of redds-sockeye, coho, chin & cutt (49% riffle w/ 28% spawning habitat) • 83% coho pre-spawn mortality • CMZ between Sand Pt & 96th allows some meander & riffle/pool bed. Naturally moderately confined (3.5,11-14') by valley walls, with some incision (3.5) & widening • At least one area of active gravel recruitment from bank but M.Pond limits input U/S gravel • Some weirs & wood, but 33% glide and few pools (8, 18% of length), 20 CW/pool • Some floodplain potential • Encroached @97th (bldgs/rds), 16% armored
TM03: Mainstem – Middle Reach Alluvium (3314 ft) 45th Ave NE to outlet of Meadowbrook Pond (~39 Ave NE) Overall Condition: Poor Fair 98th to 102nd 0.6%	• Loss of channel capacity/High flow velocities – channel is severely encroached, confined, incised, & armored (banks & streambed) • Water quality likely a concern, especially for coho • Limited rearing & refuge habitat – lacks instream structure – probably only room to add low elevation structure • Limited gravel recruitment/retention • Limited floodplain connection or	• Heavily encroached with bank armoring (46%) & bldgs, rds, bridges, yards • Channel is moderately to very confined (9-11'), incised (4'), 26% glide, little structure • High density cutt redds thru-out exc bet. 96th-100th/mid area which has almost no spawning habitat (banks armored both sides), only a few salmon redds in uppermost area • 83% coho pre-spawn mortality, Sta. TM02 (D/S M. Pd outlet @39th) avg B-IBI =13.6, 10-18, n=5

	potential • Poor riparian habitat – lots of yards 97th to 106th,& invasives LB U/S 100th, both bks 103rd, 106th	• 52% length has spawning habitat (52% riffle) • 14 pools (22% of reach length), 25 CW/pool • Ltd gravel recruitment - some bank erosion & M.Pond limits input of U/S sources of gravel • No floodplain, but floodplain potential @ 98th/44th & 42nd/ 103rd , 98th-102nd armoring protects yards - not bldgs
TM04: Mainstem – Meadowbrook Alluvium (1057 ft) Meadowbrook Pond outlet (~39 Ave NE) to confluence of north & south branches Overall Condition: Fair 1%	• Water quality likely a concern, especially for coho • Loss of channel capacity/High flow velocities – channel is severely encroached, confined, constructed, incised, & armored (banks & streambed) • Pond traps sediment - limits gravel recruitment potential D/S – spawning habitat located U/S of pond inlet • Limited floodplain connection – CMZ for alluvial fan eliminated • Pools relatively plentiful, but low quality • Could use more instream structure • Poor riparian habitat – lots of yards & invasives DS M. Pond	• High fish use-chinook, sockeye, coho, cutt • 83% coho pre-spawn mortality, Sta. TM01 (U/S M. Pd inlet) avg B-IBI = 12, 10-14, n=3 • Severely encroached w/ bank armoring (88%) buildings, rds, bridges, yards (exc @ 38th) • Highly confined @ confluence due to bldgs/rd (5-10' vs avg. active width 12-15'). Wld have had meandering channel 15-20' wide w/ CMZ 50'-100's ft wide for floodway/alluvial fan • Channel is 50% constructed (esp. @106th), or incised (3.6'), 29% glide • M. Pond traps sediment inc. spawning gravels Most of spawning habitat (26% of reach) is located U/S of pond inlet & is HQ (27% riffle) • Some wood & weirs 12 pools,45%, 7 CW/pool • Some floodplain potential @ M. Pond inlet

General Comments: Historically the North Branch would have had four areas: a meandering braided channel located on an alluvial fan near its confluence with the Mainstem, a ravine with a channel migration zone (CMZ) of 50-150 ft immediately upstream , an outwash channel (CMZ 100-300 ft), and an upland valley which probably consisted of forested swales and wetlands. The North Branch has been altered by the cumulative effect of increased runoff, loss of channel complexity, encroachment and extensive bank armoring. The channel is now incised (3-4 feet) and constrained to a narrow width (typically 8-15 feet), but has a few areas of wider areas (30 feet) that have allowed meander bend and channel bars to form. Failing bank protection and plane-bed channel type indicate ongoing incision (degradation) in response for high flow velocities. The channel has a reduced capacity and would probably be more stable at widths of greater than 30 feet (30-50 feet).

Critical Problems in Thornton Creek Watershed – NORTH BRANCH

Reach	Problems	Rationale
TN01: North Branch Thornton – Alluvial Fan (1706 ft) Confluence of north & south branches to confluence w/ Littlebrook Overall Condition: Poor 1-2.5%, median 1%	• Loss of channel capacity/High flow velocities – channel is severely encroached, confined, incised, & armored (banks & streambed) • Water quality likely a concern, especially for coho • Limited rearing & refuge habitat – lacks instream structure – probably only room to add low elevation structures • Thin to non-existent substrate with limited gravel retention potential • Poor quality spawning habitat • Poor riparian habitat – yards & invasives both bks 109th & D/S 113th	• Severely encroached w/ bank armoring(47%), buildings, rds, bridges, yards (exc@113th) • Failing bank protection (widening) & plane bed indicate ongoing incision & high vel. flows • Channel confined (13.5') & incised (bk hts >5'), & straightened. Originally wld have been meandering channel 15-20' wide w/ CMZ 50'-100's ft wide for floodway/alluvial fan. A 100' CMZ wld reduce flood hts & create riffle-pool gravel bed (Stoker, 2002) • Partly constructed channel (D/S end), compacted substrate, plane bed, 26% glide • Weirs only structure holding gravel & preventing bed scour. Otherwise substrate is thin to non-existent • One of most heavily used spawning areas for cutts, altho few salmon redds (coho & chin) • 83% coho pre-spawn mortality • Banks are source of fines in upper area • 25% length spawning habitat (63% riffle), most of it poor quality • Few pools (6) 11% of length, 21 CW/pool
TN02: NB Thornton – Lower Ravine (9102 ft) Confluence w/ Littlebrook to 19th Ave culvert inlet Overall Condition: Fair 1-7%, median 1.2%	• Loss of channel capacity/High flow velocities – channel is encroached, confined, incised, & armored (banks & streambed) • Limited rearing & refuge habitat – lacks instream structure • Water quality likely a concern, especially for coho • Access – salmon & cutt barriers • Poor spawning habitat – gravel recruitment limited by armoring • Poor riparian habitat – yards throughout, & invasives U/S 115th , 117th to 123rd, & D/S 130th	• Severely encroached by armoring (48%), yards, buildings, & rds, exc middle area (117th to 120th & 20th to 23rd) • Channel is confined (11-12'), incised (3-6'), straightened & trough-like (rectangular shape) Channel naturally confined between 117th & 126th. Higher gradient – wld have been riffle pool bed, & D/S meandering w/ CMZ 50-150' • U/S of 20th setback of 30' has reduced flow velocities & allowed meander bend & gravel bar to form • 83% coho PSM immediately D/S • Private weir TNMA-BA03 is upper limit of salmon distribution TNMA-BA02 115th culvert TNMA-BA11 is upper limit of cutts • Poor quality spawning habitat (20% reach although 51% riffle. Reach was likely a main source of gravel for lower river where channel eroded colluvium. Substrate thin & compacted 120th to 122nd . Channel glide 18% • Weirs provide available gravel retention & pools (64 pools 24% of length, 10 CW/pool) • High fines recruited from upper area, &

		potentially from middle area • Small area of active floodplain connection D/S of 23rd& 125th St culvert. Some floodplain potential @ 119-124th near park
TN03: NB Thornton – Middle Jackson Park (5566 ft) 19th Ave culvert inlet to 5th Ave culvert outlet Overall Condition: Variable - Poor to Best Available (wetland/riffle area U/S 10th) 1%	• Protect wetland/riffle area U/S 10th • Loss of channel capacity/High flow velocities – channel is encroached, confined, incised, & armored (banks & streambed) in golf course • Limited rearing & refuge habitat – lacks instream structure – probably only room to add low elevation structure unless channel can be widened • WQ likely concern for coho D/S • Access-barriers D/S • Poor spawning habitat – little gravel recruitment or retention in golf course • Poor riparian habitat – lawn throughout, esp. in golf course & 17th to 15th. Invasives 20th to 18th & open space D/S 10th	• Severely encroached in golf course by armoring (overall 14% but all in golf course), concrete-lined channel, culverts, fairways, I-5 • Channel very confined (4.4) in golf course (4-8'), straightened & incised (3-4'). Wants to be >30' (18' in wetland/riffle area U/S 10th). Naturally confined DS of 10th. • Large area of active floodplain connection (both banks) in S end of golf course • 45% glide, golf course has large areas of compacted substrate, and fines. Limited erosion activity or gravel recruitment. • All instm structure (islands, wood, weirs) limited to wetland/riffle area U/S 10th • Spawning habitat limited (7%) limited to wetland/riffle area U/S 10th (35% riffle) • 26 pools 13% of length, 31 CW/pool of higher quality, mostly associated w/ weirs • Sta. TN01 (NE 130th/10th) avg B-IBI=20, 18-22, n=4 and Sta. TN02 (5th NE Golf Course)) avg B-IBI=12, 10-14, n=2
TN04: I-5 Culvert (2192)	• WQ likely concern for coho D/S • Access-barriers D/S	• Barrier (WSDOT)
TN05: NB Thornton Shoreline (8008') Inlet of I-5 culvert to Ronald Bog Overall condition: Poor 1-6%	• Access-barriers D/S • Loss of channel capacity/High flow velocities – channel is encroached, straightened, lined, large stormwater input @ 165th but wetlands thru-out • Channel lacks instream structure • WQ likely concern for coho D/S • Poor riparian-lawn & invasives esp.165th-169th	• Heavily encroached roads, culverts & yards • 5 barriers TNMA-BA26-30 (6 with I-5, BA25) • Concrete-lined channel, 21% length armored • 60% culvert + glide (27% not accessible) • Active floodplain 150th –154th (Twin Ponds) • Large stormwater input @ 165th • Wetlands/ pools @ Peverly, Twin Pds, Ronald bog, trout pond @ 155th -rearing hab • No spawning habitat (5% riffle),5 pools (11%)

General Comments: Prior to development the South Branch would have had three areas: a meandering braided channel (15-20 feet wide with a channel migration zone of 50 ft to several hundred feet) located on an alluvial fan downstream of 30th Ave NE, a canyon section (40-100 feet wide) from 30th Ave NE to Northgate, and a low gradient valley between glacial moraines with wetlands and a poorly defined channel. The South Branch has been altered by the cumulative effect of increased runoff, loss of channel complexity, encroachment, straightening and extensive bank armoring. The channel has incised in response to increased peak flows through the original alluvial deposits into the denser lake deposits. Incision, loss of channel structure and increased flows have left the channel with a thin and unstable layer of substrate. Encroachment and armoring limit the channel's ability to develop a more stable configuration.

Critical Problems in Thornton Creek Watershed – SOUTH BRANCH

Reach	Problems	Rationale
TS01: South Branch Thornton – Nathan Hale Alluvium (1521 ft) Confluence NB & SB to outlet of Ravenna culvert Overall condition: Poor 0.6-1.5%, median 1%	• Loss of channel capacity/High flow velocities & flooding – channel is encroached, straightened, lined – has lost alluvial fan D/S 30th Ave NE. • Limited rearing & refuge habitat – lacks instream structure – probably only room to add low elevation structure unless channel can be widened • Water quality likely a concern, especially for coho • Poor spawning habitat – limited gravel • Poor riparian habitat – lawn & invasives	• Severely encroached–bldgs+34% amoring • Highly confined (active width 7-8") & lower 231' is a concrete-channel 7' wide • Would have been 15-20' wide CMZ 50-100's' • Some flood-plain potential (~50% of length) • A few weirs – very little structure • No gravel recruitment or retention • 50% spawning habitat (59% riffle) – <u>all poor</u> • Upper extent of chinook habitat 30th Ave culvert TSMA-BA02 – but not actual barrier • 83% coho pre-spawn mortality, Sta.TS01 (Nathan Hale) avg B-IBI=12, 10-16, n=4 • 6 pools (21% length) upper area, 31CW/pool
TS02: SB Thornton – Ravenna Lawton Clay (2902 ft) inc. Ravenna Nat. Area (100th-103rd) Outlet of Ravenna culvert to Lk City Wy culvert outlet. Inc. Ravenna Natural Area Overall condition: Poor 1-3%, median 2%	• Loss of channel capacity/High flow velocities & flooding – channel is encroached (mostly by yards), confined, straightened, armored. Has lost natural widening D/S canyon (Lk City Wy) • Limited rearing & refuge habitat – lacks instream structure. Will need to widen channel to add structure • Water quality likely a concern, especially for coho • Limited gravel recruitment/retention • Poor riparian habitat – lawn throughout, & patches of invasives 105-106th, 103rd	• Severely encroached by yards, bldgs, rds, bridges, & armoring (39%)-assoc rd & homes • Channel very confined (10')D/S 100thbecause encroachment has caused loss of natural widening of valley (widens bet. Lk City & Rav • No structure exc weirs 100th-105th "Widening channel wld reduce flood hts, velocity, provide room for gravel bars to form & allow addition of structure" (Stoker, 2002) • High cutt redd density, & coho migrate thru • 83% coho pre-spawn mortality • Active floodplain @ 103rd, potential @ 106th & in Ravenna Natural Area (100th-103rd) • Only 25% spawning (altho 66% riffle) D/S 106th & in Ravenna Natural Area • 14 pools (10%) 20CW/pool, none 102nd-105th
TS03: SB Thornton – Lake City Way Lower Canyon Advanced Outwash (1563 ft)	• Water quality likely a concern, especially for coho • Loss of channel capacity/High flow velocities – channel is encroached,	• Confined (11-12' – historically 40-100'), entrenched (4') but widening. Constructed channel 19th to 20th Ave • Highly encroached by bldgs, culvert @ Lk

Lk City Wy culvert outlet to 19th Ave & 100th St Overall condition: Fair 1.5%	confined, armored • Limited rearing & refuge habitat – lacks instream structure – probably only room to add low elevation structure • Poor spawning habitat – limited gravel • Poor riparian habitat 100th to 102nd (D/S Park 2) – lawn & invasives	City, 45% armoring • Thin unstable substrate, little recruitment • 22% spawning habitat (58% riffle) all poor • Potential floodplain 20th to 21st Ave (unconfin) • 13 pools (17%) 10 CW/pool • Some cutts, no salmon • 83% coho pre-spawn mortality, Sta.TS02 (Lk City Wy) avg B-IBI=12, 10-14, n=2
TS04: SB Thornton – Upper Canyon Till/Advanced Outwash (3541 ft) (inc. Park 2) 19th Ave & 100th St to Victory confluence Overall condition: Good 1-4%, median 1.6%	• High flow velocities • WQ likely concern for coho D/S • Access-barriers D/S for salmon & contains barriers for cutts • Poor riparian habitat – yards & invasives 15th to confluence w/ Victory Ck, also invasives –@103rd	• Moderately confined (13-16') & entrenched • Slightly to moderately encroached exc @ 15th Ave (severe) 13% overall armoring • Active floodplain 14th Ave & 106th St, & does have potential U/S15th & in Park 2 (U/S 8th) • 57% spawning (64% riffle), fair-good. Cutt redds in lower & upper areas • 31 pools (24%) as deep as 4', 9 CW/pool • upper extent of cutts (TSMA-BA12)
TS05: SB Thornton – Park 6 Till (2570 ft) 19th Ave & 100th St to Victory confluence Overall condition: Good 1-2%, median 1.2%	• High flow velocities but high potential to widen CMZ & connect floodplain • Limited rearing & refuge habitat – lacks instream structure • Access-barriers D/S for salmon • Fines • Needs gravel • Invasives confluence w/ Victory Ck	• Slightly to severely encroached (culverts) – not yards, avg. active width 8.5' & bk ht 3' • Originally wetlands w/ meandering channel but now incised. Very high floodplain potential along most of channel (Park 6) • Little to no instream structure, 21% glide • 10% spawning habitat (29% riffle) – near 5th • 14 pools (40%) 20 CW/pool, good pool mid area, very long one D/S 5th • Fine sediment thru-out with active sources – degraded & widening, ltd gravel recruitment • Sta.TS03 (Park 6) avg B-IBI=15.3, 14-18, n=3
TS06: SB Thornton – Northgate Pipe (2870 ft)	• WQ likely concern for coho D/S • Access-barriers D/S	• Culvert is likely a barrier, too long to assess • Historically cranberry bog & wetland
TS07: SB Thornton – Wetland Surge Pond (343 ft)	• High temperatures • Access-barriers D/S • Invasives in Park 6 – both bks	• 100% wetland (man-made) • Historically wetlands & wooded swales
TS08: SB Thornton – North Seattle Community College (456 ft)	• High temperatures • Low flows • Access-barriers D/S • Fines • Invasives	• Historically wetlands & wooded swales • Confined & entrenched, 86% glide • Fines, 0% spawning, 0% pools • Three-spined sticklebacks, no salmonids • Encroached by lawns