Coastal Streams and Embayments Prioritization along Puget Sound Shores with a Railroad

PRIORITIZATION FRAMEWORK TECHNICAL REPORT

Prepared for:

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December 31, 2019

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1.0 INTRODUCTION

The goal of this project was to develop a prioritization framework for evaluating the relative benefit to Chinook Salmon (*Oncorhynchus tshawytscha*) of restoring conditions of coastal streams and embayments impacted by the presence of the railroad operated by BNSF Railway on or near the shoreline of the Puget Sound. The causeway that supports the railroad is a widespread stressor along the shoreline, with 52 miles having the railroad on the shoreline and an additional 21 miles with the railroad within 200 feet of the shoreline (Figure 1, Simenstad et al. 2011). In many instances, the railroad forms a barrier between the coastal watershed and the shoreline, restricting the movement of fish as well as affecting the ecosystem processes regulating the delivery of water, sediment, wood, and organic matter into the nearshore. This truncates the size of the estuarine habitats that naturally occur in the transitional area between fresh and saltwater. These changes impact the quality and quantity of habitat available for salmon and other animals who rely on the nearshore and estuarine habitats of Puget Sound. The prioritization completed in this study focused primarily on the benefits to Chinook Salmon that are possible by restoring stream and estuary habitats at the railroad crossing. Chinook Salmon were the emphasis due to their reliance on coastal streams (Beamer et al. 2013) and estuary habitats (Beamer et al. 2003, 2006), their listing as threatened under the Endangered Species Act (ESA), and their importance as food for Southern Resident killer whales who are listed as endangered under ESA.

Marine nearshore and lower creek reaches throughout the Puget Sound are important rearing habitats for many salmonid species in addition to Chinook Salmon, including Coho Salmon (*O. kisutch*), Chum Salmon (*O. keta*), Steelhead (*O. mykiss*), Sockeye Salmon (*O. nerka*), and Pink Salmon (*O. gorbuscha*). Juvenile Chinook and Chum Salmon are the 2 salmon species that use the nearshore and estuarine habitats most extensively (Simenstad et al. 1982, Fresh 2006), while, juvenile Coho, Pink and Steelhead also use these habitats but to a lesser extent (Beamer et al. 2003, 2006, 2013). Marine nearshore environments provide distinctly different conditions for juvenile salmon than the freshwater portions of the watershed. The fish encounter changes in water salinity, typically cooler water temperatures, new prey items (often larger in size and energy content), the ebb and flow of tides, new habitat configurations, and different predators and competitors. The amount of time outmigrating salmonids spend in the estuary and marine nearshore varies among species, by life history strategy, between stocks and even individuals.

Railway construction in Washington began in the 1870s and accelerated after statehood as predecessors to the Northern Pacific Railroad developed railroads along Salish Sea tidelands. Northern Pacific merged with 4 other railroad companies in 1970 to form the Burlington Northern Railroad, the predecessor to today's BNSF. The rail lines along the Salish Sea serve a combination of passengers and freight. The rail lines were often initially constructed as trestles along the shoreline with the railroad elevated above mean higher high water (MHHW). Subsequent backfilling and hardening with ballast and riprap have resulted in the current configuration. During backfilling many stream crossings became managed as culverts, which

Figure 1. Map of BNSF Railway Along Salish Sea shorelines in the Study area.

appear to be sized primarily for maintaining drainage and preventing flooding impacts to the railroad. The causeway, or raised track along the shoreline areas, traverses many shoreline landforms including along the toe of coastal bluffs and across the mouths of coastal embayments. The railroad was often sited waterward of the historic tidal high-water mark, and therefore the causeway can create an abrupt transition from deep water to the elevated track. A few segments of railway continue to be maintained as trestles; however, most of the railroad along the Salish Sea is maintained as traditional at-grade railway with tracks over wooden or concrete sleepers with rock ballast.

The presence of culverts can impact stream habitat and fish migration. Depending on the type and size, culverts may affect habitat area, water quality, upstream or downstream channel conditions, ecological connectivity for fish and wildlife. Stream crossings along the BNSF Railway include a variety of structures including trestles, 4-sided box culverts, as well as round culverts. Box culverts and trestles tend to be larger or more modern structures that may be sized to allow for debris and wildlife to move through the crossing. In addition, culverts require regular maintenance to prevent debris from blocking the culvert and to avoid the risk of catastrophic culvert collapse or failure. Culverts channelize the stream into a structure, often dramatically reducing the stream width and preventing any relationship between the stream and adjacent floodplains. Therefore, in-stream flows increase, often creating flows that preclude upstream migration and scour downstream habitat. Culverts associated with the railroad were designed and constructed long ago before the maintenance and fish passage issues were understood or regulated.

Culvert and embankment fill can cover fish habitat on channel beds and banks. By concentrating stream flow in a narrow pipe, stream velocities are often faster than natural flood-plain based stream systems. This process leads to downstream deposition of sediment and increased erosion. Increased stream slopes, long culverts, and high stream velocities can all impair or prevent upstream passage of fish. In addition, some culverts are perched such that the outlet discharges far above the substrate or waterbody, thereby precluding upstream migration. In addition, culverts often lack substrate and are disconnected from stream bank habitats that create habitat structure and forage resources in natural systems. Crossing structures also reduce the potential for transport of large woody debris (LWD) or for LWD to become embedded in the streambed. Regular maintenance of culverts tends to focus on maintain the structure’s integrity and preventing debris from blocking the flow of water through the culvert.

Collectively, the streams that cross the BNSF Railway along the marine shorelines include more than 377 square miles (241,362 acres) of total watershed area and 234 miles of stream length. Figure 2 shows stream mouths along the Salish Sea shoreline identified by GIS. In addition to stream crossings, several embayments occur along the marine shoreline. Embayments are sheltered estuaries and lagoons, often containing saltmarsh vegetation, that receive little wave action to form beaches (Shipman 2008). The BNSF Railway corridor includes several historical embayments that were created by the causeway, in addition to many natural embayments such as coastal lagoons and barrier estuary systems.

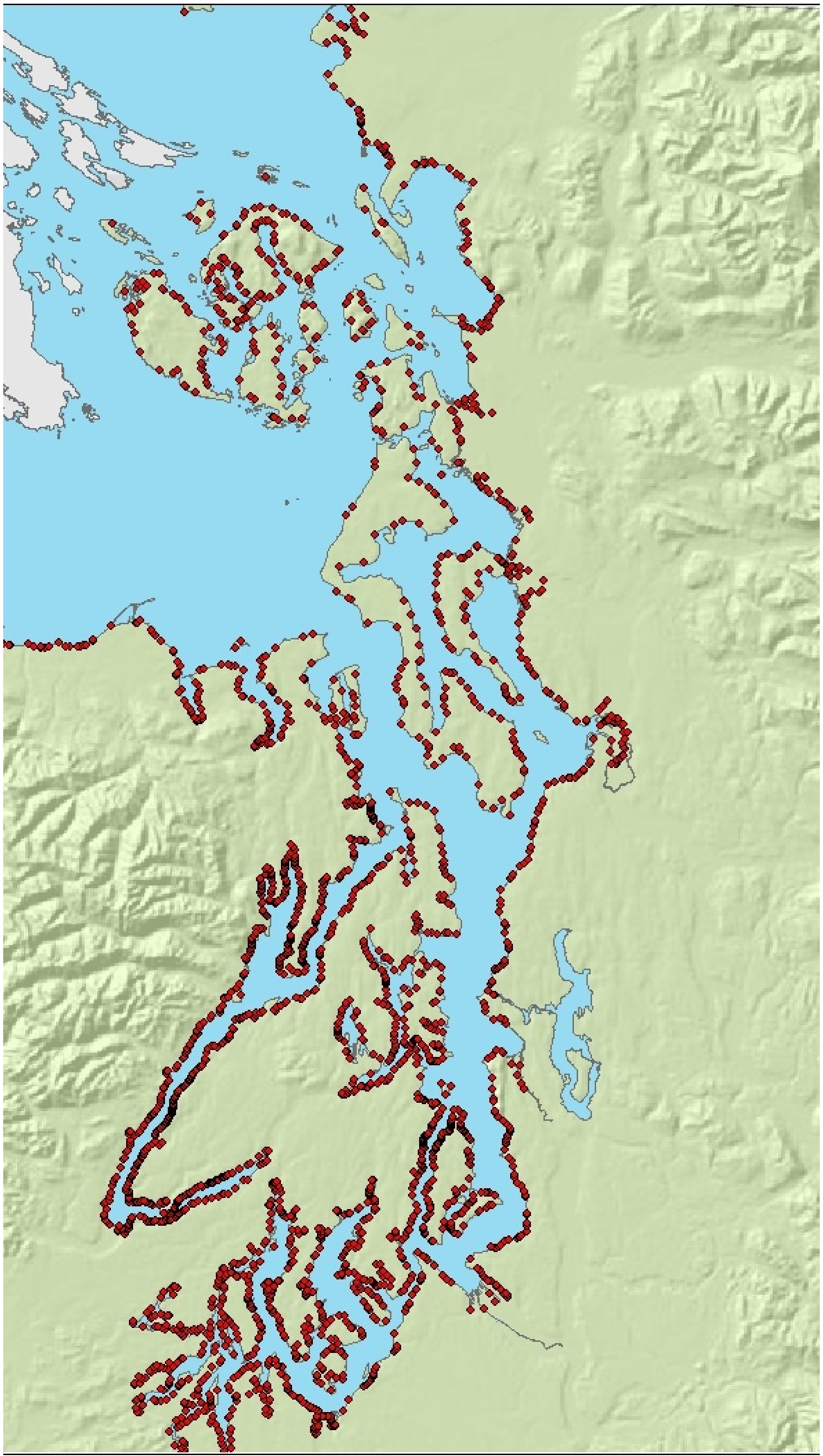

Figure 2. Coastal Stream Mouths along the Puget Sound shoreline.

2.0 PROJECT APPROACH

The project approach had 3 main steps, each of which is described in the following sections of the report:

1) GIS and field culvert data collection (biological, physical, etc.) (Section 3.0).
2) Prioritization framework development (Section 4.0).
3) Evaluation of prioritization framework scores to inform future decisions (Section 5.0).

This sequence allowed for an understanding of the data that could potentially be included in the framework and then a prioritization of culverts based on actual available data. Methods and results of the field inventory (Section 3.0) and prioritization framework development (Section 4.0) are described separately, as the fieldwork provided the foundation for compiling the data in the prioritization framework.

To draw upon the expertise and local knowledge of restoration and conservation specialists in the Puget Sound area, an Advisory Group was assembled for the project. Advisory Group participants included representatives from the Washington Department of Fish and Wildlife (WDFW), Washington State Department of Ecology (Ecology), BNSF, county governments, and non-profit organizations (Table 1). Tribal participation by the Tulalip Tribes was included in the project team leading the project.

Table 1. Members of the Advisory Group

Name	Agency / Entity
Dava Kaitala	BNSF
Courtney Wallace	BNSF
Hugh Shipman	Washington Department of Ecology (ret.)
Jay Krienitz	WDFW - Estuary and Salmon Restoration Program
Tish Conway-Cranos	WDFW - Estuary and Salmon Restoration Program
Kathleen Pozarycki	Snohomish County
Kristin Williamson	South Puget Sound Salmon Enhancement Group
Doris Small	WDFW
Pad Smith	WDFW

The project was developed as a collaborative effort with agency staff, interested experts, and BNSF environmental managers helping facilitate data collection and providing oversight for site prioritization. Over the course of the project, the Advisory Group was convened in 3 meetings, one in May 2018, a second in October 2018, and a final in September 2019. The meetings covered the following topics:

- Meeting 1
  - Project Goals and Objectives
  - Project Approach
  - Project Schedule
  - Field Data Collection Planning
- Meeting 2
  - Field Data Collection Results
  - Draft Stream Prioritization Framework
  - Draft Embayment Prioritization Framework
- Meeting 3
  - Review of Preliminary Outputs from Prioritization Frameworks

The Advisory Group provided input at these key steps throughout the project. Its role included providing review of interim deliverables, which was instrumental in developing the final prioritization framework.

3.0 CULVERT AND EMBAYMENT INVENTORY

3.1 Inventory Methods

3.1.1 Existing Information and Field Reconnaissance

During initial stages of the project, it was determined that no existing database identifying the location, condition, or number of culverts along the BNSF Railway exists. Therefore, a major component of the initial fieldwork was to create a comprehensive inventory of known stream crossings and structures. This systematic effort began with a GIS evaluation of known and predicted streams and identified the intersection of those stream segments with the railroad to identify predicted stream crossing locations (Figure 3). Field crews were sent to these locations and explored along the railroad to identify stream crossings (Section 2.0).

A preliminary inventory of predicted stream crossings was generated by intersecting stream hydrography data provided by WDFW with the existing railroad and shoreline. This generated a list of 236 points where streams of varying lengths and watershed areas were predicted to cross the railroad operated by BNSF Railway within 200 feet of a marine shoreline. The field inventory found that many smaller streams have no apparent outlet across the railroad. In addition, some streams have been routed parallel to the railroad and may cross the railroad through more than 1 culvert. Finally, some culverts that were identified in the field do not appear to be associated with known streams. These may drain residential areas or wetlands that are adjacent to the railroad. Streams in the study area vary in length and size from very short predicted stream lengths (as short as 8 meters) to creeks that flow more 39 km. Larger rivers that cross the BNSF Railway corridor, including the Nisqually, Puyallup, Duwamish, Snohomish, Skagit, Skykomish, and Nooksack rivers, were not included in this analysis because these crossings are larger bridges and trestles and tend to be more than 200 feet from the marine shorelines.

Potential embayments were identified by reviewing aerial photos and consulting with regional experts. These sites were inventoried in the field and through a desktop exercise where analysts reviewed aerial imagery and available GIS data to assist in evaluating the sites.

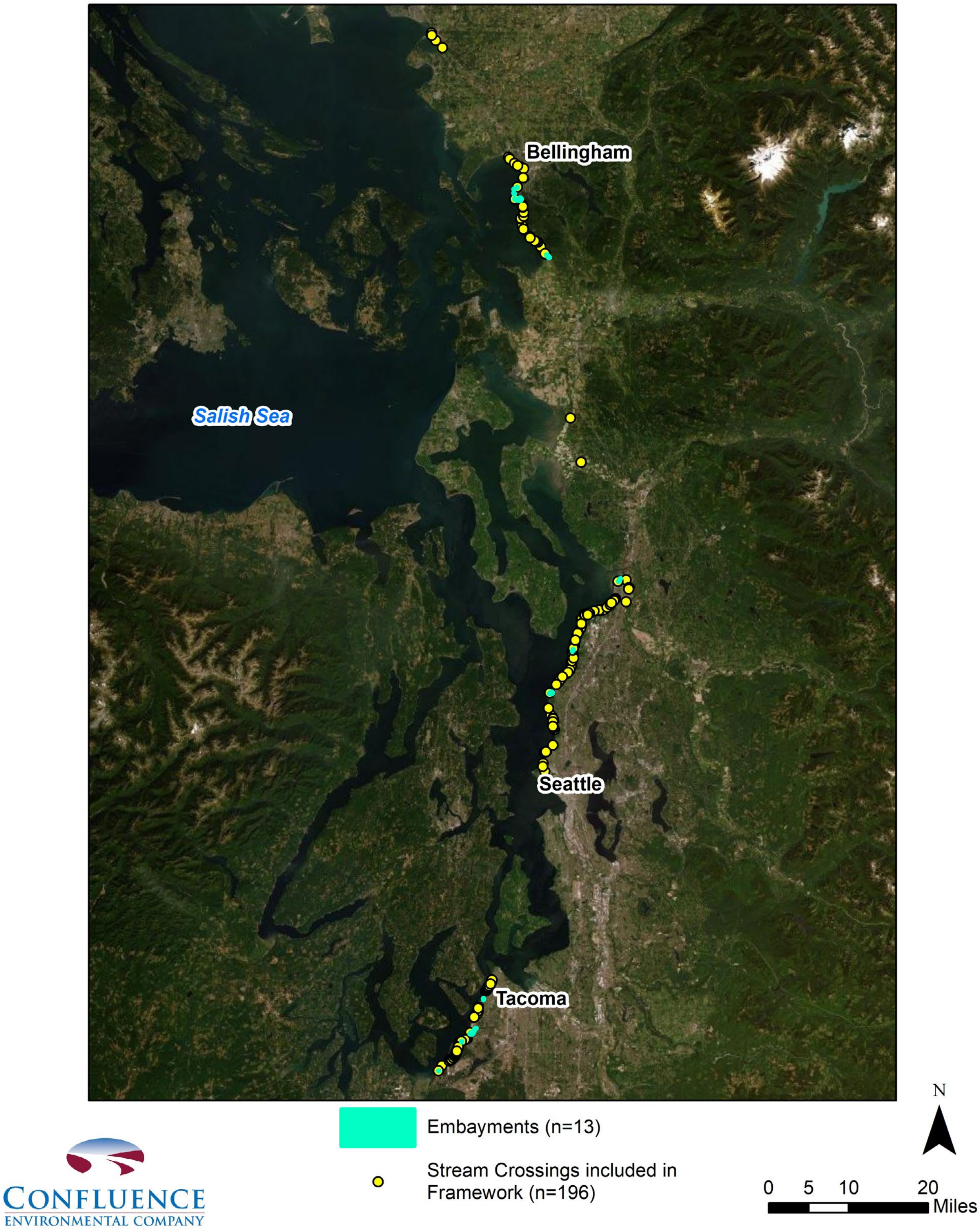

Figure 3. Overview of stream crossings and embayments included in framework

3.1.2 Comprehensive Field Inventory

Predicted stream crossing locations were used to create a field inventory study plan. The field effort comprised a complete inventory effort for the BNSF trackway between Sequalitchew Creek just north of the Nisqually River to the Canadian border. Fieldwork was conducted primarily in the summer months (May through September), when flows were low. Sites were visited by teams of 3 field staff that initiated surveys from the marine shoreline, in most instances accessing the sites using a small vessel or by foot along the marine shoreline. Prior to visiting sites along the railroad, field staff completed BNSF Contractor Safety Training and a project-specific safety plan was implemented to ensure staff safety along the railroad corridor. BNSF was notified for access approval prior to all field days. Any culverts observed within the study area were characterized.

A field survey protocol was adapted from the WDFW culvert inventory methods (WDFW 2019). The field survey form included information about the site location, downstream conditions, stream crossing structure and outlet conditions, and upstream and stream inlet conditions (Appendix D). Additional information was collected for sites that included an embayment regarding presence of outlet structures or seeps in the railroad embankment, presence of scour pools or freshwater inlets to the embayment, and presence of salt-tolerant vegetation. For each crossing structure, data collected included submeter location information using a GPS (RTK GPS was used when available) as well as inlet, outlet, upstream, downstream, and site context photos.

During the field inventory, some of the culverts were inaccessible due to property restrictions upstream or downstream of the crossing structures. A subset of predicted stream crossings did not appear to have associated stream crossings and either did not flow as streams in the current landscape, had buried culverts that were not visible at low tide, or had been diverted into other infrastructure. In several areas there appeared to be ditches or channels that conveyed streamflow along the upstream edge of the railroad which either intercepted stream, wetland, or seep runoff that drained through culverts. Furthermore, several culverts were dry at the time of inventory and may convey primarily stormwater runoff or ephemeral streams to the Salish Sea shoreline.

If the culvert lacked flow, limited information was collected to document the location of the culvert. In most cases downstream conditions were characterized first before field staff crossed the BNSF right-of-way to access the upstream area. When staff were near or crossing the BNSF right-of-way, a lookout watched to ensure staff were aware of any trains traveling on the tracks.

Railroad-bounded embayments were also characterized; however, embayments can be large features on the landscape, so these features were assessed using a combination of field effort and office review of available aerial photos and GIS data.

Data were recorded in the field using digital cameras, GPS systems, and paper site inventory forms. After fieldwork was completed, photos and GPS information were downloaded, and field data was input into a project database.

3.2 Culvert and Embayment Inventory Field Observations

A total of 196 stream crossing structures were identified and inventoried along the shoreline between Olympia and Canada. Some predicted stream crossing structures were inaccessible due to their context or private property restrictions. Of the inventoried crossing locations, 49 did not appear to be associated with previously known streams. These culvert structures may convey streamflow from urban infrastructure (e.g., stormwater conveyance networks) or may be primarily used to support drainage from wetlands or seeps that are upstream of the railroad. A small number of streams were inventoried and included in the analysis despite having trestle bridges in place. While these bridges and their abutments may not be sized to fully avoid impacts to ecosystem processes, they were all deemed to be wide enough to allow fish movement and therefore be unlikely targets for restoration for fish access. These sites included: Little Squalicum Creek, Padden Creek, Oyster Creek, Chambers Creek, and an unnamed creek near Steilacoom.

Throughout the inventory area, there was a wide range in various characteristics of the culverts and associated streams. Most inventoried structures were either round or oval culverts (67% of sites; see Figure 4). Culverts ranged between 12 inches and 102 inches in width, with most structures between 24 inches and 48 inches in width. Other types of crossings included box culverts and trestles (Figure 5).

While most culverts discharged above mean higher high water, 26 appeared to backwater at high tide to the upstream end of the culvert, while an additional 31 appeared to backwater such that MHHW extended partway to the upstream of the culvert. Structures had slopes ranging from 0% or slightly negative (i.e., lower on upstream end) to as steep as approximately 19%. Field data showed that at least 65 sites appeared to have more than 200 feet of stream habitat upstream of the crossing, with stream lengths in culverts ranging from a minimum of 10 feet to a maximum of 384 feet.

At least 80 structures appeared to be perched at low tide with structures discharging between 0 and 25 feet above grade (Figure 6). Water depth in structures varied between 0 and 13.2 inches, with 52 culverts having water depths of 1 inch or more. A small number of structures had been modified since they were initially installed, either to repair a failing structure or to extend the serviceable life of the crossing structure. Some of these modified structures may have different capacities than the initial structures (Figure 7).

Figure 4. Examples of round culverts encountered in field survey—dual concrete (left), metal (center), concrete (right)

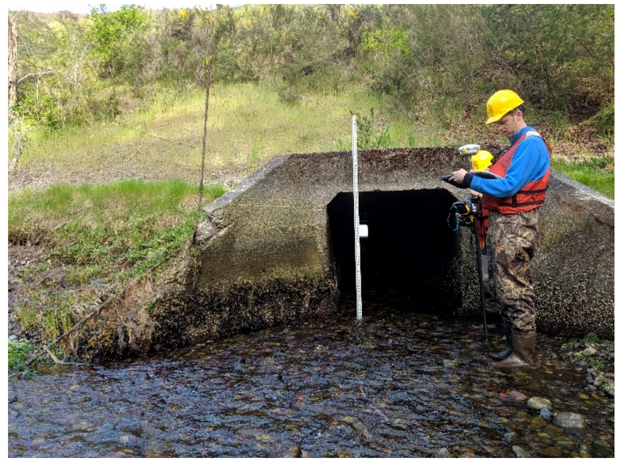

Figure 5. Other crossing types encountered—trestle (left) and box culvert (right)

Figure 6. Examples of stream culverts that are at grade (left) and perched (right)

Figure 7. Example of culvert that has been slip-lined to extend serviceable life, which has reduced the culvert size

Embayments were characterized separately from stream crossings. A total of 13 embayment sites were identified where the railroad cut-off a portion of the historic shoreline from being fully connected to Puget Sound or the railroad altered the connection between historic lagoons or estuaries and Puget Sound (Figure 8). Four of the 13 sites were behind culverts and are also included in the stream crossing inventory, while 8 sites have trestles and 1 site has no observed connection to the adjacent marine shoreline. Each embayment site tends to be unique, with each site representing unique pre-development conditions and different responses to development. Seven of 13 sites include notable stream inputs of freshwater and stream habitat upstream of the embayment; 1 site likely had historical stream inputs that have been reconfigured due to urban development; and the remaining 5 sites likely lacked freshwater stream inputs historically and currently.

Data for both the streams and embayments were compiled into a ESRI ArcGIS geodatabase. Further description of this data is provided in the Geodatabase User Guide (Appendix C).

Figure 8. Locations of embayments and examples of embayment types

4.0 PRIORITIZATION FRAMEWORK

4.1 Framework Development

Frameworks were developed for rating the current ecological value for streams and embayments. In addition to data from the field inventory (Section 3.0), data were integrated from the Puget Sound Nearshore Estuary Restoration Program (PSNERP), WDFW stream and fish presence data, Ecology digital aerial photos, Ecology's Puget Sound Watershed Characterization Project, and NOAA's Coastal Change Analysis Program (Table 2). Ultimately, a dataset provided by WDFW called the Synthetic Stream dataset provided a significant component of the stream and watershed data. This dataset is comprised of stream locations developed by Terrainworks that has been verified by WDFW as a representative characterization of stream locations and has been integrated by WDFW with data about fish habitat status and watershed conditions.

Table 2. Compiled Data Sources and Access

Data Source	Data Used	Link
Puget Sound Nearshore Estuary Restoration Program (PSNERP)	Historic and Current Shoreforms	http://www.pugetsoundnearshore.org/
WDFW	Statewide Washington Integrated Fish Distribution	https://data-wdfw.opendata.arcgis.com/datasets/statewide-washington-integrated-fish-distribution
WDFW	WDFW Synthetic Streams	Data derived from NetMap developed by Terrainworks www.terrainworks.com
Ecology	Shoreline aerial photos	https://fortress.wa.gov/ecy/shorephotoviewer/Map/ShorelinePhotoViewer
Ecology	Puget Sound Watershed Characterization Project	https://fortress.wa.gov/ecy/coastalatlas/wc/MappingPage.html
NOAA	Coastal Change Analysis Program (C-CAP)	https://coast.noaa.gov/digitalcoast/tools/lca.html

Criteria for stream crossings were based on the likelihood of juvenile Chinook Salmon use and upstream habitat quality (Table 3). Attributes were grouped into these two categories in order to capture the two main ways the quality of stream habitat can influence juvenile salmonid growth and success. The likelihood of juvenile Chinook Salmon use category represents the potential of the stream as direct habitat for individuals. On the other hand, the upstream habitat quality category represents the potential of the stream to provide prey and other resources to the nearshore environment. This has an indirect effect on juvenile Chinook Salmon success. The upstream habitat score is based on existing conditions. It is foreseeable that restoration to address the stream mouth culvert would also include upstream habitat restoration that would increase the quantity and quality of stream habitat, thus changing the calculation of the upstream habitat score.

The likelihood of stream use by juvenile Chinook Salmon was influenced by field research by Beamer et al. (2013) and Zackey et al. (2015). Although Chinook Salmon do not spawn in small coastal streams (instead relying on larger river systems), these researchers documented juvenile Chinook using the lowermost portions of non-natal streams. Beamer et al. (2013) identified four main factors influencing whether juvenile Chinook were present in the 73 small streams they sampled in the Whidbey Basin: 1) proximity to nearest Chinook Salmon bearing river, 2) watershed area, 3) stream channel slope, and 4) whether a culvert backwaters at high tide. These categories and approximate thresholds described in Beamer et al. (2013) were included in the scoring framework to characterize the likelihood of juvenile Chinook using a stream. Additional parameters used in the scoring were if salmon were documented in the stream and if the stream mouth included a stream delta or pocket estuary. Pocket estuaries were documented in Beamer et al. (2003 and 2006) as being preferentially used by juvenile Chinook compared to adjacent beach habitats. The framework scoring assumed that the juvenile Chinook stream use observations documented in the Whidbey Basin are applicable to all shorelines evaluated in the study. This is an assumption that should be revisited in the future as a greater understanding of juvenile Chinook (and other salmon) use of these habitats is gained through further research.

Upstream habitat was characterized based on riparian condition in the lower watershed as well as the presence of habitat features suggesting that the stream could support salmonids. Riparian condition indicates the potential for shade, large woody debris inputs or terrestrial insect prey items. Presence of large woody debris indicates the potential for habitat forming processes in the stream channel. The absence of anthropogenic structures and development that have been associated with lower function of stream ecosystems for fisheries was also assessed.

Parameters in Table 3 were characterized from either field observations or interpreted from regional GIS data. Chinook spawning streams and rivers were identified from SSHIAP data. Euclidean buffer distances of 7, 14 and 20 kilometers were generated around each river mouth to identify distance categories for each stream crossing site for the Proximity to Documented Chinook river parameter. Pocket estuaries are defined within the PSNERP dataset. Sites with pocket estuaries, barrier estuaries, historic barrier embayments, stream deltas or barrier beaches that encompass or are immediately adjacent to stream crossings were assigned scores. Tidal inundation or backwatering characteristics were defined based on field observations. Field observers recorded whether the stream crossing is observed or predicted to backwater at high tide. Scores were assigned based on whether the entire structure's length is predicted to backwater or only part of the structure's length. Salmon spawning is based on historic field observations of salmonid spawning activity as recorded by WDFW. Intrinsic potential is a habitat modeling approach based on channel confinement calculations based on 10 meter digital elevation model (DEM) datasets derived by Terrainworks. Watershed size is derived from drainage calculations using 10 m DEM's to calculate the drainage area. Drainage calculations occurred as part of the PSNERP project as well as part of the Terrainworks dataset. These areas were used to determine the watershed size for streams within or immediately adjacent to the watershed. Stream gradient was calculated from the slope of stream segments from the upstream segment to the downstream segment for the lower 200 feet of stream. This parameter was also calculated in the field using a clinometer to evaluate the first 200 feet upstream of the stream crossing. Field data was integrated with calculated data because the upstream was not accessible for many stream segments. Upstream culverts within the first 200 feet upstream of stream crossings were identified during the field inventory culverts on the streams described by the WDFW Synthetic stream layer and comparing them to the culverts within the WDFW barrier database. These datasets were used to identify upstream road crossings (potential culverts) and culverts. The riparian buffer condition was evaluated using C-CAP land cover data derived from satellite imagery. This imagery is assessed for land cover classes and identified developed, agricultural, forestry, and wetland land classes. Developed and agricultural land use classes were characterized as 'developed' and used to evaluated land use characteristics within 200 feet of stream channels. Bank armoring was characterized in the field by trained observers who characterized whether bank armoring or inlet armoring is present within the first 200 feet upstream of the stream crossing. Woody debris was also assessed in the field where woody debris was classified as large (> 12 inch diameter), medium (6 to 12 inch diameter) and small (<6 inch diameter). Wood debris pieces within the active stream channel were assessed for the first 200 linear feet upstream of the stream crossing. Water quality was assessed for metals degradation by Ecology using its water quality classification method which assigned values range from low to high metals degradation to watersheds. These values were then assigned to streams within the watershed.

Table 3. Coastal Stream Prioritization Framework

Likelihood of Stream Use by Juvenile Chinook Salmon			
Parameter	**Metric**	**Score**	**Data Source**
Proximity to WDFW documented Chinook river	< 7 km	5	GIS
	7-14 km	3	
	14-20 km	1	
	>20 km	0	
Presence of pocket estuary, stream delta, or PSNERP identified barrier beach (BAB) or barrier estuary (BE)	Pocket estuary, barrier estuary (BE), or historic embayments	5	PSNERP, historic embayments; field data; aerial photos or stream delta indicators
	Stream delta or barrier beach (BAB)	3	
	None	0	
Tidal inundation extends upstream of culvert (backwater)	Yes	3	Field data
	Partial	1	
	No	0	
Salmon spawning or intrinsic potential	Chinook spawning or intrinsic potential	4	WDFW Synthetic stream or SWIFD data
	Documented salmonid spawning	3	
	Salmonid intrinsic potential	2	
	No documented use	0	
Watershed size	300 acres	5	WDFW Synthetic stream data
	100-300 acres	3	
	< 100 acres	0	
Stream gradient	<3%	3	WDFW Synthetic stream data
	3.0-6.5%	2	
	>6.5%	0	

Upstream Habitat Access & Quality			
Parameter	**Metric**	**Score**	**Data Source**
Another culvert or instream modification affecting access to upstream habitat within 200 ft of railroad	No culvert or road crossing	3	Field data, WDFW barrier database, WDFW Synthetic stream data
	Upstream road crossing	1	
	Culvert within 200 ft	0	
Riparian vegetation quality	Good/excellent	2	Field data
	Fair	1	
	Poor	0	
Riparian buffer (100 ft of lower 200 m of stream)	50-100% natural vegetation	2	NOAA C-CAP land cover data
	30-50% natural vegetation	1	
	0-30% natural vegetation	0	
Bank armoring (not associated with culvert)	None	2	Field data
	On One Bank	1	
	On Both Banks	0	
Woody debris in stream	>5 pieces of large (> 12 inch diameter) or medium (> 6 inch diameter) woody debris	2	Field data
	1-5 pieces of large or medium woody debris	1	
	No woody debris	0	
Water quality – metals degradation	Low metals degradation (good water quality)	5	Ecology watershed characterization – water quality – metals degradation
	Moderate	3	
	Moderate-high	1	
	High metals degradation (poor water quality)	0	

Some stream crossings are associated with embayments. These were assessed in both the embayment and stream crossing; however, additional characterization occurred for embayments particular to the unique characteristics of these sites. The prioritization framework for embayments follows a similar logic and structure to the stream crossings (Table 4); however, additional priority was assigned to wetland and total area.

Embayments were characterized using some similar methods to the stream crossings. For example, proximity to major Chinook rivers is used for both stream crossings and embayments. The Puget Sound Nearshore Ecosystem Restoration Program (PSNERP) used historic maps to classify historic shoreforms along the nearshore (Simestad et al. 2011). The presence of historic barrier estuary, barrier lagoon, coastal lagoon or open coastal inlet shoreline features are clear indicators of historic estuarine habitats that may have been isolated or impacted by railroad development. Larger impoundments contain large amounts of potential wetland and estuarine habitats and therefore larger sites are assigned greater potential value. Impoundments were measured as the area upstream of the marine outlet or crossing below the predicted ordinary high water mark as mapped using aerial photos. Furthermore, the presence of a stream entering an embayment or estuary indicates the presence of freshwater stream habitat that salmonids may access for foraging, rearing or migration. The presence of salmonid spawning in the system is an indicator of the potential habitat value for salmonids. Upstream habitat for embayments considers the length of stream habitat accessible with greater lengths conferring greater value, the size of the contributing watershed with larger watersheds more likely to have perennial flow that can form stable stream channels, and watersheds with higher water quality providing better conditions for salmonid and salmonid prey item growth and development.

Table 4. Prioritization Framework for Embayments

Likelihood of Stream Use by Juvenile Chinook Salmon			
Parameter	**Metric**	**Score**	**Data Source**
Proximity to major Chinook river	< 7 km	5	GIS
	7-14 km	3	
	14-20 km	1	
	>20 km	0	
Site historically was an embayment (PSNERP categories Barrier Estuary (BE), Barrier Lagoon (BL), Coastal Lagoon Marsh (CLM) or Open Coastal Inlet (OCI)	Yes	5	PSNERP, historic embayments; field data; aerial photos or stream delta indicators
	No	0	
Size of impoundment	>3 acres	3	Field data/GIS
	1-3 acres	2	
	<1 acre	1	
Stream is present	Yes	5	WDFW Synthetic stream or field data
	No	0	
Documented presence of spawning salmon in associated stream	Yes	5	WDFW Synthetic stream or SWIFD data
	No	0	

Upstream Habitat Access & Quality			
Parameter	**Metric**	**Score**	**Data Source**
Length of accessible stream (<6.5% slope) present upstream of railroad	>400 ft	3	WDFW Synthetic stream data
	200-400 ft	2	
	< 200 ft	1	
Watershed size	>300 acres	3	GIS, Synthetic stream data
	100-300 acres	1	
	< 100 acres	0	
Water quality – metals degradation	Low metals degradation (good water quality)	5	Ecology watershed characterization – water quality – metals degradation
	Moderate	3	
	Moderate-high	1	
	High metals degradation (poor water quality)	0	

4.2 Prioritization Binning

Scores are summed within categories to arrive at a total score for each category. For example, the scores comprising the Likelihood of Chinook Use score add up to a single score; however, scores across different categories are not intended to be summed. Instead, scores translate into prioritization bins (Table 5).

Table 5. Prioritization Bins for Stream Crossing and Embayment Sites

		Likelihood of Stream Use by Juvenile Chinook		
		Low (0-6)	Moderate (7-13)	High (14-24)
Upstream Habitat Access and Quality	High (8-14)	Moderate	High	Highest
	Moderate (5-7)	Low	Moderate	Highest
	Low (0-4)	Low	Moderate	High

Prioritization bins were not assessed for embayments. Like stream systems, the scores for each axis of site attributes informs the potential priorities, and sites that score high for both likelihood of use by juvenile chinook and habitat access and quality are the highest priority sites. However, it was recognized that the embayment sites each represent unique circumstances that are difficult to generalize into meaningful prioritization categories.

4.3 Prioritization Results

4.3.1 Stream Sites

For streams, the Likelihood of Stream Use by Juvenile Chinook Salmon scores range between 0 and 24 while Upstream Habitat scores range between 0 and 14. The largest number of sites received between 3 and 8 points for Likelihood of Stream Use (116 of 196 sites), with 62 sites scoring between 9 and 24 points and 18 sites receiving 0 to 2 points (Figure 9). Upstream Habitat scores show a narrower range, with most sites receiving scores between 4 and 10 (95 of 196 sites) with 8 sites scoring 3 or fewer points and 6 scoring 11 or more (Figure 10). Scores are plotted on to illustrate upstream habitat and likelihood of salmon use on different axes (Figure 11). Sites scoring near the origin of the figure (0,0) are low priorities while sites scoring near the edges (high scores in either component) are higher priorities.

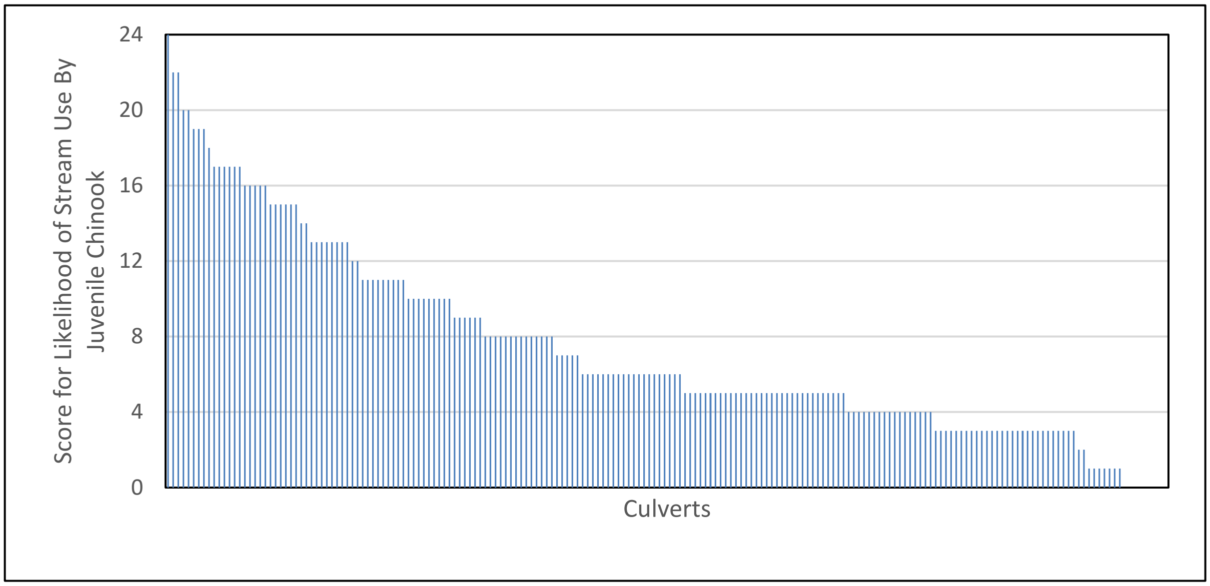

Figure 9. Likelihood of Stream Use by Juvenile Chinook Scores

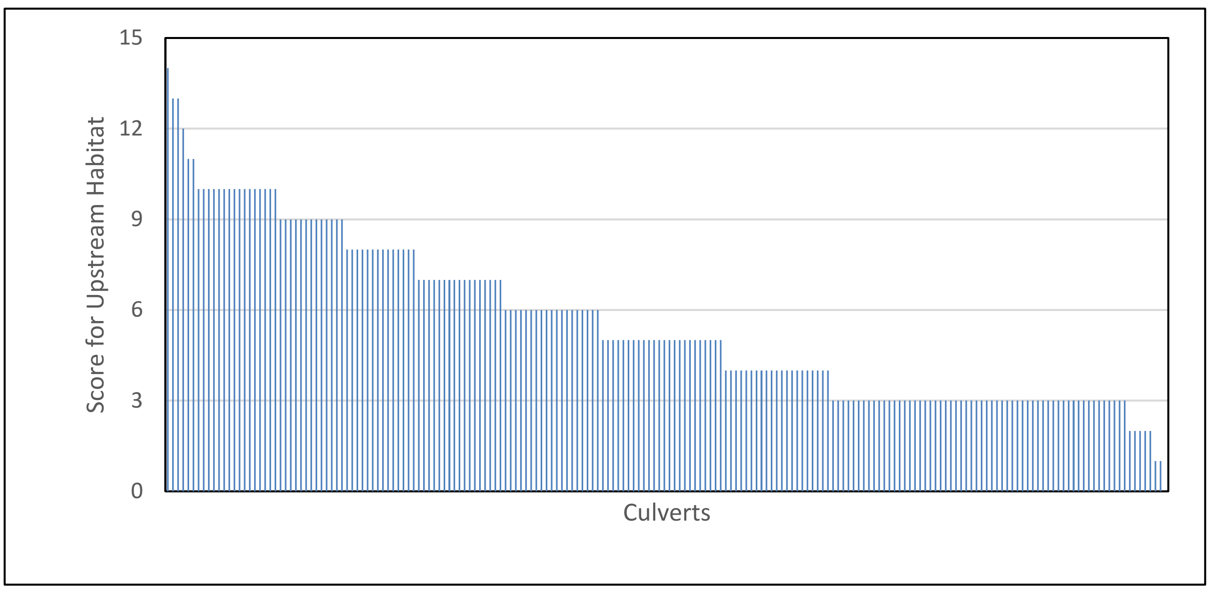

Figure 10. Upstream Habitat Scores

The twenty-five highest scoring streams for each of the scoring categories are shown in Figures 12 and 13. The figures highlight the attributes that make up each score and the variation in scoring for each parameter. The top scoring culverts in the Likelihood of Juvenile Chinook Salmon Use category (Figure 12) are primarily named streams that occur throughout the Puget Sound. Conversely, the top scoring culverts in the Upstream Habitat category (Figure 13) are primarily unnamed streams. These streams are potentially smaller, ephemeral, and may just convey stormwater associated with nearby infrastructure. Overall, the highest scoring groups for each of the categories share just three named stream crossings between them. These culverts are clustered in the upper quadrant of Figure 11. The stacking of the contributing scores in Figures 12 and 13 allows for clear visualization of the major and minor contributing elements to the overall score for a given culvert. Stacked bar charts provide a visual representation of the characteristics comprising a site's overall score.

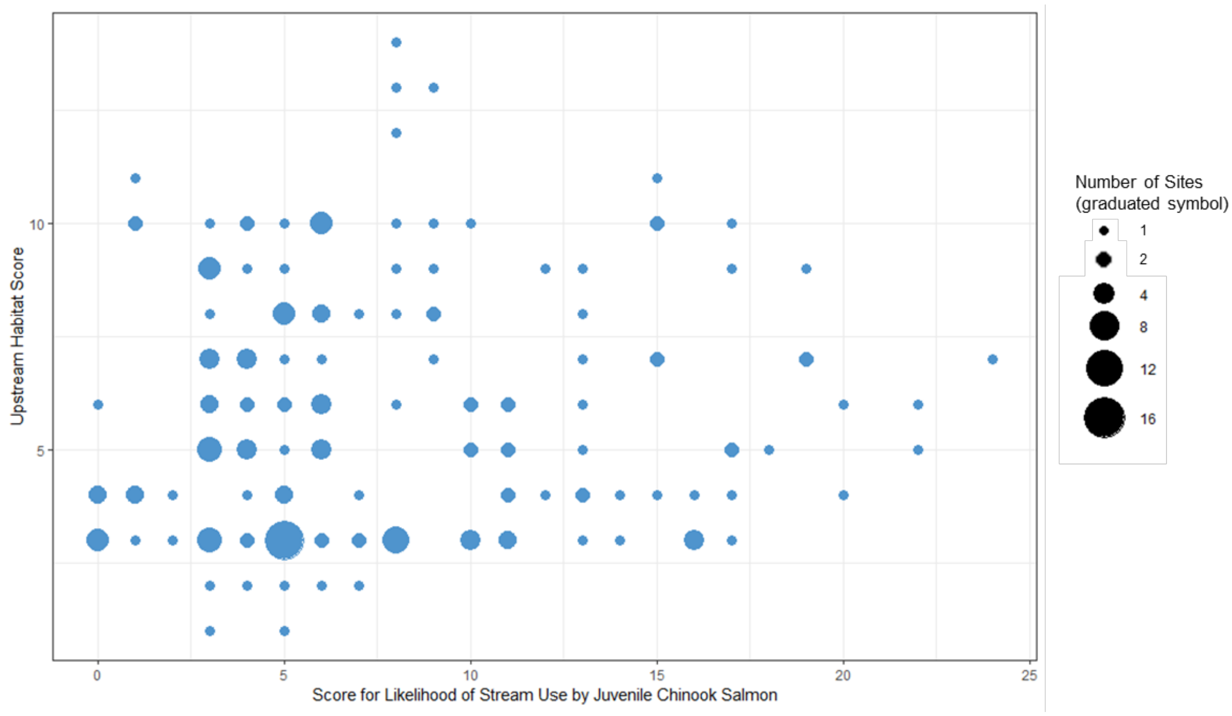

Figure 11. Score distribution for stream crossing sites for Upstream Habitat and Likelihood of Salmon Stream use.

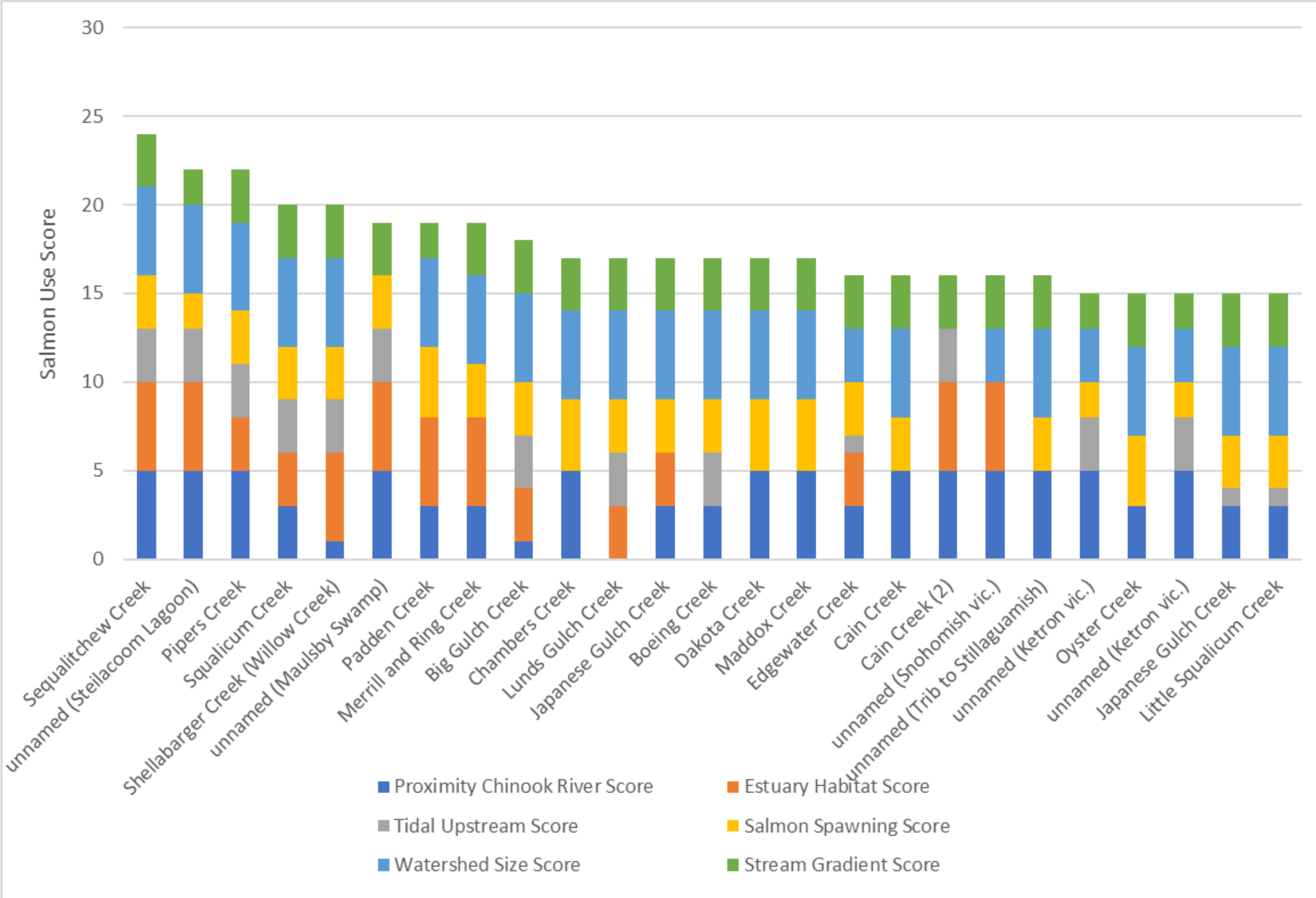

Figure 12. Highest scoring culverts on named streams for the likelihood of juvenile Chinook Salmon use scoring category.

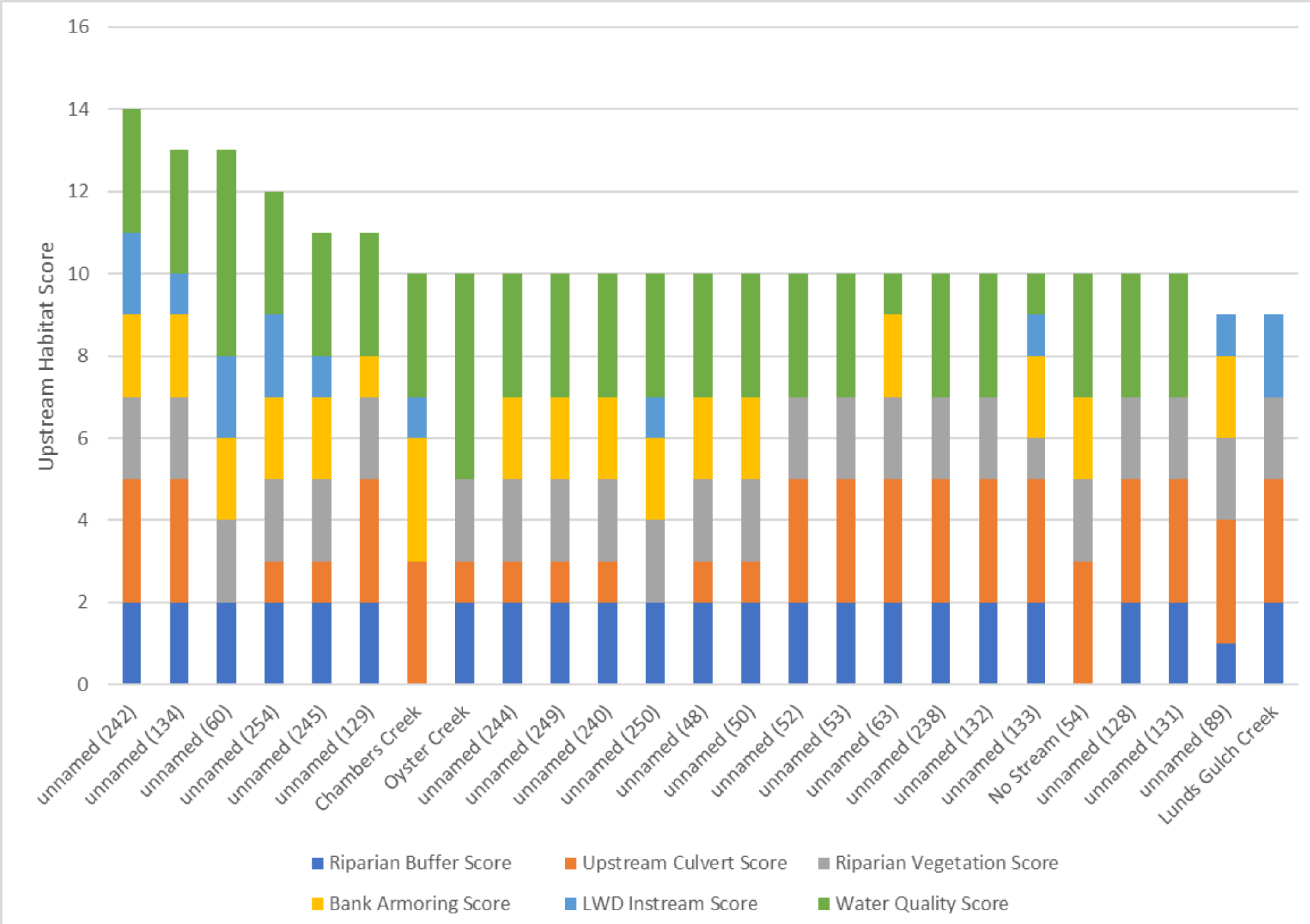

Figure 13. Highest scoring culverts on named streams for the upstream habitat quality scoring category (Numbers identify rating IDs).

The ArcGIS natural breaks classification was used to identify high, moderate, and low score groupings for the Likelihood of Stream Use by Juvenile Chinook and Upstream Habitat categories. Table 6 shows the category score assignment bins.

Table 6. Category Score Assignment Bins Using Natural Breaks

	Likelihood of Stream Use by Juvenile Chinook	Upstream Habitat
High	14 – 24	8 – 14
Moderate	7 – 13	5 – 7
Low	0 – 6	0 – 4

The prioritization tiers assigned using the category bins prescribed in Table 6 are shown in Figure 14. Out of the 196 streams evaluated, 17 were assigned to the highest priority tier, 27 to high, 65 to moderate, and 87 to low. The highest tier sites and their category scores are presented in Table 7.

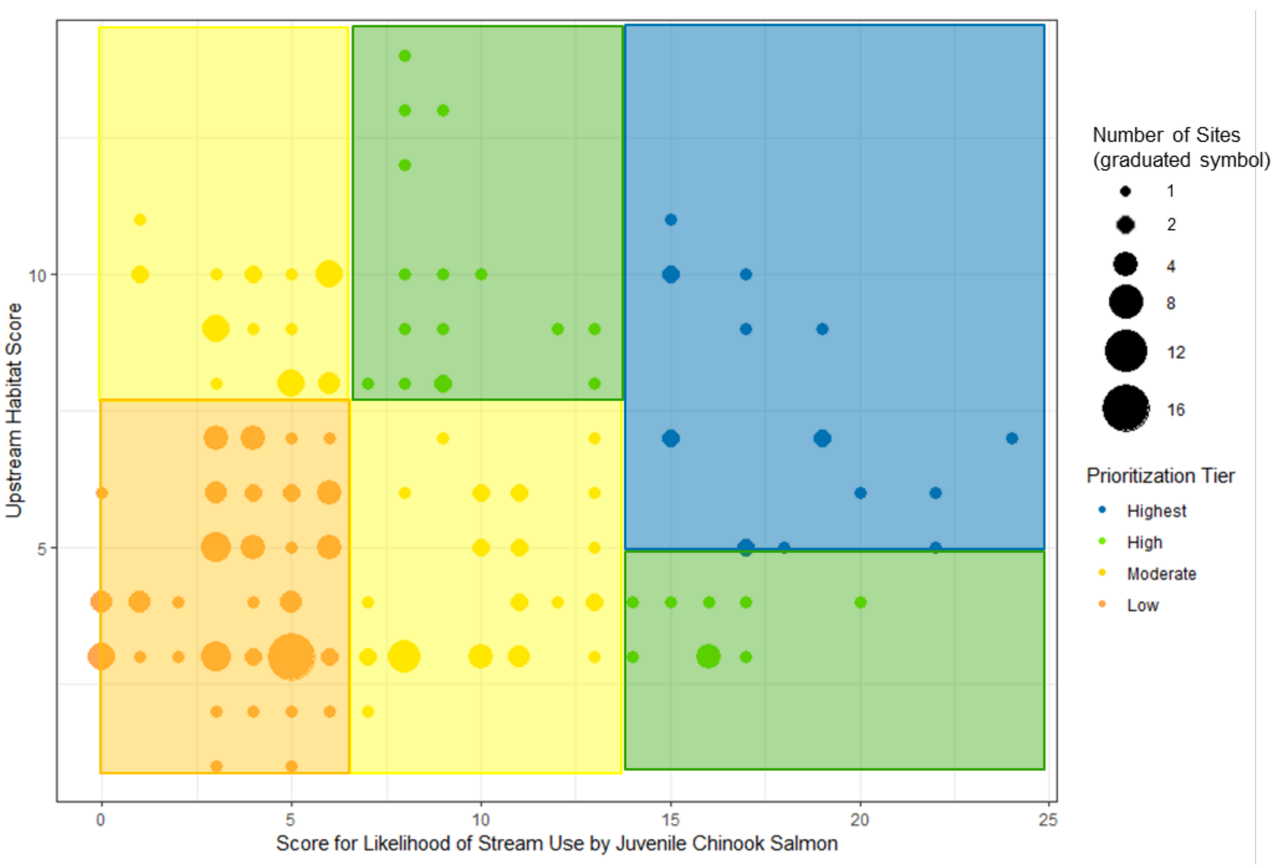

Figure 14. Score distribution for stream crossing sites for Upstream Habitat and Likelihood of Salmon Stream Use with prioritization tiers.

Table 7. Highest Priority Tier Streams

Rating_ID	Stream_Name	Likelihood of Stream Use by Juvenile Chinook	Upstream Habitat	Prioritization Tier
232	Sequalitchew Creek	24	7	Highest
255	Unnamed*	22	6	Highest
1	Pipers Creek	22	5	Highest
258	Squalicum Creek	20	6	Highest
89	Unnamed	19	9	Highest
2	Padden Creek*	19	7	Highest
18	Merrill and Ring Creek	19	7	Highest
38	Big Gulch Creek	18	5	Highest
189	Chambers Creek	17	10	Highest
150	Lunds Gulch Creek	17	9	Highest
99	Japanese Gulch Creek	17	5	Highest
220	Boeing Creek	17	5	Highest
245	Unnamed	15	11	Highest
6	Oyster Creek*	15	10	Highest
244	Unnamed	15	10	Highest
98	Japanese Gulch Creek	15	7	Highest
257	Little Squalicum Creek*	15	7	Highest
*Site currently has a multi-span trestle in place, therefore, may be less of a priority for restoration. Included in table based on category scores.				

The prioritization tiers provide a guideline to assess restoration and conservation potential at each of these locations. Appendix A provides site summaries for the top tier sites (17 sites) and illustrates the types of information available to summarize conditions at each stream site. The upstream habitat score is based on existing conditions; therefore, restoration projects to address the stream mouth culvert may also include restoration of upstream habitats so they are better able to support juvenile Chinook rearing. Given this, the prioritization tier assigned for a site with a low score for upstream habitat could be adjusted if the restoration would include upstream habitat improvements. For example, Shellabarger Creek received the highest score for likelihood of stream use by juvenile salmon among those sites not assigned to the highest prioritization tier. If restoration associated with the railroad crossing is expected to include improvement of upstream habitat in ways that would change the upstream habitat score, then the site could be re-evaluated and possibly change prioritization tier.

4.3.2 Embayment Sites

For embayments, the Likelihood of Site use by Juvenile Chinook Salmon scores range between 5 and 21, with an average score of 14. The salmon use scores are highly influenced by site location and proximity to Chinook rivers. The contributions to these scores for each site are shown in Figure 15. These scores suggest that most sites have moderate to high Likelihood of Chinook Salmon site use.

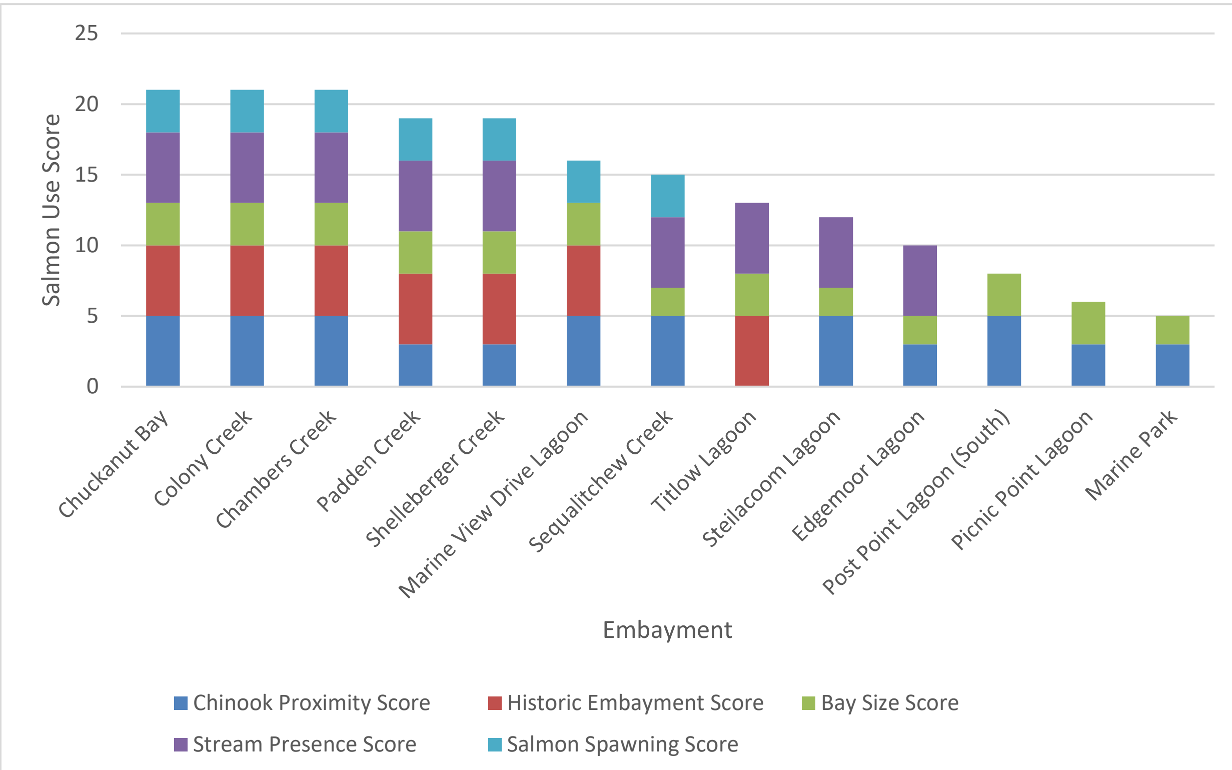

Figure 15. Score distribution for Likelihood of Salmon Use for Embayments.

Upstream and estuarine habitat scores range from 0 to 7 with an average score of 4. The lack of stream inputs to a subset of embayments, identified by Shipman (2008) as lagoons which are categorized by their lack of significant upstream freshwater inputs results in those embayments receiving 0 points in the upstream habitat component of the prioritization framework (Figure 16).

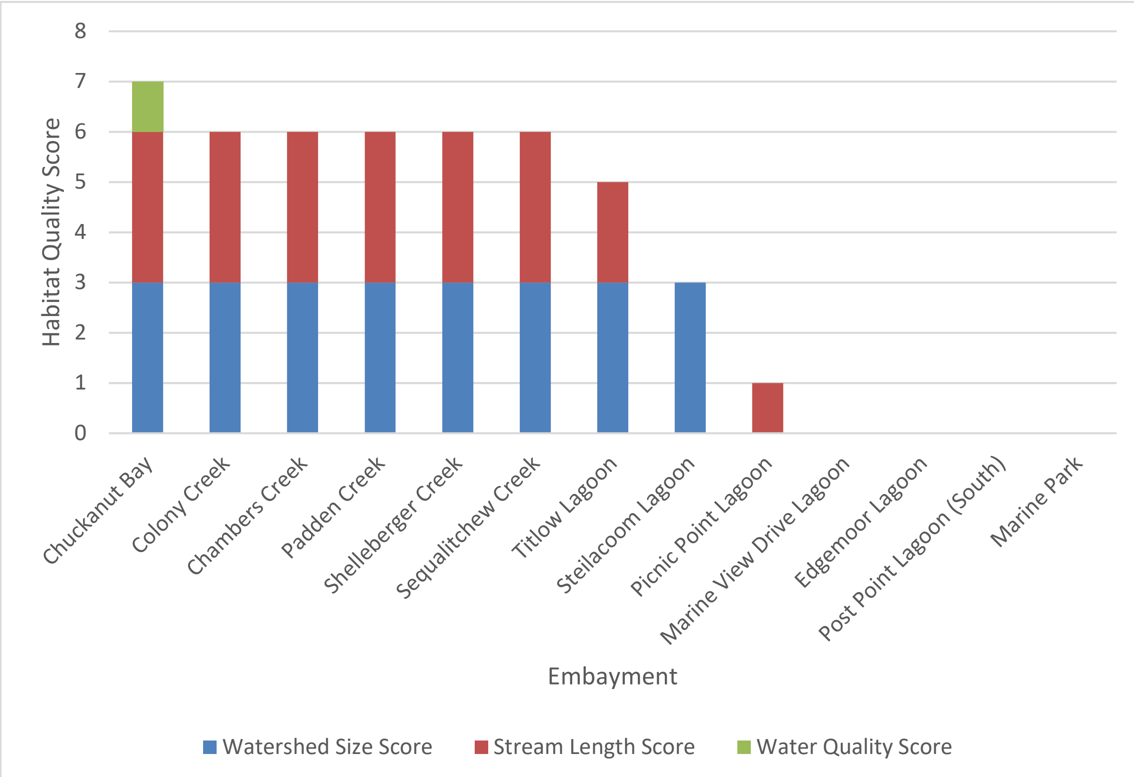

Figure 16. Score distribution for Upstream and Estuarine Habitat scores for Embayments.

Evaluating both components of prioritization scores reveals that scores tend to be aligned along the diagonal axis with increasing Likelihood of Chinook Use and Habitat Quality appearing to be related for the sites evaluated, with a few sites having high Chinook Use scores and low Habitat Quality scores (Figure 17).

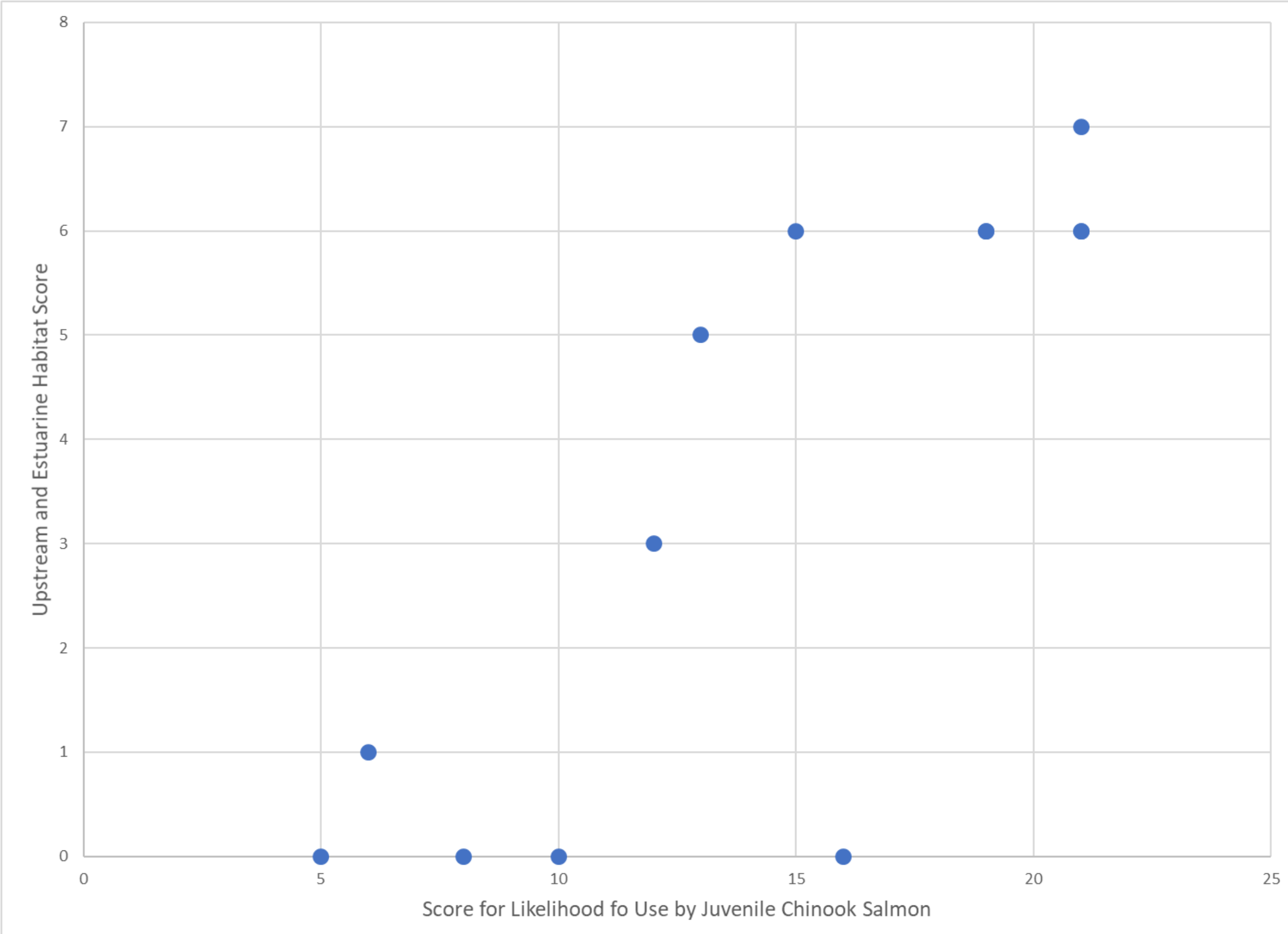

Figure 17. Score distribution for Embayment sites for Upstream Habitat and Likelihood of Salmon Stream use.

The top scoring site is Chuckanut Bay, with Chambers Creek, Colony Creek, Shellabarger/Willow Creek, and Padden Creek scoring 19 to 21 points for Chinook Use and 6 points for Habitat Quality. These sites likely represent the highest priority estuary sites. The complete ratings for all sites is shown in Table 8. Of these high priority sites, only Shellabarger/Willow Creek does not currently connect to Salish Sea through a trestle. However, Shellabarger/Willow Creek is currently undergoing a multiphase restoration and recovery effort to daylight the creek and reconnect the existing marsh habitat to the Salish Sea.

Table 8. Embayment Salmon Use and Habitat Quality Scores

Site Name	Salmon Use Score	Habitat Quality Score	Embayment Type
Marine Park	5	0	Barrier Lagoon
Picnic Point Lagoon	6	1	Closed Lagoon
Post Point Lagoon (South)	8	0	Barrier Lagoon
Edgemoor Lagoon	10	0	Closed Lagoon
Steilacoom Lagoon	12	3	Barrier Estuary
Titlow Lagoon	13	5	Barrier Estuary
Sequalichew Creek	15	6	Barrier Estuary
Marine View Drive Lagoon	16	0	Closed Lagoon
Padden Creek	19	6	Barrier Estuary
Shelleberger Creek	19	6	Barrier Estuary
Colony Creek	21	6	Barrier Estuary
Chambers Creek	21	6	Barrier Estuary
Chuckanut Bay	21	7	Barrier Estuary

[1] Embayment types are: Barrier Lagoon (Tidal inlet isolated by barrier beach with no significant freshwater input or stream); Closed Lagoon (Tidal inlet with no surface connection to Salish Sea and no significant freshwater input or stream); Barrier Estuary (Tidal inlet isolated by barrier beach with a considerable input of freshwater from stream or upland drainage) per the typology described by Shipman 2008.

Coastal embayments provide unique services to migrating fish (Beamer et al. 2003; Fresh 2006). Cereghino et al. (2012) identifies more than 305 small embayments in the Salish Sea that have been destroyed since the 19th century. The unique ecological services provided by these features cannot be replaced by other habitat types, and the loss of these habitat features means that fish are travelling greater distances between embayments today than historically. Therefore, protection and restoration of embayments has been identified as a restoration priority for the Salish Sea. Of the 13 embayments evaluated here, 7 are currently connected to the Salish Sea via culverts, while 6 have trestles crossing the embayment. Even in instances where trestles are present, site hydrology is often limited as Chuckanut Bay illustrates where an undersized trestle opening limits hydraulic flows and is contributing to siltation in Chuckanut Bay.

Three of the sites evaluated as part of this assessment – Chuckanut Bay, Sequalichew Creek Estuary and Chambers Bay - were previously identified as regional restoration priorities as part of a Salish Sea restoration planning process (PSNERP 2012). Many additional embayment sites have been identified by local governments and planning efforts as priorities. Summary maps and scores for the embayments identified along the BNSF railroad are shown in Appendix B.

5.0 APPROACHES TO ADDRESSING IMPLEMENTATION

The prioritization framework was developed to identify the most beneficial stream and embayment sites to focus restoration efforts to benefit juvenile Chinook Salmon. It was envisioned that addressing priorities can be undertaken in a number of ways, including BNSF addressing as part of maintenance/upgrade activities, independent restoration actions undertaken by other restoration partners (i.e., not BNSF), and restoration as mitigation for other projects with ecological impacts.

Since this prioritization focused solely on Chinook benefits, additional considerations should be factored in to further evaluate whether to implement restoration at a site. Priorities identified through this study must be integrated with restoration objectives for the entire stream system and the feasibility of restoration. Feasibility of restoration includes landowner support, community support, technical considerations, and funding availability.

This framework provides a screening tool for identifying and evaluating potential uplift from habitat improvement projects along the BNSF Railway. The specific proposal for each site is dependent on site-specific factors. However, in general, projects would tend to follow a similar approach to Washington State Department of Transportation’s culvert replacement program (WSDOT 2019). These efforts have tended to focus on providing larger structures to provide fish passage on streams that provide potential fish habitat. Given the length of BNSF culverts evaluated here, most structures would likely be opportunities for replacement structures with zero slope or stream simulation design guidance (WDFW 2019). These design guidelines would likely lead to large structures that discharge at grade and are either box culverts (bottomless or 4-sided) or short trestles.

Sites may also be advanced for improvements on the basis of associated habitat improvements occurring in the watershed or adjacent to the railway. These may be associated with independent restoration, rail maintenance needs, or mitigation proposals. Mitigation proposals may include project specific mitigation, in lieu fee, advanced mitigation, or mitigation banking.

6.0 RECOMMENDATIONS

A productive dialogue with BNSF was developed through this study and the company’s input to the Advisory Group was very helpful to the direction of the project. Continuing this dialogue with BNSF is highly recommended to understand the company’s perspectives on high priority sites, potential restoration treatments (e.g., larger pipes, box culverts, or trestle bridges), and how to successfully advance restoration projects along the railway. Given the potential implementation pathway to restoring sites as part of BNSF track maintenance activities, discussion of the company’s short-term and long-term maintenance plans would help restoration proponents identify how they may be able to contribute to improve a site action beyond what is needed for maintenance.

In concert with this work with BNSF, restoration proponents can work to advance the high priority projects. This includes consideration of the feasibility issues described above and consideration of how the project integrates with other restoration and protection activities in the watershed.

It is recommended that the State identify a person or small group of persons to serve as a liaison to BNSF on habitat restoration topics and opportunities along the Puget Sound shoreline. The idea is that the liaison will develop an understanding of the information needed before engaging BNSF, understand BNSF's interests when working along the shoreline, be aware of past restoration collaborations, and develop a long-term working relationship with counterparts at BNSF. The expectation is that the liaison will help foster an ever-strengthening working relationship between State agencies and BNSF which will foster successful habitat restoration along the railroad.

It is recommended that efforts are undertaken to develop a mitigation policy such that mitigation credit can be achieved through work at the streams and embayments that were the focus of this study. In addition, such mitigation policy development should consider the beaches and other habitats between streams for a more holistic discussion of mitigation policy as it relates to projects along the railway. These discussions require BNSF, agency, and tribal participation.

From a technical perspective, it is recommended that more information is gathered on juvenile Chinook and other salmon use of coastal streams and embayment habitats beyond the Whidbey Basin where the cornerstone research applied in this study was conducted. Juvenile salmon from other stream systems in other parts of Puget Sound may use the habitats differently. Similarly, additional understanding of the parameters and associated thresholds influencing the likelihood of fish use would be beneficial to expand beyond the Whidbey Basin research. In addition, WDFW is continuing work on guidelines for evaluating fish passage in tidal areas. The current study did not explicitly assess fish passage since there is not an established protocol in tidal environments. As guidance is available from WDFW, it is recommended that sites are evaluated and fish passage is factored into decisions about which projects to advance. At the regional scale or on a site-by-site basis of whether to advance a project, consideration of climate change, notably sea level rise and any projected changes to precipitation patterns, should be included in an expanded analysis of each site's existing conditions and future restoration treatment needs.

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Appendix A

Stream Crossing Site Summaries

Stream Name: Sequalitchew Creek

Rating ID: 232

Shoreline Photo

Downstream Conditions

Culvert Outlet

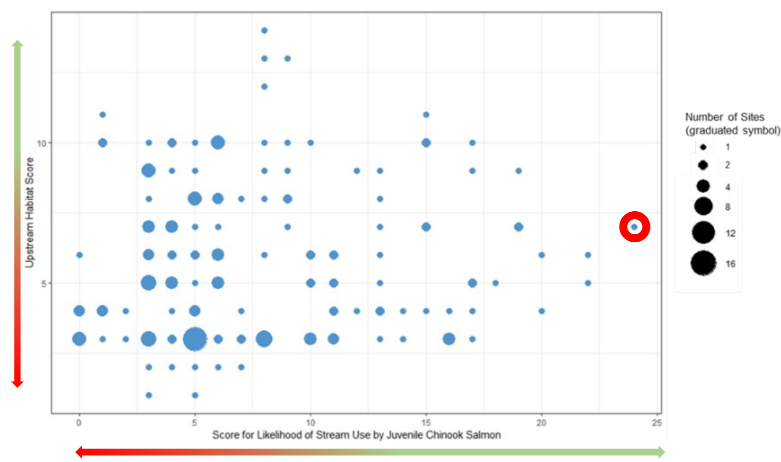
Upstream Conditions

Scoring Summary:

- Overall Salmon Use Score: 24 (max score)
- Overall Upstream Habitat Quality Score: 7

Culvert Characteristics:

- Historic salmon run in creek
- Excellent riparian corridor with productive upstream habitat
- Relatively unimpacted stream with restoration potential



Stream Name: Unnamed

Rating ID: 255

Shoreline Photo

Trestle Conditions

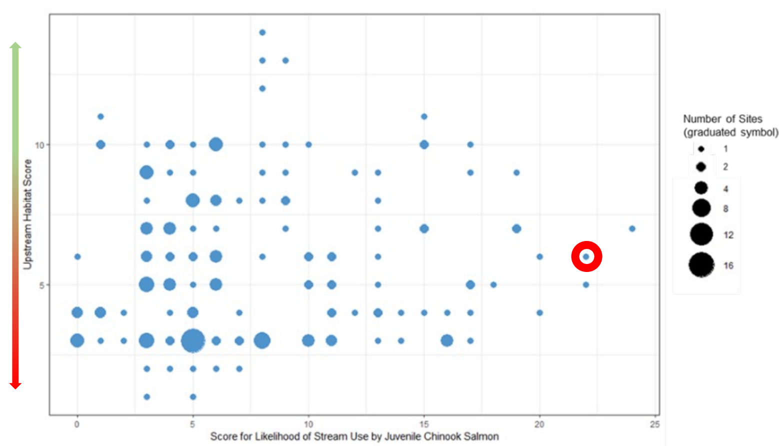
Upstream Conditions

Scoring Summary:

- Overall Salmon Use Score: 22
- Overall Upstream Habitat Quality Score: 6

Characteristics:

- Located in Steilacoom
- Railroad on trestle across opening where stream meets the shoreline
- Not likely to be a current fish barrier



Stream Name: Unnamed

Rating ID: 255

Shoreline Photo

Trestle Conditions

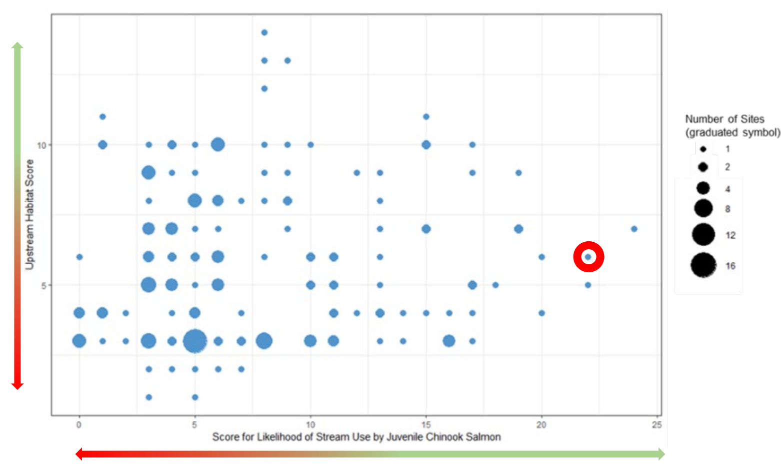
Upstream Conditions

Scoring Summary:

- Overall Salmon Use Score: 22
- Overall Upstream Habitat Quality Score: 6

Characteristics:

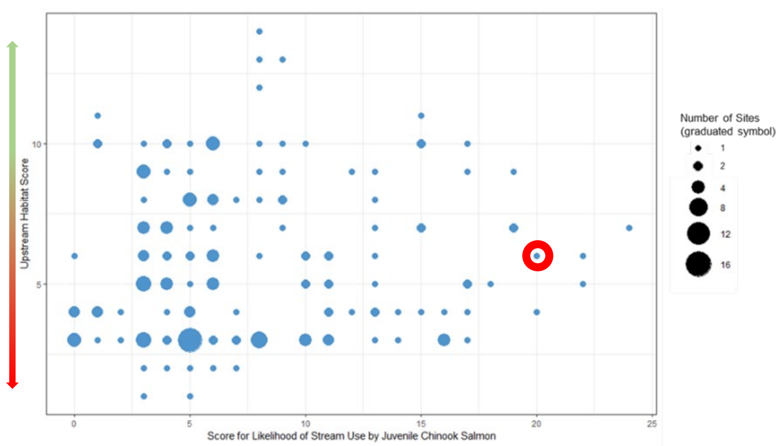
- Located in Steilacoom
- Railroad on trestle across opening where stream meets the shoreline
- Not likely to be a current fish barrier



Stream Name: Squalicum Creek

Rating ID: 258

Shoreline Photo



Scoring Summary:

- Overall Salmon Use Score: 20
- Overall Upstream Habitat Quality Score: 6

Characteristics:

- Located within Bellingham Bay
- Outlet is armored and in a relatively developed area
- Stream crosses a roadway just 165 ft upstream of culvert

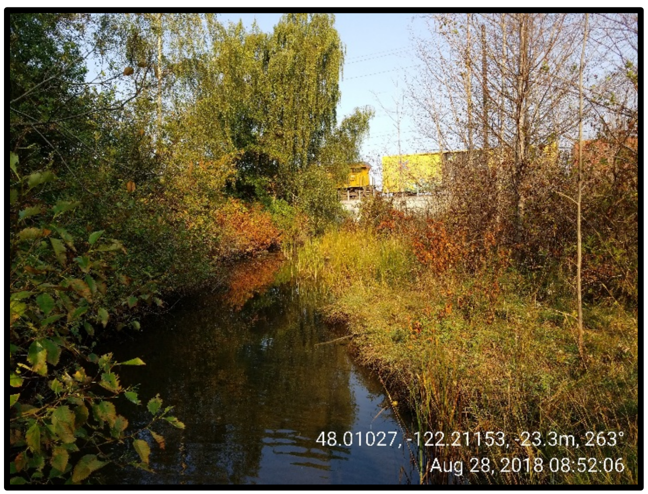
Stream Name: Unnamed

Rating ID: 89

Shoreline Photo

Downstream Conditions

Culvert Outlet



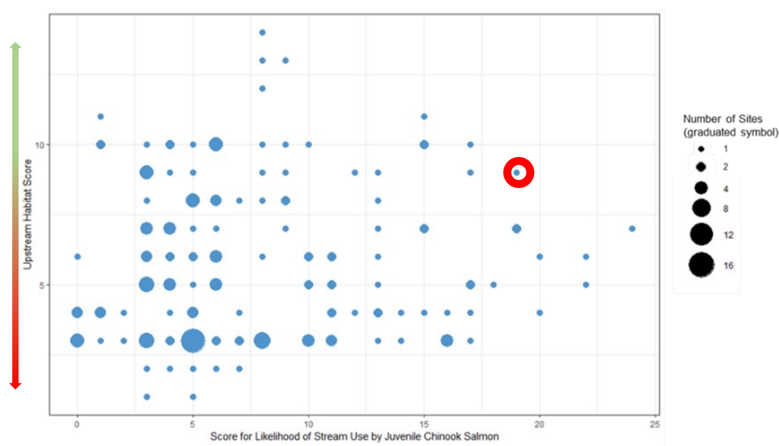
Upstream Conditions

Scoring Summary:

- Overall Salmon Use Score: 19
- Overall Upstream Habitat Quality Score: 9

Characteristics:

- Located near Everett
- Definite tidal influence on upstream end of culvert
- Riparian zone vegetated with natives and trees
- Culvert buried up to ¾ of its width in sediment



Stream Name: Padden Creek

Rating ID: 2

Shoreline Photo –picture shows shoreline just north of culvert

Downstream Conditions

Trestle

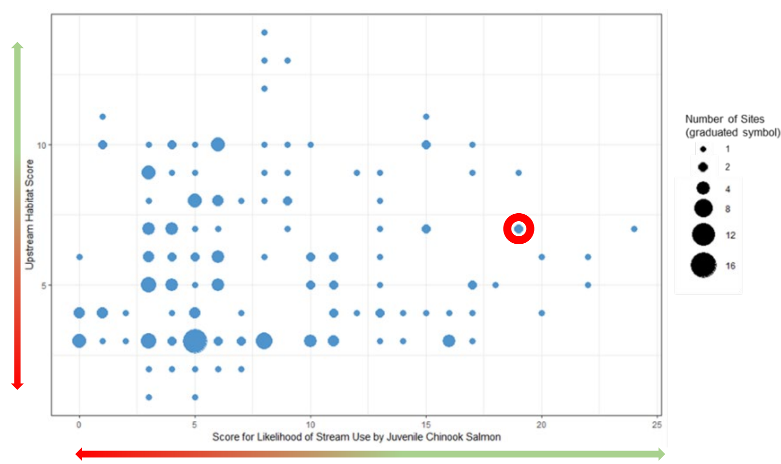
Upstream Conditions

Scoring Summary:

- Overall Salmon Use Score: 19
- Overall Upstream Habitat Quality Score: 7

Characteristics:

- Stream crossing is currently spanned by a trestle
- Definite tidal influence upstream of the railroad
- Upstream habitat is a fringe marsh with narrow riparian potential



Stream Name: Merrill and Ring Creek

Rating ID: 18

Shoreline Photo

Downstream Conditions

Culvert Inlet

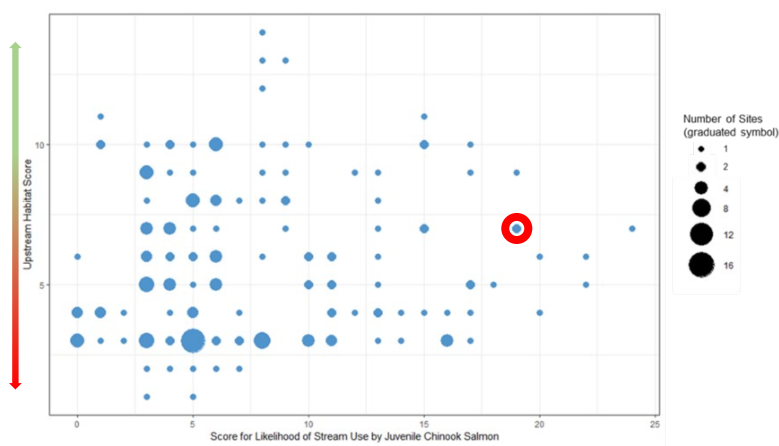
Upstream Conditions

Scoring Summary:

- Overall Salmon Use Score: 19
- Overall Upstream Habitat Quality Score: 7

Characteristics:

- All three culverts showed in image to the left were inventoried – western-most culvert was dry
- Downstream channel runs through terrestrial vegetation before entering the intertidal



Stream Name: Big Gulch Creek

Rating ID: 38

Shoreline Photo

Culvert Outlet

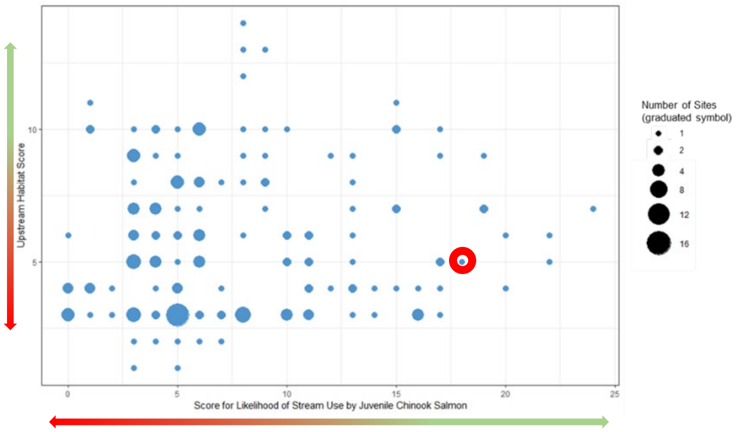
Upstream Conditions

Scoring Summary:

- Overall Salmon Use Score: 18
- Overall Upstream Habitat Quality Score: 5

Culvert Characteristics:

- Stream runs near Big Gulch Wastewater Treatment Plant
- Recorded salmon spawning in the stream and supportive estuarine habitat
- Drains large watershed



Stream Name: Chambers Creek

Rating ID: 189

Shoreline Photo

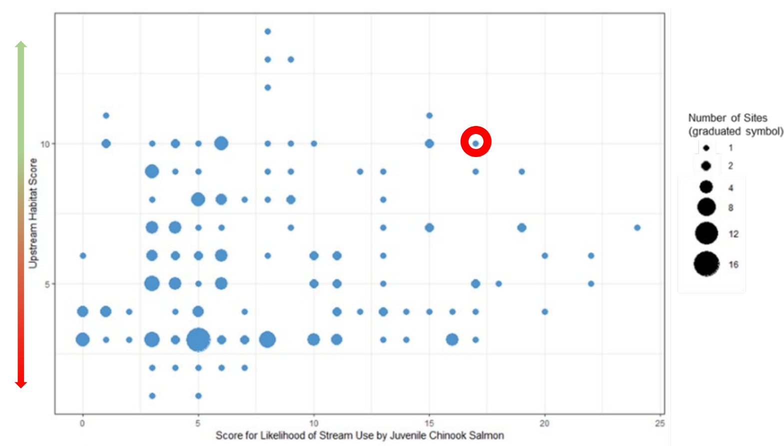
Scoring Summary:

- Overall Salmon Use Score: 17
- Overall Upstream Habitat Quality Score: 10

Characteristics:

- Site is also considered within the embayments prioritization
- Crossing is already a trestle so not likely a high priority for restoration

Trestle



Stream Name: Lunds Gulch Creek

Rating ID: 150

Shoreline Photo

Downstream Conditions

Culvert Inlet

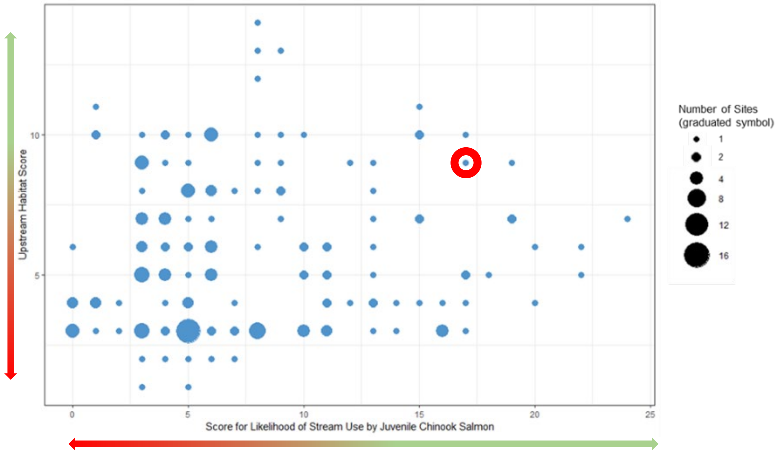
Upstream Conditions

Scoring Summary:

- Overall Salmon Use Score: 17
- Overall Upstream Habitat Quality Score: 9

Characteristics:

- Box culvert conveys flow and provides walkway under the railroad for park visitors
- Excellent habitat – beach-goers have seen fish in stream
- Culvert still undersized for amount of flow



Stream Name: Japanese Gulch Creek

Rating ID: 99

Shoreline Photo

Downstream Conditions

Culvert Outlet

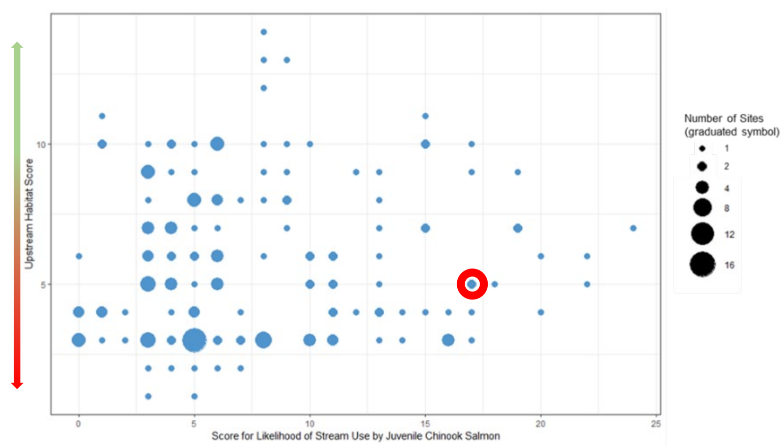
Upstream Conditions

Scoring Summary:

- Overall Salmon Use Score: 17
- Overall Upstream Habitat Quality Score: 5

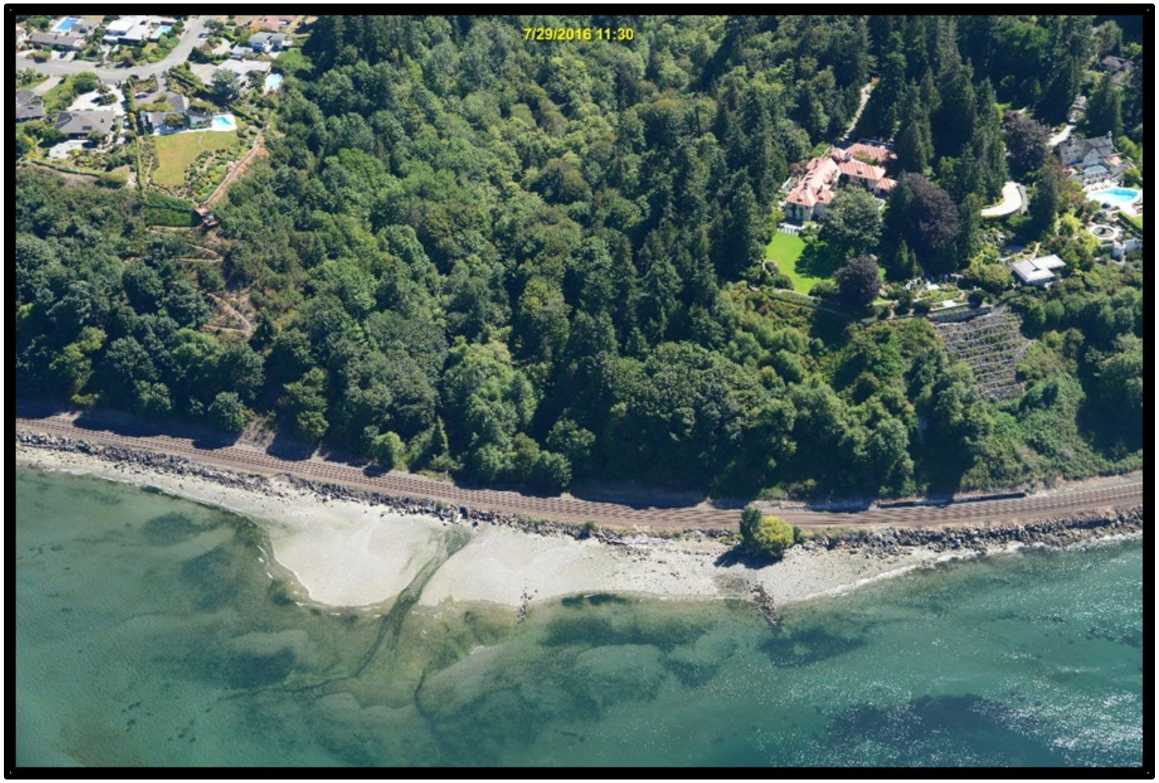
Characteristics:

- This culvert is >700 feet from the Puget Sound and the stream flows through another culvert before emptying into the Sound
- Upstream was inaccessible – Himalayan blackberry thicket



Stream Name: Boeing Creek

Rating ID: 220



Shoreline Photo

Culvert Inlet

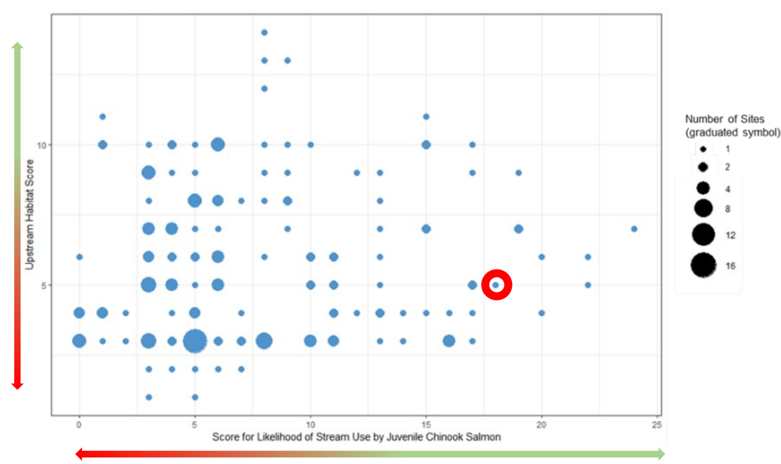
Upstream Conditions

Scoring Summary:

- Overall Salmon Use Score: 17
- Overall Upstream Habitat Quality Score: 5

Characteristics:

- Culvert allows both the stream and pedestrians to access the beach
- There are two decommissioned culverts just south of this crossing



Stream Name: Unnamed

Rating ID: 245

Shoreline Photo

Downstream Conditions

Culvert Inlet

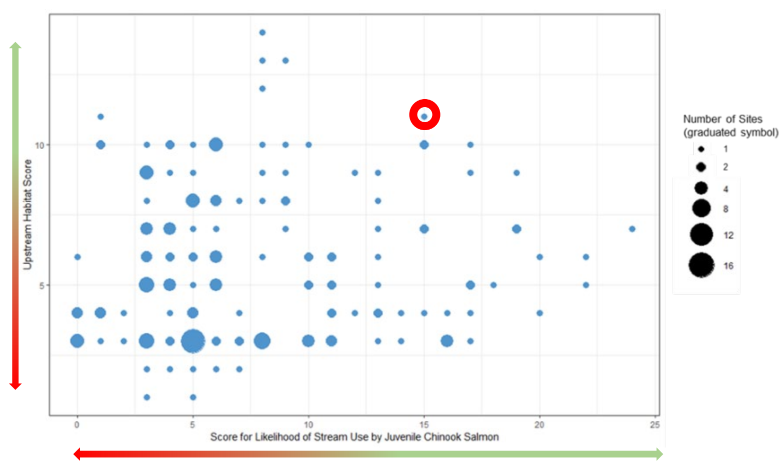
Upstream Conditions

Scoring Summary:

- Overall Salmon Use Score: 15
- Overall Upstream Habitat Quality Score: 11

Characteristics:

- Located across from Ketron Island
- Upstream riparian zone contains many native species (including salal, red alder, and lady fern)



Stream Name: Oyster Creek

Rating ID: 6

Shoreline Photo

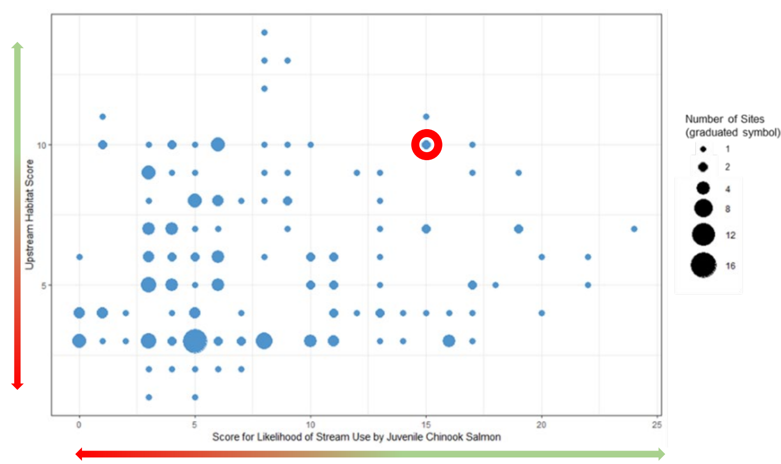
Downstream Conditions

Scoring Summary:
- Overall Salmon Use Score: 15
- Overall Upstream Habitat Quality Score: 10

Characteristics:
- Located within Bellingham Bay, just south of Pigeon Point
- Stream crossing is already a trestle, so site is not likely a high priority for restoration

Upstream Conditions

Culvert Inlet



Stream Name: Unnamed

Rating ID: 244

Shoreline Photo

Downstream Conditions

Culvert Inlet

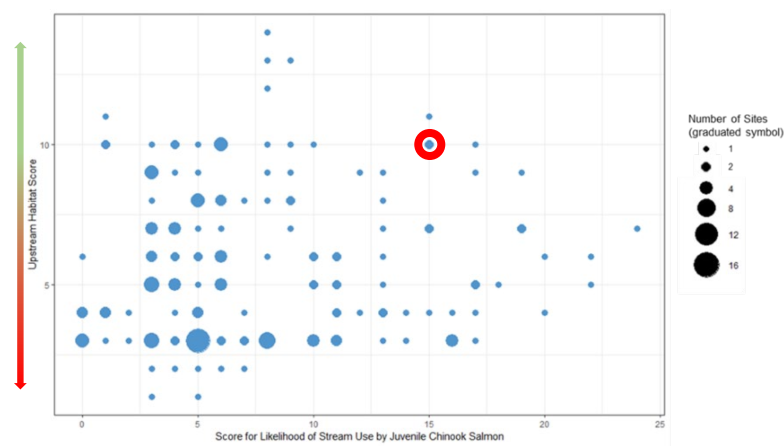
Upstream Conditions

Scoring Summary:

- Overall Salmon Use Score: 15
- Overall Upstream Habitat Quality Score: 10

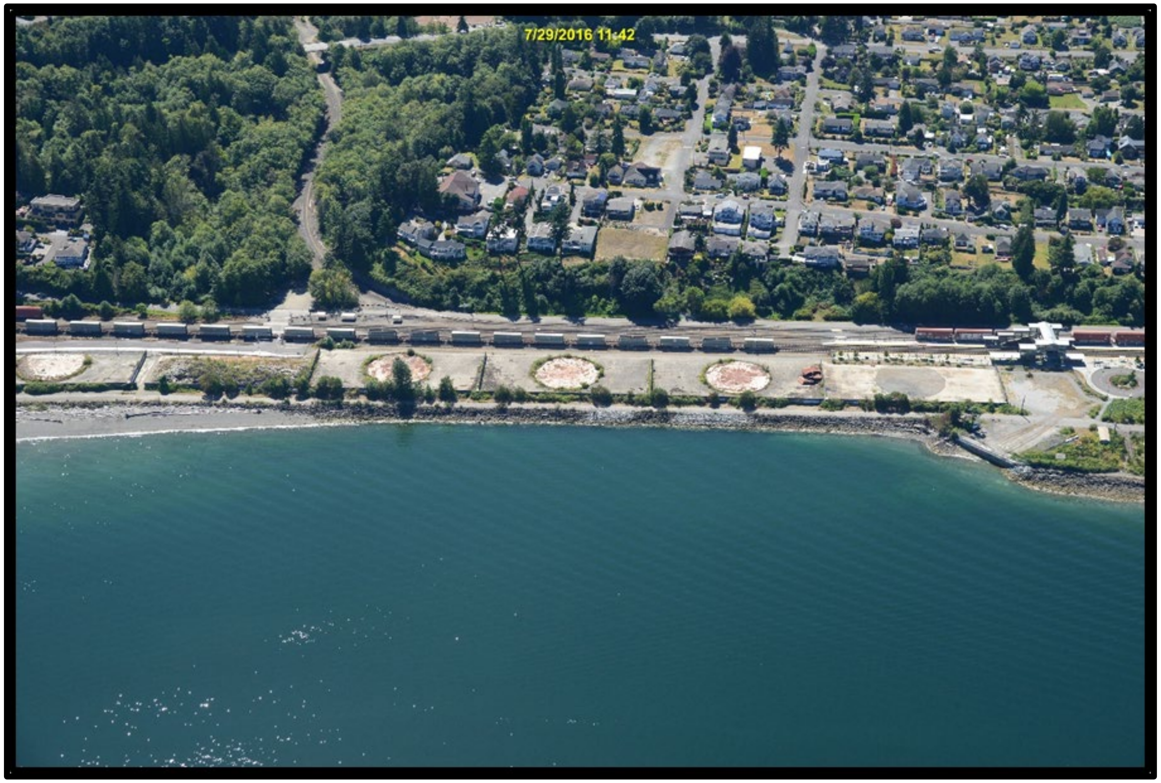
Characteristics:

- Culvert is partially damaged but still convey flow to beach
- Stream comes down steep, narrow gully just upstream of culvert – not likely to be fish passable
- Native plants within riparian zone



Stream Name: Japanese Gulch Creek 2

Rating ID: 98



Shoreline Photo

Culvert Inlets

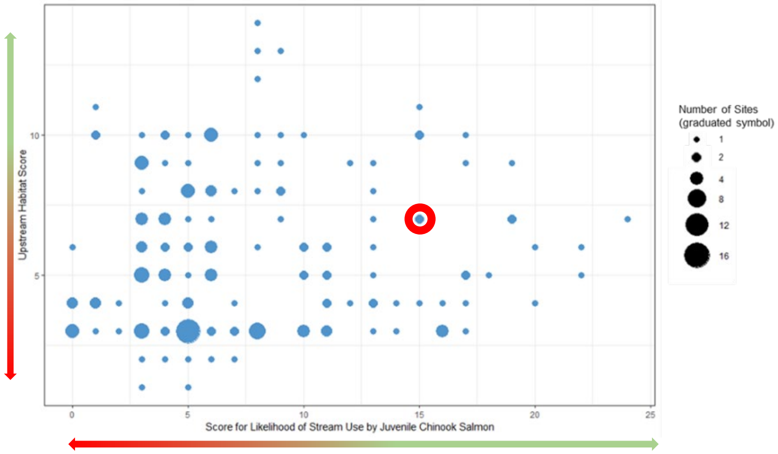
Upstream Conditions

Scoring Summary:

- Overall Salmon Use Score: 15
- Overall Upstream Habitat Quality Score: 7

Characteristics:

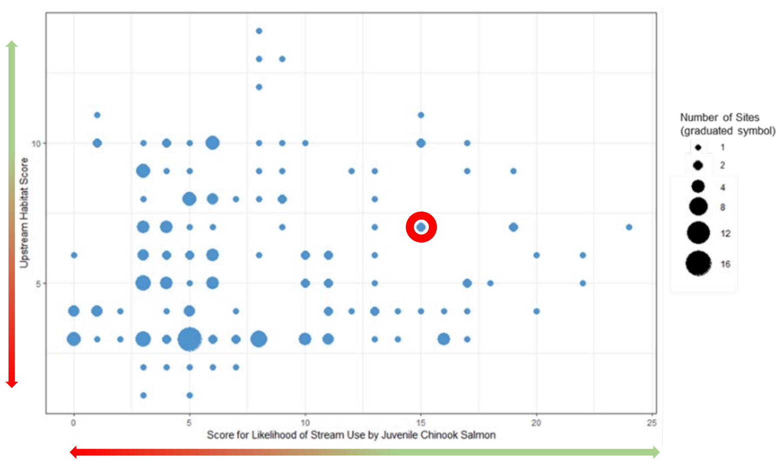
- One of a pair of culverts conveying stream under railroad and associated infrastructure
- Restoration efforts for Japanese Gulch are already underway



Stream Name: Little Squalicum Creek

Rating ID: 257

Shoreline Photo



Scoring Summary:

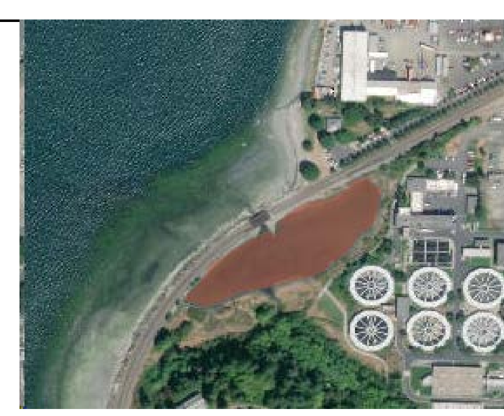
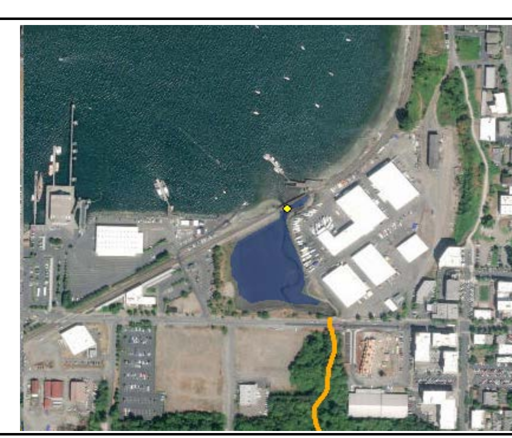
- Overall Salmon Use Score: 19
- Overall Upstream Habitat Quality Score: 7

Characteristics:

- Located in Bellingham
- Culvert lets out onto a beach in Bellingham Bay
- Outlet is armored and culvert partially backwaters at high tide

Appendix B

Embayment Site Summaries

Shoreline Embayments adjacent to BNSF Railroad (Salish Sea)				
Site Name	**Salmon Use Score**	**Habitat Quality Score**	**Site Context**	**Tidal Connection**
Picnic Point Lagoon	**6**	**1**		None observed
Chuckanut Bay	**21**	**7**		Trestle
Post Point Lagoon (South)	**8**	**0**		Culvert
Edgemoor Lagoon	**10**	**0**		Culvert
Titlow Lagoon	**13**	**5**		Culvert
Marine Park	**5**	**0**		Trestle
Padden Creek	**19**	**6**		Trestle

Salmon Use and Habitat Quality Scores are Draft and Subject to revision (September 11, 2019)

Site Name	Salmon Use Score	Habitat Quality Score	Site Context	Tidal Connection
Colony Creek	21	6		Trestle
Marine View Drive Lagoon	16	0		Culvert
Steilacoom Lagoon	12	3		Trestle
Shelleberger Creek	19	6		Culvert
Chambers Creek	21	6		Trestle
Sequalichew Creek	15	6		Culvert

Appendix C

Geodatabase User Guide

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TABLES

1.0 INTRODUCTION

The BNSF Railway Coastal Streams and Embayments geodatabase was developed to capture three inter-related datasets that support identification and prioritization of Chinook salmon habitat along streams and embayments that cross the BNSF railroad.

These three inter-related datasets are:

- BNSF Field Inventory of Stream Crossings and Embayments
- BNSF Stream Crossing Prioritization
- BNSF Embayment Prioritization

Supporting information on the technical data developed and the prioritization framework applied to these sites are summarized in the *Prioritization Framework Technical Report* and this *User's Guide*. This guide is intended to help users understand the purpose for data collection, the methods of data collection and the appropriate uses of data.

2.0 GEODATABASE FORMAT

Data is organized into an ArcGIS 10.4 personal geodatabase. This format was selected because it is shareable and allows for multiple datasets to be combined into a common data management system. Multiple datasets are incorporated into this geodatabase to facilitate analysis and review of source data.

2.1 BNSF Field Inventory

Data contained in this dataset track closely the data form form described in the Technical Report. The data contains a GIS point dataset that identifies the locations where stream crossings or embayments were inventoried. For sites that contained culverts with flow or with predicted streams the field staff collected the full data inventory. For sites where pipes crossing the BNSF right-of-way were observed but the pipes were not conveying flow and were not associated with predicted streams the field staff collected photographic evidence of the crossing and abbreviated data. While GPS data was collected at these sites, the GPS data was frequently collected just offshore of the observed culvert and therefore does not represent the actual location of the culvert. For culverts that were fully inventoried the field staff collected RTK and post-processed GPS data representing the culvert outlet. For many culverts staff collected inlet data too, however data was consolidated to show a single point in this dataset.

Below are brief summaries of the data fields and the contents of each data field.

Site Survey Information

- ObjectID_1 : GIS generated field that provides a unique identifier to each point

- Source: GPS data collection method. RTK = Real Time Kinetic GPS using a local base station, Algorithm = Predicted culvert location with no field collected data point; GPS = Trimble GeoExplorer post-processed GPS.
- Rating_ID: Unique identifier assigned to each stream crossing location and structure. This field is used to join data within GIS software.
- Stream_Name: Stream name if known.
- Field_Staff: Field staff initials. HLH = Hans Hurn (Confluence); SRV = Suzanne Vieira (Confluence); PLB = Phil Bloch (Confluence); ASG = Amy Groesbeck (Confluence). Additional staff may have participated in field visit to collect photos or GPS data. These individuals were responsible for recording data on data form.
- Date: Date of field data collection
- Time: Time of field data collection (local time)
- Tidal_Elev: Tidal elevation predicted from NOAA tides and charts for the nearest tidal reference station given the date and time of data collection
- Tidal_Stat: Tidal station used from NOAA tides and charts to calculate predicted tides

Downstream Observations

- DS_Landfor: Downstream beach landform. Characterized as Rocky Coast, Beach, Embayment or Delta. UTD used to describe Unable to Determine (inaccessible sites).
- Water_to_C: Distance to waterline from stream crossing structure outlet in feet
- Slope_to_W: Slope (percent) from crossing to waterline
- Slope_culv: Culvert slope (percent) from inlet to downstream outlet. Negative values suggest a culvert with reversed flow.
- Intertidal: Identifies whether there is evidence of a defined flow channel across the intertidal and if so whether that is across the upper intertidal or lower intertidal.
- DS_Bankful: Downstream bankfull width
- Stream_Len: Stream length from the crossing to end of channel following the thalweg of the stream channel.
- Streambed_: Streambed substrate (Dominant). Options are mud, sand, gravel, cobble, bedrock or artificial.
- Streambed1: Streambed substrate (Subdominant). Options are mud, sand, gravel, cobble, bedrock or artificial.
- Channel_De: Channel depth (feet) at outfall outlet

Structure Outlet Observations

- Number_Str: Number of structures present at the crossing. A number greater than 1 suggests that multiple culverts are present. If more than one culvert is present at a single crossing they may have independent Rating ID numbers.

- Structure_: Structure type. Options are trestle, round culvert, box culvert or other (type described).
- Structure1: Structure material. Options are concrete, corrugated steel or other (free entry)
- Structure2: Structure condition. Options are excellent, good, fair, poor or unknown. If signs of failure are observed they should be recorded.
- Structure3: Structure width measured as the internal diameter in inches
- Outlet_per: Identifies whether the outlet is perched
- Outlet_p_1: For outlets that are perched identifies the distance between the outlet and the adjacent substrate in feet.
- Structur_4: Structure length from inlet to outlet as measured using laser rangefinder in yards
- Slope_of_C: Slope of culvert in percent as measured using clinometer
- Rise_Calcu: Calculated rise from one end of the culvert to the other using RTK GPS collected at top of structure at inlet and outlet expressed in feet.
- Run: Calculated distance between inlet and outlet using RTK GPS locations. Distances are expressed in meters.
- Slope Calc: Calculated stream crossing structure slope using RTK rise and Run
- Substrate_: Dominant substrate in culvert. Options are mud, sand, gravel, cobble, bedrock or artificial.
- Substrate1: Depth of substrate in the structure in inches.
- Outlet_Arm: Crossing structure armoring at left bank
- Outlet_A_1: Crossing structure armoring at right bank
- Water_dept:Water depth in structure in feet.
- Elevation_: Elevation at the outlet in NAVD 88
- Plunge_Poo: Is a plunge pool present at the structure outlet?
- Plunge_P_1: Plunge pool depth in feet
- Hydraulic_: Are there any hydraulic controls present for plunge pool?
- Backwater: Does the structure backwater at high tide? Options are yes (structure fully backwaters at high tide), partially (structure may be backwatered at some tidal elevations, but backwatering does not extend past the outlet), no.
- Notes: Notes on structure outlet

Structure Inlet Observations

- Stream_bank: Stream bankful width 10’ upstream of crossing in feet.
- Stream_200: Identifies whether more than 200 feet of stream were observed upstream of the crossing.
- Stream_slo: Stream slope (percent) as measured in the field using a clinometer over the first 200 feet upstream of the structure or to the max distance the stream was observed.

- Thalweg_De: Depth of stream at 10′ upstream of the structure in feet.
- Thalweg__1: Average depth of thalweg for 200′ upstream of structure in feet.
- Streambe_3: Streambed Dominant Substrate upstream of structure. Options are mud, sand, gravel, cobble, bedrock or artificial.
- Streambe_4: Streambed Subdominant Substrate upstream of structure. Options are mud, sand, gravel, cobble, bedrock or artificial.
- Riparian_C: Riparian condition. Options are Excellent (closed canopy within 100 feet of stream), good (canopy and sub-canopy vegetation present), fair (patchy canopy vegetation), and poor (limited or no riparian vegetation).
- Salwater_v: Identifies whether salt-tolerant vegetation is present upstream of the culvert.
- Knotweed: Identifies whether knotweed is present upstream of crossing.
- Blackberry: Identifies whether blackberry is present upstream of crossing.
- English_Iv: Identifes whether English ivy is present upstream of crossing
- Invasive_S: Identifies whether other invasive species are present upstream of crossing.
- LWD_Count: Number of woody debris pieces 12″ or greater in diameter present in first 200 feet of upstream habitat.
- LWD_Count1: Number of woody debris pieces between 6 and 12″ in diameter present in first 200 feet of upstream habitat.
- LWD_Coun_1: Number of woody debris pieces less than 6″ in diameter present in first 200 feet of upstream habitat.
- Stream_arm: Stream armoring type left bank
- Stream_A_1: Stream arming length in feet along left bank
- Stream_A_2: Stream armoring type right bank
- Stream_A_3: Stream arming length in feet along right bank
- Inlet_armo: Type of armoring present at inlet of structure
- Inlet_ar_1: Length of armoring present at inlet of structure
- Stream_flo: Estimated type of stream flow source. Options are perennial stream (flow present at time of survey through a defined stream channel); ephemeral stream (dry stream channel present); seep (flow from non-stream source); stormwater (stream source appears to connect to anthropogenic infrastructure)
- Upstream_C: Identifies whether another culvert structure is observed within the first 200-feet of stream channel upstream of the inlet.
- Inlet_bloc: Identifies whether there is a dam or other blockage at the culvert inlet
- Drop_Heigh: Height of inlet drop in feet
- Inlet_elev: Inlet elevation in NAVD88
- NOTES_1: Any notes on structure inlet or upstream.
-

Embayment

- Water_Cros: Identifies whether an identifiable water crossing (culvert) is present connecting the embayment to marine waters.
- Seeps: Identifies whether there are seeps through the embankment suggesting either a leaking embankment or a potential buried culvert location.
- Scour_Pool: Identifies whether there is a scour pool present upstream of the crossing.
- source_1: Identifies whether there is a stream or freshwater source of water delivering water into the embayment.
- Salt_Marsh: Identifies whether there is salt marsh vegetation present in the embayment.
- NOTES_12: Notes on the embayment.

2.2 BNSF Stream Crossing Prioritization

Data in this file follow the prioritization framework described in the Technical Report. The data is presented so fields used to calculate the salmon use index are grouped together and fields used to calculate the upstream habitat index are grouped together. In addition, fields show the metric used in the prioritization framework adjacent to the field showing the value assigned to that metric. This facilitates potential updates for new information or adjustments to the prioritization framework in the future or by other user groups. Scores applied follow the format shown in Table 1.

Table 1. Coastal Stream Prioritization Framework

Likelihood of Stream Use by Juvenile Chinook Salmon			
Parameter	**Metric**	**Score**	**Data Source**
Proximity to major chinook river	< 7 km	5	GIS
	7-14 km	3	
	14-20 km	1	
	>20 km	0	
Presence of pocket estuary, stream delta, or PSNERP identified barrier beach (BAB) or barrier estuary (BE)	Pocket estuary or barrier estuary (BE)	5	PSNERP, historic embayments; field data; aerial photos or stream delta indicators
	Stream delta or barrier beach (BAB)	3	
	Historic BE	5	
	None	0	
Tidal inundation extends upstream of culvert (backwater)	Yes	3	Field data
	Partial	1	
	No	0	
Salmon spawning or intrinsic potential	Chinook spawning or intrinsic potential	4	WDFW Synthetic stream or SWIFD data
	Documented salmonid spawning	3	
	Salmonid intrinsic potential	2	
	No documented use	0	
Watershed size	➢ 300 acres	5	WDFW Synthetic stream data
	100-300 acres	3	

Likelihood of Stream Use by Juvenile Chinook Salmon			
Parameter	**Metric**	**Score**	**Data Source**
	< 100 acres	0	
Stream gradient	<3%	3	WDFW Synthetic stream data
	3.0-6.5%	2	
	>6.5%	0	

Upstream Habitat Access & Quality			
Parameter	**Metric**	**Score**	**Data Source**
Length of accessible stream (<6.5% slope) present upstream of railroad	>400 ft	3	WDFW Synthetic stream data
	200-400 ft	2	
	< 200 ft	1	
Another culvert or instream modification affecting access to upstream habitat within 200 ft of railroad	No culvert or road crossing	3	Field data, WDFW barrier database, WDFW Synthetic stream data
	Upstream road crossing	1	
	Culvert within 200 ft	0	
Riparian vegetation quality	Good/excellent	2	Field data
	Fair	1	
	Poor	0	
Riparian buffer (100 ft of lower 200 m of stream)	50-100% natural vegetation	2	NOAA C-CAP land cover data
	30-50% natural vegetation	1	
	0-30% natural vegetation	0	
Bank armoring	None	5	WDFW Synthetic stream data
	On One Bank	3	
	On Both Banks	0	
Woody debris in stream	>5 pieces of large or medium woody debris	2	Field data
	1-5 pieces of large or medium woody debris	1	
	No woody debris	0	
Water quality – metals degradation	Low metals degradation (good water quality)	5	Ecology watershed characterization – water quality – metals degradation
	Moderate	3	
	Moderate-high	1	
	High metals degradation (poor water quality)	0	

Below are brief summaries of the data fields and the contents of each data field.

- OBJECTID_1: GIS generated field that provides a unique identifier to each point Source: GPS data collection method. RTK = Real Time Kinetic GPS using a local base station, Algorithm = Predicted culvert location with no field collected data point; GPS = Trimble GeoExplorer post-processed GPS.
- Rating_ID: Unique identifier assigned to each stream crossing location and structure. This field is used to join data within GIS software.
- Proximity_: Proximity to major chinook river. Distances were estimated based on a series of buffers applied to major chinook rivers. Data in this field shows the distance category (0 to 7 km = 1, 7-14 km = 2; 14-20 km = 3; 20+ km =4)
- Proximity1: Proximity to major chinook river score.
- Estuary_Ha: Estuary habitat type as calculated from PSNERP historic and current habitats data layer.
- Estuary__1: Score for presence of pocket estuary, stream delta, barrier beach or barrier estuary.
- Tidal_Upst: Idenfies whether tidal inundation extends upstream of culvert. Uses the backwater field from the field inventory.
- Tidal_Up_1: Score for presence of tidal inundation
- Salmon_Spa: Identifies whether salmon spawning has been documented in the stream (SWIFD data), whether Chinook salmon Intrinsic potential has been calculated above 0 (Synthetic Streams data) or whether any salmonid (Coho or Steelhead) intrinsic potential has been calculated above 0 (Synthetic Streams data).
- Salmon_S_1: Score for presence of salmon spawning.
- Watershed_: Watershed area as shown for the lowest segment of the stream system connected to the stream crossing in the Synthetic Streams Data
- Watershed1: Score for watershed area.
- Stream_Gra: Stream gradient for the lowest segment (typically approximately 100 m) in Synthetic Streams Data
- Stream_G_1: Score for stream gradient
- Overall_Sa: Overall salmon score is the sum of Proximity1, Estuary_1, Tidal_Up_1, Salmon_S_1, Watershed1, and Stream_G_1 scores.
- Upstream_S: Length of accessible stream with less than 6.5% slope.
- Upstream_1: Score for Length of accessible stream.
- Upstream_C: Presence of another culvert or instream modification upstream. Options are no culvert or road crossing; upstream road crossing, or culvert within 200 feet. Upstream road crossings were assessed from Synthetic Stream data set. Culverts within 200 feet were assessed from field survey data.
- Upstream_2: Score for upstream culverts or in-stream structures.

- Riparian_V: Classification of riparian vegetation condition in upstream habitat area based on field data field Riparian_C. Options are Excellent (closed canopy within 100 feet of stream), good (canopy and sub-canopy vegetation present), fair (patchy canopy vegetation), and poor (limited or no riparian vegetation).
- Riparian_1: Prioritization score for riparian vegetation quality.
- Bank_Armor: Presence of riparian armoring on neither, one or both banks of stream upstream of crossing. Data is assessed from field data fields Stream_arm and Stream_A_2.
- Bank_Arm_1: Prioritization score for bank armoring upstream of culvert.
- LWD_Instre: Count of total number of pieces of large or medium woody debris in upstream area. Counts are sum of LWD_Count (number of woody debris pieces larger than 12" diameter present in first 200 feet of upstream habitat) and LWD_Count1 (number of woody debris pieces between 6 and 12" diameter present in first 200 feet of upstream habitat).
- LWD_Inst_1: Prioritization score for woody debris in stream.
- Water_Qual: Water quality – metals degradation characterization based on ecology watershed characterization for watershed closest to or containing the stream crossing. High metals degradation suggests low water quality and low metals degradation suggests high water quality.
- Water_Qu_1: Prioritization score for water quality – metals degradation.
- Overall_Up: Overall upstream score is the sum of Upstream_S, Upstream_C, Upstream_2, Riparian_1, Bank_Arm_1, LWD_Inst_1, Water_Qu_1, and Up_Rip_P_S.
- Feasibilit: Pending development. This field is intended to capture factor(s) relating to feasibility of restoration at the site.
- Feasibil_1: Pending development. This field is intended to capture the prioritization score for the feasibility factors.
- Fish_Use_W: Identifies whether the stream is categorized as type F and therefore predicted to be capable of supporting fish life.
- Stream_Nam: Stream name if known.
- Related_St: Related structures. These identify other structures included in the inventory effort that are upstream or downstream of the structure.
- Fish_Use: Identifies whether the Synthetic stream dataset identifies the stream as type F.
- Chan_ID: Identifies the Channel ID used in the WDFW synthetic streams data. This field is used to create database connections between the stream crossing data and the Synthetic stream data.
- Embayment: Characterizes whether there is an associated embayment.
- Up_Rip_per: Riparian buffers of 100 feet were buffered around the lower 200 m of stream habitat for each stream. Habitat types were classified as natural or developed using NOAA C-CAP data. These data were combined to create a percent natural index

that ranges from 0 to 1 and represents the fraction of the riparian area that is a natural landcover type.

- Up_Rip_P_S: Upstream riparian buffer score.

2.3 BNSF Embayment Prioritization

Data in this file follow the prioritization framework described in the Technical Report. The data is presented so fields used to calculate the salmon use index are grouped together and fields used to calculate the upstream habitat index are grouped together. In addition, fields show the metric used in the prioritization framework adjacent to the field showing the value assigned to that metric. This facilitates potential updates for new information or adjustments to the prioritization framework in the future or by other user groups. Scores applied follow the format shown in Table 2.

Table 2. Prioritization Framework for Embayments

Likelihood of Stream Use by Juvenile Chinook Salmon			
Parameter	**Metric**	**Score**	**Data Source**
Proximity to major Chinook river	< 7 km	5	GIS
	7-14 km	3	
	14-20 km	1	
	>20 km	0	
Site historically was an embayment (PSNERP categories Barrier Estuary (BE), Barrier Lagoon (BL), Coastal Lagoon Marsh (CLM) or Open Coastal Inlet (OCI)	Yes	5	PSNERP, historic embayments; field data; aerial photos or stream delta indicators
	No	0	
Size of impoundment	<3 acres	3	Field data/GIS
	1-3 acres	2	
	<1 acre	1	
Stream is present	Yes	5	WDFW Synthetic stream or field data
	No	0	
Documented presence of spawning salmon in associated stream	Yes	5	WDFW Synthetic stream or SWIFD data
	No	0	

Upstream Habitat Access & Quality			
Parameter	**Metric**	**Score**	**Data Source**
Length of accessible stream (<6.5% slope)	>400 ft	3	WDFW Synthetic stream data
	200-400 ft	2	

Upstream Habitat Access & Quality			
Parameter	**Metric**	**Score**	**Data Source**
present upstream of railroad	< 200 ft	1	
Watershed size	>300 acres	3	GIS, Synthetic stream data
	100-300 acres	1	
	< 100 acres	0	
Water quality – metals degradation	Low metals degradation (good water quality)	5	Ecology watershed characterization – water quality – metals degradation
	Moderate	3	
	Moderate-high	1	
	High metals degradation (poor water quality)	0	

The embayment dataset is a polygon data field that depicts the boundary of the embayment as interpreted from aerial photos following field inventory. Field data is supplemented with aerial interpretation for these sites. Below are brief summaries of the data fields and the contents of each data field.

- OBJECTID_1: GIS generated field that provides a unique identifier to each point Source: GPS data collection method. RTK = Real Time Kinetic GPS using a local base station, Algorithm = Predicted culvert location with no field collected data point; GPS = Trimble GeoExplorer post-processed GPS.
- Name: Embayment name.
- Area__Acre: GIS calculated area of polygon representing embayment area.
- EmRating_ID: Unique identifier assigned to each embayment site. This field is used to join data within GIS software.
- Stream_in: Identifies whether a freshwater stream is documented or predicted to flow into the embayment.
- Intl_conn: Identifies whether there is a known or predicted connection to the marine waters (options are none, yes or unknown) and the type of structure (trestle vs. culvert)
- Chinook_pr: Identifies the distance in km to the nearest major Chinook salmon river
- Chinook__1: Priorization score for embayments for proximity to major Chinook river.
- Historic_E: Identifies whether PSNERP or other data indicates the presence of historic or current barrier estuary (BE), barrier lagoon (BL), Coastal Lagoon March (CLM) or Open Coastal Inlet (OCI).
- Historic_1: Prioritization score for historic or current embayment habitat class.
- Bay_Size: Size of impoundment measured in acres using GIS.
- Bay_Size_s: Score for size of impoundment.

- StreamPres: Identifies whether a stream is known or predicted to flow into the embayment.
- StreamPr_1: Score for presence of stream inlet.
- Salmon_Spa: Identifies whether salmonids are documented to spawn in the associated stream. Salmon spawning data is derived from Synthetic Stream and SWIFD data.
- Salmon_S_1: Score for presence of salmon in associated stream.
- Salmon_Use: Cumulative salmon use score for embayments comprised of the sum of Chinook__1, Historic_1, Bay_Size_s, StreamPr_1, and Salmon_S_1. Scores have a potential range of 1 to 23 points.
- Watershed_: Watershed area calculated for associated stream based on synthetic stream dataset.
- Watershed1: Prioritization score for watershed area.
- Stream_Len: Length of accessible stream at less than 6.5% slope upstream of railroad derived from WDFW synthetic stream dataset.
- Stream_L_1: Prioritization score for upstream stream length.
- Water_Qual: Water quality – metals degradation characterization based on ecology watershed characterization for watershed closest to or containing the stream crossing. High metals degradation suggests low water quality and low metals degradation suggests high water quality.
- Water_Qu_1: Prioritization score for water quality – metals degradation.
- Habitat_Qu: Cumulative upstream habitat access and quality score comprised of sum of Stream_L_1, Watershed1, and Water_Qu_1.

3.0 DATA QUALITY AND APPROPRIATE USE

This geodatabase includes data collected in the field for the purpose of characterize stream crossings and embayments as well as data integrated from public and non-public GIS datasets relevant to the prioritization of stream crossings for juvenile Chinook salmon habitat. Field data collected for this project were collected from May 2018 through May 2019. Where data is completed it comprises the best available information regarding the stream crossing and was validated based on multiple trained field observers. Often digital photos were also collected which can be used to verify or aid in the interpretation of ambiguous field observations. Furthermore, Ecology provides a comprehensive shoreline aerial photo dataset over multiple time periods which can aid interpretation of site-specific information. Field staff were unable to access several sites due to property restrictions or the presence of infrastructure that prohibited safe site access. Future inventory efforts could more fully characterize these sites.

In creating the prioritization framework and scores, available GIS information was used to supplement the field data. These datasets were compiled or created for many different purposes. In some cases, these GIS datasets information that may be inaccurate or incomplete. For example, the WDFW synthetic stream dataset is a major data resource supporting this prioritization effort. This data is also used to support WDFW's culvert program and has proven to be a highly reliable dataset. However, this data relies heavily on predictions for watershed area, stream flow path, and stream slope that are in turn based on topographic information compiled for Washington State. Topographic information likely includes some errors and may not reflect the current configuration of some watersheds. These errors are therefore inherited by the current analysis. For example, in connecting the culverts to the predicted stream locations many of the streams appear to be flowing through culverts that are near, but not exactly coincident with predicted stream locations. In some instances, stormwater and urban infrastructure may have radically altered the flow path for streams and therefore made the topographic representation of these streams inaccurate.

The field data and prioritization information are based on the best data available and scientific understanding as compiled in October 2019. Scientific studies and datasets that are under development or distributed after this date may supersede information compiled as part of this project.

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Appendix D

Field Data Form

SITE SURVEY INFORMATION		
Field staff	Date/Time*	Site ID/Stream name

DOWNSTREAM OBSERVATIONS

Downstream landform (Check one) Rocky Coast ☐ Beach ☐ Embayment ☐ Delta ☐		Shortest distance from waterline to crossing	
Slope % from waterline to crossing		Defined stream channel across intertidal? (If none, skip to next section). UPPER ☐ LOWER ☐ NONE ☐	
Downstream stream bankfull width (10' downstream)		Stream length from crossing to <u>end of channel</u>	
Streambed substrate (Dominant/Subdominant) Mud ☐/☐ Sand ☐/☐ Gravel ☐/☐ Cobble ☐/☐ Bedrock ☐/☐ Artificial ☐/☐		Channel Depth at Outfall Outlet	

STRUCTURE OUTLET OBSERVATIONS

Number of structures (if multiple, answer for each)		Structure Type Trestle ☐ Round Culvert ☐ Box Culvert ☐ Other ☐ ______	
Structure Materials Concrete ☐ Corrugated Steel ☐ Other ☐ (specify and photo)		Structure Condition (any signs of failure) Excellent ☐ Good ☐ Fair ☐ Poor ☐ Unknown ☐	
Structure width/internal diameter (in or ft)		Outlet perched? YES ☐ Height:_______________ NO ☐	
Structure length (ft)		Slope of crossing structure (outlet to inlet)	
Substrate inside structure (Dominant) Mud ☐ Sand ☐ Gravel ☐ Cobble ☐ Bedrock ☐ Artificial ☐		Depth of substrate in structure	
Crossing structure armoring at outlet (type and length)	LB: RB:	Water depth in structure	(No water in culvert ☐)
GPS (outlet point and downstream line)		Elevation at outlet (NAVD88 ☐ or MLLW ☐)	
Plunge pool present? YES ☐ Depth:________________ NO ☐		Hydraulic control present for plunge pool	
Does structure backwater at high tide? YES ☐ PARTIALLY ☐ NO ☐		Photos: Stream Channel through Intertidal ☐; Culvert Outlet ☐; Other ☐____________________)	

Notes:

*Record *Tidal Elevation During Survey* after the fact.

STRUCTURE INLET/UPSTREAM OBSERVATIONS

Stream bankfull width 10' (or further) upstream of crossing		> 200' of stream YES ☐ NO ☐	Stream slope % (200' upstream average)	

Thalweg depth	10': 200' Avg.:	Streambed substrate (Dominant/Subdominant) Mud ☐/☐ Sand ☐/☐ Gravel ☐/☐ Cobble ☐/☐ Bedrock ☐/☐ Artificial ☐/☐

Riparian Habitat Excellent (closed canopy) ☐ Good ☐ Fair ☐ Poor (no mature canopy) ☐	Saltwater-tolerant vegetation present? (Specify)	YES ☐ NO ☐

Invasive species present (circle all) Knotweed ☐ Blackberry ☐ English Ivy ☐ Other ☐ (notes)	LWD present in first 200' >12" diameter LWD count _____ ; 6-12" LWD Count ________; <6" LWD Count _____

Armoring along left bank (type and length)		Armoring along right bank (type and length)	
Crossing structure armoring at inlet (type and length)	LB: RB:	Stream flow source perennial stream ☐ ephemeral stream ☐ seep ☐ stormwater ☐	

Is there another culvert or structure within 200'? YES ☐ NO ☐	Drop from US channel bed to culvert or dam blocking inlet? Drop ☐ height:_______________ blockage ☐ None ☐

Elevation at inlet (NAVD88 ☐ or MLLW ☐)		GPS inlet	Photos: (Culvert Inlet ☐; Upstream Habitat ☐; Other ☐___________)

Notes:

RECORD ANY FISH PRESENT!!

Embayment		
Is there an identifiable water crossing (culvert, etc.)	YES ☐	NO ☐
Are there seeps through gravel/rock embankment?	YES ☐	NO ☐
Is there a scour pool upstream of crossing?	YES ☐	NO ☐
Is there a stream or freshwater source into embayment	YES ☐	NO ☐
Is there salt marsh veg. in embayment	YES ☐	NO ☐
Notes:		

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