KING COUNTY FISH PASSAGE BARRIER PRIORITIZATION SUMMARY REPORT

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King County

Department of Natural Resources and Parks
Water and Land Resources Division

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1. Executive Summary

In 2018 King County Executive Constantine launched development of a Fish Passage Restoration Program (FPRP). The Executive directed county departments to proactively address the problem of fish passage barriers created by King County assets. Restoration of fish passage is a key component of the county's Clean Water Healthy Habitat initiative, which reflects an increased focus on integrating public investments and working across a myriad of programs to achieve the best outcomes for clean water and healthy habitat.

In collaboration with federal, tribal, state, and city officials, this program identifies barriers to fish passage, assesses the potential benefits of restoring fish passage at identified barriers, coordinates with other protection and restoration actions in the county, plans for improved sequencing of barrier remedies and acceleration of fish passage investments, and oversees projects that remedy fish passage barriers that will allow the most salmon to swim to the best habitat in the shortest time.

In 2021, King County completed a two-year field inventory of all county assets in streams to determine which blocked upstream salmon migration.[1] To complete the inventory, the county identified and visited more than 3,000 locations to determine if in-stream structures and water crossings were barriers to fish passage based on the 2019 Washington Department of Fish and Wildlife (WDFW) Fish Passage Inventory, Assessment, and Prioritization Manual (WDFW, 2019). **The inventory identified more than 900 county assets in streams that are partial or total fish passage barriers.**

County staff worked with staff representing tribes, state agencies, and federal agencies to develop a prioritization method to apply to the county barrier inventory. Barrier prioritization of the barrier inventory identifies which barriers block the most and best salmon habitat, and which barriers occur on streams that would not provide substantial habitat benefits. After a series of workshops to discuss and evaluate different prioritization frameworks**, the prioritization group reached consensus on a formula to score each county barrier based on**:

- Stream habitat quantity and quality,
- Watershed habitat quality,
- Connectivity, and
- Presence of priority salmon species.

730 county barriers were ranked, with scores ranging from one to 95 (out of a maximum of 100). About 200 county barriers have incomplete priority scores due to data gaps that prevent scoring for one or more of the parameters noted previously. This is mostly due to the barrier occurring on a currently unmapped stream, which prevents scoring for stream habitat quantity and quality.

A total of 65 county barriers score higher than 50 points and would cumulatively provide 61% of the total possible habitat gain from all county barrier remedies. Individual and cumulative habitat gains

[1] Consistent with the geographic scope of the *Washington v. United States* case related to salmon passage and the state's road culverts, the scope of the County inventory includes areas of the county that provide potential salmon habitat and does not address areas upstream of natural fish passage barriers, such as Snoqualmie Falls, which provide habitat for trout but not migratory salmon species.

diminish quickly for barriers scoring less than 50 points. For example, remedy of all 247 of the county barriers scoring no more than 20 points would provide only 7% of the total possible habitat gain from all county barrier remedies.

The prioritization results will inform development of county plans for fish passage restoration in the coming years. The results show that remedies of the high scoring barriers will restore salmon access to most of the habitat currently blocked by county barriers. **By 2032, the county plans to restore fish passage at enough high priority county barriers to restore salmon passage to at least half of the total habitat blocked by county barriers.**

Over time, the county plans to update the prioritization to reflect new and improved information. New information includes:

- Identification of newly assessed barriers and barrier remedies that would affect the Stream Habitat Quantity and Quality and Connectivity scoring; and
- Better mapping of stream locations to fully score the 216 county barriers with currently incomplete priority scores.

Updates to the prioritization are planned in late 2022 to reflect planned improvement of stream mapping. Thereafter, updates would be at least every 2 years to reflect updated barrier data. While the factors for prioritization have been finalized, scoring for the barriers will constantly evolve as the program develops and barriers are corrected.

The King County barrier database, including prioritization scoring, is available for download at the King County GIS Open Data website (https://gis-kingcounty.opendata.arcgis.com/) under "Fish Passage Sites/fp fishpassagesites points."

2. Introduction

In 2018 King County Executive Constantine launched development of a Fish Passage Restoration Program (FPRP). The Executive directed county departments to proactively address the problem of fish passage barriers created by King County assets. Restoration of fish passage is a key component of the county's Clean Water Healthy Habitat initiative, which reflects an increased focus on integrating public investments and working across a myriad of programs to achieve the best outcomes for clean water and healthy habitat.

In collaboration with federal, tribal, state, and city officials, this program identifies barriers to fish passage, assesses the potential benefits of restoring fish passage at identified barriers, coordinates with other protection and restoration actions in the county, plans for improved sequencing of barrier remedies and acceleration of fish passage investments, and oversees projects that remedy fish passage barriers that will allow the most salmon to swim to the best habitat in the shortest time.

Over the past several years, King County staff have identified barriers to salmon passage that are the responsibility of the county. This report summarizes work to assess which remedies of county barriers have the most benefits for salmon and their habitat. Restoration of fish passage at the highest priority barriers provides a key tool that will help the county greatly accelerate gains in salmon habitat over the next several decades.

3. Background

In 2021, King County completed a two-year field inventory of all county assets in streams to determine which blocked upstream salmon migration.[2] To complete the inventory, the county assessed in-stream structures and water crossings using methodology outlined in the 2019 Washington Department of Fish and Wildlife (WDFW) Fish Passage Inventory, Assessment, and Prioritization Manual (WDFW, 2019).

The inventory identified more than 900 salmon passage barriers that are the responsibility of King County. These barriers occur in a wide range of situations. Some of the barriers occur on large creeks within undeveloped valleys and ravines. Other barriers occur on highly altered roadside or agricultural drainage ditches that convey natural streams. Some county barriers have dozens of miles of potential upstream salmon habitat while upstream lengths for others meet physical requirements for fish-bearing criteria but provide little to no meaningful stream area that would ever benefit adult or juvenile salmon.

Prioritization allows analysis of the barrier inventory to identify which barriers block the most and best salmon habitat, and which barriers occur on streams that would not provide substantial habitat benefits.

[2] Consistent with the geographic scope of the *Washington v. United States* case related to salmon passage and the state's road culverts, the scope of the County inventory includes areas of the county that provide potential salmon habitat and does not address areas upstream of natural fish passage barriers, such as Snoqualmie Falls, which provide habitat for trout but not migratory salmon species.

3.1. Prioritization Workshops

From September 2019 to December 2021, King County hosted seven workshops with tribal, state, federal, and county staff to develop the methodology for prioritizing the relative habitat benefits from restoring salmon passage at fish passage barriers. The initial workshops focused on defining the scope and framework for the prioritization effort. The workshop discussed the merits and drawbacks of scoring-and-ranking prioritization compared to optimization analysis.[3] The general consensus was that a scoring-and-ranking prioritization approach for the county inventory would be most intuitive and useful for barrier prioritization.

Workshops in 2020 focused first on validating assumptions and identifying relevant metrics to incorporate into prioritization scoring. These metrics needed to be pertinent to habitat benefits and available as a measured variable with valid and similar resolution across the full barrier inventory. Key metrics that the initial workshops identified for consideration included:

- Barrier severity: as assessed in the inventory (0%, 33%, or 67% passable);
- Stream habitat quantity and quality: a summation of upstream stream segments analyzed for the intrinsic potential of upstream habitat for juvenile coho rearing;
- Connectivity: based on the number and severity of other barriers down- and upstream of a given barrier;
- Habitat quality: based on land cover GIS layers; and
- Potential use by Chinook or Lake Sammamish kokanee.

The prioritization participants agreed to use an analysis of the geomorphic potential of a stream reach to provide habitat for rearing coho salmon as the primary surrogate for stream habitat quantity and quality. The analysis of juvenile coho rearing habitat encompasses the most wide-ranging extent of potential salmon habitat in county streams. Basing the stream habitat quantity and quality on a single species provides a valid measure of salmon habitat that is simple and easy to understand. Most of two workshops spent time providing input to the intrinsic potential analysis and its output.

Once workshops established the intrinsic potential approach, the county presented different formulas for prioritization scoring. To test the formulas, the county calculated priority scores for barriers in three test subbasins: Cherry Creek in Water Resource Inventory Area (WRIA) 7, Bear Creek in WRIA8, and Soos Creek in WRIA9. A workshop in October 2020 provided scores with a draft formula for the Cherry Creek and Bear Creek subbasins. Participant input from this workshop identified several issues with the initial formula and suggestions for modifications of the metrics or the formula. The county then reformulated the priority formulas to test a variety of different approaches.

[3] Scoring-and-ranking prioritization assigns a score to a barrier based on a formula combining barrier-specific metrics related to barrier characteristics, location, amount and type of habitat, etc. The higher the score, the higher the priority of the barrier for remedy. Optimization analysis combines input variables like the spatial relationships of a barrier network, remedy costs, and ecological variables to identify which barrier remedies maximize the total increase in accessible upstream habitat given the input constraints (such as a given budget). Kemp and O'Hanley (2010), Martin and Levine (2017), and Martin (2019) compare the merits and constraints of scoring-and-ranking prioritization methods and optimization analyses.

In a June 2021 workshop, the county presented three different formula options and test scoring in all three test subbasins. The workshop participants agreed that the updates addressed some of the issues with the original formula and provided additional input. The county again updated the prioritization options based on the suggestions. In a workshop in July 2021, tribal and WDFW staff agreed on a final consensus formula to apply to the full county barrier inventory.

A December 2021 workshop presented the prioritization scores for the majority of the inventory of county barriers. This workshop detailed some minor adjustments to the scoring formula to account for the wide range of barrier settings that occurred when applying the formula to the full barrier inventory. These adjustments targeted methods to ensure that scores better account for the relative salmon habitat benefits of a specific barrier remedy.

Sections below detail:

- Initial formulas that the county tested;
- The final formula that achieved consensus approval by workshop participants; and
- Results of prioritization of the full county barrier inventory.

3.2. Prioritization Methodology

The inventory of barriers at county assets involved field assessment of more than 3,400 potential sites. As the county team started the inventory, it was clear that they would identify hundreds of county assets that were partial or full fish passage barriers. As the inventory moved closer to completion in late 2020, the assessment data showed that the county would be responsible for more than 900 fish passage barriers as assessed by the full inventory.

The goal of the county's Fish Passage Restoration Program is to get the most salmon to the best habitat as soon as possible. With more than 900 fish passage barriers to consider, the county needs a useful, credible system to characterize which barriers would restore salmon access to the most and best habitat.

Prior to the workshops, county staff reviewed prioritization methods applied in other parts of the United States. These fell into two general categories:

- Scoring-and-ranking methods based on scoring barrier attributes or metrics with assigned points combined into a standard formula. Formulas can use information such as simple qualitative information (Hoffman, 2006) to more detailed descriptive and ecological data from GIS or field surveys. Examples include culvert prioritization in the Nestucca/Neskowin Watersheds in western Oregon (Hoffman, 2006), the WDFW prioritization index (from the 2019 WDFW Manual), the Upper Columbia Salmon Recovery Board Fish Passage Prioritization, and the Chehalis Fish Passage Barrier Prioritization, the Olympic Peninsula Fish Barrier Culvert Prioritization, and various prioritization methods developed by the Oregon Department of Fish and Wildlife over the last 15 years. Martin (2019) provides a detailed overview of scoring-and-ranking prioritization methods in the eastern United States. Each of these prioritization methods developed a formula of regionally relevant metrics to score barriers in their inventories.

- Optimization methods provide tools to evaluate barrier removal scenarios that open up the most habitat given constraints like the amount of available funding. Optimization considers the spatial relationships between barriers within watersheds to look at how barrier remedies combine to allow fish to reach the most possible habitat given input constraints. Examples include FISH*Pass* in California and FishWerks in the Great Lakes. Kemp and O'Hanley (2010) provide a detailed overview of optimization methods.

Based on input from the workshops, the county selected a scoring-and-ranking method to develop and apply to the full inventory of county fish passage barriers. Of the two methods, workshop participants generally found a scoring-and-ranking approach to be more intuitive for users and the public. Workshop participants were also concerned that optimization approaches are susceptible to wholesale changes in recommended priorities due to changes in inherently uncertain variables like future budgets, individual project costs, project feasibility, and the ongoing addition of more barriers to regional datasets.[4]

After selection of scoring-and-ranking as the preferred prioritization method, the county worked to adapt an approach similar to the Upper Columbia Salmon Recovery Board barrier prioritization formula. This involved seeking relevant metrics and supporting data sources that could be combined into a scoring formula for the King County barrier inventory.

4. Prioritization Metrics

Intuitively, the ideal prioritization formula would score barriers highest if:

- They block substantial amounts of high quality habitat,
- Salmon can reach them without being blocked by downstream barriers,
- Salmon that swim past the barrier site would not be blocked by other barriers upstream, and
- The barrier occurs on a stream that is used by species of interest.

At the core, formulas that provide scores that increase and decrease based on the fundamental drivers of these barrier parameters is the goal for King County.

County staff researched a broad range of scoring-and-ranking barrier prioritization approaches that have been developed for different parts of the country. These included approaches developed by the Nature Conservancy for barriers in the eastern United States where salmon returning from the ocean to reproduce are not important drivers for restoring stream connectivity. Approaches used on the west coast typically focused on prioritizing barriers based on benefits for restoring salmon access to healthy river and stream habitat. Even given the different kinds of fish in the different parts of the county, formula metrics usually included elements addressing:

- The amount of stream habitat blocked by a barrier (habitat quantity);[5]

[4] In optimization methods, the barrier portfolio that generates the maximum habitat gain could change entirely if cost, access, or additional barrier information assumed for the analysis is not accurate. In the future, the county may pursue optimization tools to support decisions on project portfolios in shorter term capital programs that maximize habitat gain.

[5] Some formulas evaluated this for each species of interest, while others did this based on a single value for a barrier irrespective of different habitat use for different fish species.

- The existing and future habitat conditions of the barrier's watershed (habitat quality);[6]
- The number and severity of barriers present in the stream network (habitat connectivity); and
- The number or stock status of fish species that were present or potentially used the waterway near the barrier (species use).

County staff searched for data sources in the different categories that covered the entire area of the barrier inventory and that could inform metric scoring for a prioritization model. Consistent data across the inventory provided a key screening factor for data sources. Table 1 identifies the possible data sources considered for use in prioritization scoring.

Table 1. Possible Data Sources Considered for Fish Passage Barrier Prioritization Scoring.

METRIC	POSSIBLE DATA SOURCE				
Habitat Quantity	National Hydrography Dataset	King County Watercourse GIS Layer	NOAA Intrinsic Potential Analysis		
Habitat Quality	GIS Land Cover Layers	Puget Sound Watershed Characterization Project	Variable Infiltration Capacity model	Ecology 303(d) list	NorWeST Database
Connectivity	King County Barrier Inventory	WDFW Fish Passage Barrier Database	King County Road GIS Layer		
Species Presence/Status	Statewide Washington Integrated Fish Distribution	Salmon & Steelhead Habitat Inventory & Assessment Program	King County fish distribution maps	DNR Water Typing	SalmonScape

4.1. Stream Habitat Quantity and Quality

For the barrier inventory, county staff cross-referenced various data sources for watercourse locations, county asset location, parcel information, and topography to identify locations to field survey to determine if the site represented a county asset in a watercourse with potential salmon habitat. If the field visit found these conditions at the site, the team assessed the site to determine if it was a fish passage barrier. Most of the inventoried barriers occurred on mapped streams.[7]

The best representation of King County watercourses is the King County watercourse layer. While this layer doesn't capture some smaller streams with potential salmon habitat and county barriers, it is the most comprehensive, countywide data layer available currently. This layer is the foundation for developing a metric for Stream Habitat Quantity and Quality.

Overlayed on the stream network, National Marine Fisheries Service developed an analysis of coho rearing intrinsic potential of the mapped watercourses (Agrawal *et al.* 2005; Burnett *et al.*, 2007; McMahon, 1983; Rosenfeld, *et al.*, 2016; Rosenfeld, *et al.*, 2000, Williams, *et al.*, 2006). The extent of coho rearing habitat occurs in all kinds and sizes of waterways and provides a conservative measure of the extent of potential habitat for all salmon and steelhead in King County waterways. This intrinsic

[6] This could include conditions related to stream flow or water temperature under existing conditions and predicted future conditions based on climate change modeling.

[7] For some sites, barriers identified in the inventory occurred on streams that standard watercourse GIS layers did not capture. This presented a challenge for determining Stream Habitat Quantity and Quality, since most watercourse GIS layers missed some headwaters and other small streams where field observations documented potential fish use.

potential analysis evaluates habitat suitability for the juvenile coho rearing habitat based on physical attributes of 200 meter stream segments. The analysis uses habitat suitability curves to evaluate the value of each stream segment for juvenile coho rearing based on stream gradient, valley width confinement, and stream depth.[8] When combined with the King County watercourse layer, the intrinsic potential values represent the potential habitat quality of a stream segment in consideration of the segment's gradient, confinement, and depth.[9] The intrinsic potential scores for all upstream reaches are summed to generate the value for Stream Habitat Quantity and Quality.

Prioritization efforts like the Upper Columbia Salmon Recovery Board barrier prioritization evaluated habitat quantity for several fish species and integrated the values into the habitat quantity scoring. Due to concerns about accurate information on Chinook and steelhead habitat extent in King County, and since the coho rearing habitat analysis already included most of the potential salmon habitat in county waterways, the county decided to base habitat quantity on the King County watercourse layer overlaid with the coho rearing intrinsic potential values.

4.2. Habitat Quality of the Watershed

In most prioritization efforts, habitat quality of the stream's watershed is described by combining relevant land cover GIS layers to generate scores tied to land cover types that are correlated with high or low quality stream habitat. For salmon, forested land cover over more area of a watershed is associated with high quality stream habitat, while higher percentage of impervious land cover types has been shown to result in lower quality stream habitat. Data sources for land cover are readily available. NOAA's Coastal Change Analysis Program (C-CAP) provides a recent and accurate source for forested land cover throughout the country and for King County.[10] For impervious land cover, King County Impervious Surface GIS layer is the most comprehensive and current data source.

With climate change expected to affect stream flow and water temperatures over the next several decades, future habitat quality has been factored into other prioritization efforts. In most cases, resource managers looked at modeled conditions for future climate change scenarios at the barrier site. For the King County prioritization, workshop participants thought that climate effects should be addressed during project design versus as part of the prioritization. Changes in water temperature at barriers in the county inventory would be difficult to differentiate given the similar elevation and hydrology characteristics of the vast majority of county barrier sites. For example, flows in all but a few of the streams with county barriers are primarily supported by rainfall and not snowmelt. Localized influences on water temperature, like presence of springs or groundwater flow, likely are more

[8] The intrinsic potential analysis calculated the gradient, depth, and channel confinement for 200 meter reaches along the full King County watercourse layer. Depth estimates are based on a regression using the basin size weighted by precipitation, with spot verification based on depths measured during the inventory and assessment of county barriers.

[9] One data gap from the intrinsic potential analysis is that the habitat suitability curves for coho rearing do not apply to lakes, ponds, and wetlands. These parts of the watercourse network therefore are not included in the current intrinsic potential analysis. For the basin areas upstream of county barriers, most of these situations are relatively small ponds or wetlands.

[10] The percent forested coverage is based on the 2016 C-CAP Deciduous Forest, Evergreen Forest, Mixed Forest, Palustrine Forested Wetland, Estuarine Forested Wetland categories.

determinative of future climate change resiliency than modeled future temperatures. Also, predictions of future temperature at a particular barrier location misses the connected nature of the stream system that salmon migrate through during their lives. Streams higher in a single watershed would generally see less temperature influence than the larger streams and rivers closer to Puget Sound. Prioritizing sites high in a watershed with lower future temperatures would inadvertently lead to lower relative priority scores to remedy barriers that block salmon from swimming to these same upstream areas. Consensus from the workshops was that climate change data sources would not help differentiate the relative benefits provided by remedy of barriers in the King County inventory.

4.3. Connectivity

The number and severity of barriers along a stream determines how "connected" the stream habitat is for migrating salmon.

Most prioritization formulas consider the severity of the specific barriers, with more complete barriers typically scoring higher. King County tested a number of options to incorporate barrier severity for prioritization, with points assigned ranging from ten to thirty percent of the total points available. Review in workshops identified that the barrier severity parameter tended to swamp other metrics to the extent that complete barriers with very little upstream habitat would score higher than partial barriers that block very substantial amounts of habitat. This occurred even when the number of points for the severity parameter was only ten percent of the total available points.

Barriers with few other barriers downstream pose fewer challenges to salmon reaching upstream habitat once a barrier is remedied. Similarly, barriers with fewer upstream barriers provide better access to upstream habitat. Connectivity can be characterized by the number of barriers, the severity of barriers, or the distance between barriers.

The county tested a number of different parameters associated with barrier number, severity, and location.

- Downstream connectivity parameters evaluated included the number and severity of mapped barriers downstream of the specific barrier being scored and whether a barrier was within or upstream of a cluster of very-closely-spaced barriers. To consider challenges associated with more intense instream development along a waterway, the county also considered parameters related to clusters of several barriers in close proximity, or the existence of very long stream reaches enclosed entirely in pipes. These parameters represent how challenging it would be for salmon migrating upstream to reach a particular county barrier.
- Upstream connectivity evaluated included parameters that looked at the number and severity of upstream barriers (similar to downstream connectivity) and the density of barriers (barrier per stream length) in the subbasin where the barrier is located.

4.4. Species Presence and Status

Consistent with the overall goal of getting the most salmon to the best habitat as quickly as possible, barrier prioritization in King County focuses on potential habitat for anadromous salmonids and native kokanee. Within that overall program focus, Chinook salmon in King County and the broader Puget

Sound region hold an elevated importance since they are both listed as threatened on the Endangered Species Act (ESA) and are the primary food source for the ESA listed Southern Resident Killer Whale population. In Lake Sammamish, native kokanee stocks are critically depressed. Given their importance and currently depressed status, passage barriers that block Chinook or native kokanee from upstream habitat merit additional priority. King County staff defined areas of county watersheds that contain potential Chinook and kokanee habitat. Barriers within these areas receive extra points to reflect the benefits of fish passage restoration at those sites for Chinook and kokanee.

5. Final Prioritization Formula

With input on the metrics and parameters from workshops in early 2020, county staff generated preliminary prioritization scores for county barriers in the Cherry Creek and Bear Creek subbasins. A workshop in October 2020 presented these scores for discussion, input, and suggestions. Generally, workshop participants found that the prioritization scoring showed promise, but some elements needed revision to better reflect the relative habitat benefit of individual barrier remedies.

The formula combines scores for different metrics. Some metrics include several different parameters. For each metric or parameter, the county calculated a barrier-specific value. This metric value is converted to a metric score based on rules detailed in Section 4.1.

In particular, testing with the initial formula revealed that the barrier severity parameter provided most of the points for many of the barriers, and also resulted in relatively high scores for complete barriers regardless of the scores for any of the other metrics. As a result, some complete barriers on small streams with small amounts of poor quality upstream habitat were ranking toward the top of the scoring. In some cases, partial barriers much further downstream scored significantly lower than the upstream complete barriers. Workshop participants recommended additional analysis and revision to reconcile these counterintuitive results.[11] Upstream connectivity was another parameter that resulted in markedly higher scores for the furthest upstream barrier in a system.

In response to the input, the county tested out a number of revisions for the parameters and formulas in the Cherry Creek, Bear Creek, and Soos Creek subbasins. Options analyzed included reducing or removing points for the barrier severity parameter, several options with different point allocations for habitat quantity, and developing new parameters for Connectivity (basin barrier density and barrier clustering). In two workshops in the summer and fall of 2021, participants reached consensus on a final prioritization formula that is summarized in Table 2.

[11] WDFW staff noted that the barrier severity categories from the WDFW assessment method are somewhat qualitative.

Table 2. Summary of Final Prioritization Metrics, Parameters, and Scoring.

Metric	Parameter	Max. Possible Points
Stream Habitat Quantity & Quality	$\sum(IP\ Score\ of\ upstream\ segments)$ The Stream Habitat Quantity and Quality score is normalized to 55 pts. max. *IP: coho rearing intrinsic potential*	55
Watershed Habitat Quality	Land Cover (% forested)	8
	Land Cover (% impervious area)	7
Connectivity	# & Severity of Downstream Barriers	15
	Barrier Clusters: For long pipes or high density sites/clusters- gets points if site is not within or upstream of a long pipe or barrier cluster.	5
	Subbasin Barrier Density	5
Species Presence & Status	Chinook or Lake Sammamish Kokanee Benefits	5
	Total Max Score	**100**

5.1. Final Parameter Scoring

1.1.1. Stream Habitat Quantity and Quality

Table 3 shows the scoring framework for Stream Habitat Quantity and Quality. Stream Habitat Quantity and Quality is based on a combination of upstream length and analysis of the intrinsic potential of upstream stream segments as coho rearing habitat. The upstream length looks at the number of 200 meter stream segments mapped upstream of a barrier. Coho rearing intrinsic potential quantifies the potential of each stream segment to provide coho rearing habitat. The intrinsic potential is based on habitat suitability curves for coho rearing based on stream segment gradient, depth, and valley confinement (see Section 3.1).

Table 3. Stream Habitat Quantity and Quality Scoring.

Stream Habitat Quantity and Quality
Scoring Formula
$\sum(IP\ Scores\ of\ upstream\ segments)$
RULES: *i) HQ score is 55 pts. for sites with Stream Habitat Quantity and Quality values of ≥30;* *ii) For sites with Stream Habitat Quantity and Quality values<30, the Stream Habitat Quantity and Quality score is normalized based on a value of 30.* ***IP**: coho rearing intrinsic potential for 200 meter stream segments*

The sum of the intrinsic potential value for all upstream segments provides a Stream Habitat Quantity and Quality value for each of the county barriers. For example, if a given barrier has 4 stream segments upstream, with intrinsic potential values of 0.10, 0.40, 0.45, and 0.50, the value for Stream Habitat Quantity and Quality would be 1.45 (0.10 + 0.40 + 0.45 + 0.50).

While testing formulas in the three test basins, the score for Stream Habitat Quantity and Quality is generated by giving the full score of 55 points to the county barrier with the highest Stream Habitat Quantity and Quality value in the test basins. Scores for all other barriers were then normalized based on the Stream Habitat Quantity and Quality value to the top scoring barrier. For example, if a barrier had a Stream Habitat Quantity and Quality value that is 40 percent of the Stream Habitat Quantity and Quality value, the Stream Habitat Quantity and Quality score would be 22 (or 40 percent of 55).

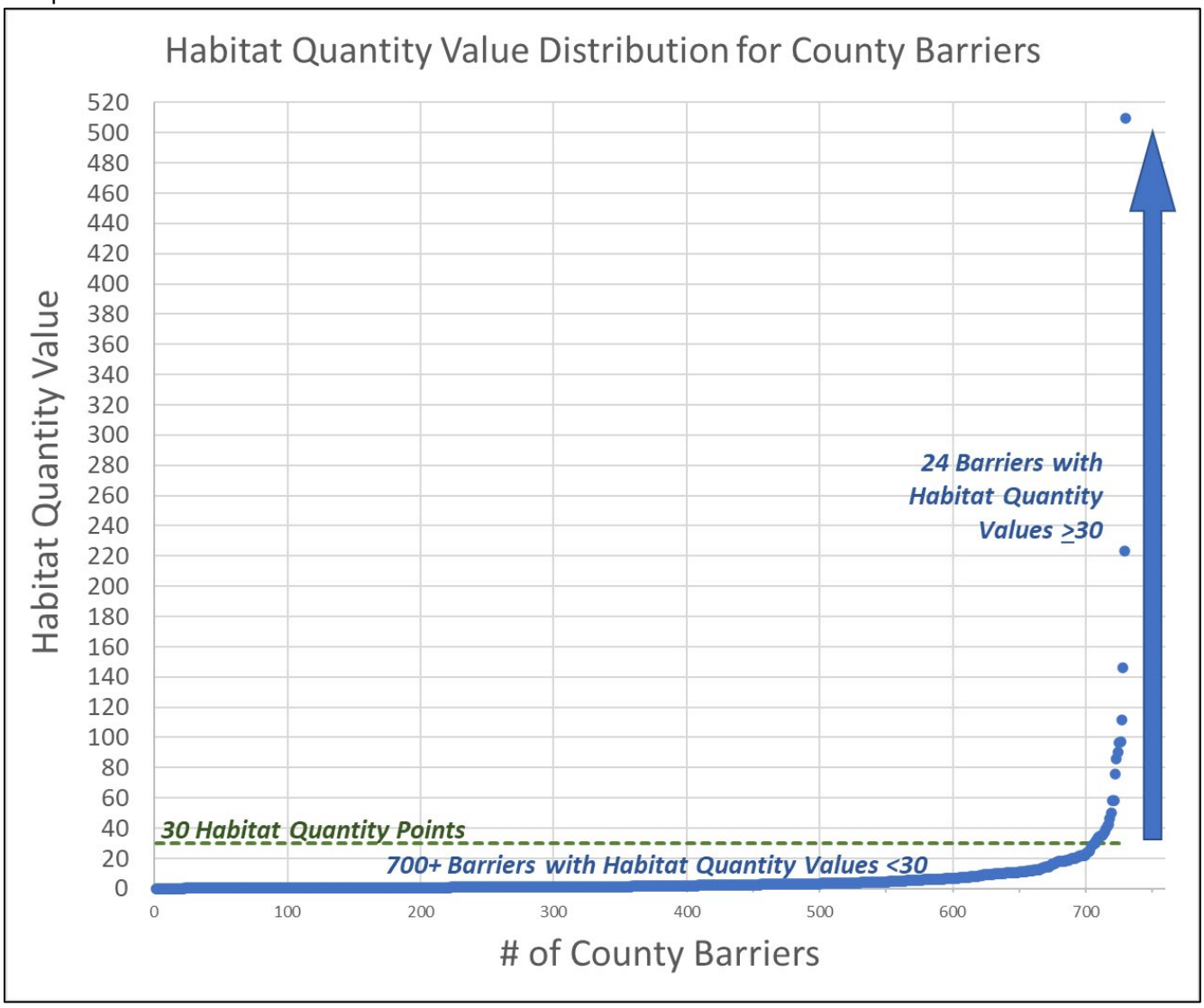
When the county scored the full county barrier inventory, the data revealed that two dozen county barriers had extremely high values for Stream Habitat Quantity and Quality (as high as 509). The high scores result from a great deal of upstream habitat length that provides good coho rearing potential. Excluding these 24 sites, the rest of the county barriers had Stream Habitat Quantity and Quality values ranging from zero to 30. Figure 1 depicts the distribution of Stream Habitat Quantity and Quality values and shows the skew in values on the high end.

County barrier FPS-4355[12] has the highest Stream Habitat Quantity and Quality value of 509. Normalizing the Stream Habitat Quantity and Quality scores against a value of 509 would mean that the hundreds of county barriers with values of 30 or less would have a Stream Habitat Quantity and Quality score of less than 3.2 (or $(30 \div 509) \times 55 = 3.2$). To provide a more meaningful distribution of Stream Habitat Quantity and Quality scores for the vast majority of county barriers with a Stream Habitat Quantity and Quality value of less than 30, all barriers with Stream Habitat Quantity and Quality values 30 or higher received 55 points for Stream Habitat Quantity and Quality, and the other scores were normalized based on a value of 30.

For example, barrier FPS-2098 on Cottage Lake Creek under Avondale Road NE has a Stream Habitat Quantity and Quality value of 111, which converts to 55 points for Stream Habitat Quantity and Quality since the value is greater than 30. FPS-2420 on Peterson Creek under 196th Ave SE has a Stream Habitat Quantity and Quality value of 20, which converts to 36.7 Stream Habitat Quantity and Quality points (or $(20 \div 30) \times 55 = 36.7$).

[12] FPS is a site identification acronym that means Fish Passage Site in the county's Geographic Information System database.

Figure 1. Distribution of Stream Habitat Quantity and Quality Values for All County Barriers with Complete Scores.[13]



Barriers that occurred on streams that were not mapped on the watercourse layer had no values for Stream Habitat Quantity and Quality due to lack of mapped streams to analyze for the coho IP. [14] Due to the lack of any data to generate a score for the Stream Habitat Quantity and Quality metric, these barriers have incomplete prioritization scores.[15] See Section 7 for more details on future updates that will address barriers with incomplete prioritization scores.

[13] Barriers that occurred on streams that were not mapped on the watercourse layer had no Stream Habitat Quantity and Quality values due to lack of coho IP analysis on unmapped streams. These barriers have incomplete prioritization scores.

[14] Some barriers that occurred on mapped watercourses subject to coho IP analysis still had Stream Habitat Quantity and Quality value and score of zero. Since these barriers had data to determine a Stream Habitat Quantity and Quality score, their prioritization scores are complete.

[15] Prioritization updates will include updates to the stream mapping and coho IP analysis that will complete the scoring of all inventoried barriers.

1.1.2. Watershed Habitat Quality

The stream's Watershed Habitat Quality metric was based on two parameters – the percent of forested land cover and the percent of impervious surface.

Table 4 shows the scoring framework for the Watershed Habitat Quality parameters.

Table 4. Scoring Framework for Watershed Habitat Quality Parameters.

Watershed Habitat Quality			
% Forested Area* (2016 C-CAP)	**Score**	**% Impervious Area (2015 KC Impervious Surface)**	**Score**
<20%	0	>10%	0
20 to 40%	1	7 to 10%	1
40 to 65%	3	5 to 7%	3
65 to 75%	5	3 to 5%	5
>75%	8	<3%	7
* % Forested based on C-CAP Deciduous Forest, Evergreen Forest, Mixed Forest, Palustrine Forested Wetland, Estuarine Forested Wetland			

1.1.3. Connectivity

The Connectivity metric was based on three parameters:

- The number and severity of barriers downstream from the scored barrier site;
- Whether the scored barrier site is within or upstream of a tight cluster of barriers (Table 5) or a piped conveyance barrier that is more than 1,000 feet long; and
- The density of barriers in a subbasin upstream of the most downstream barrier blocking salmon access from salt water.

Table 5 shows the scoring framework for the parameter based on the number and severity of downstream barriers.

Table 5. Scoring for the Number and Severity of Downstream Barriers.

Number and Severity of Downstream Barriers		
Likelihood of Access = Product of Individual Passability at All Known Downstream Barriers		
Likelihood of Access	**Score**	**Notes**
0	1	at least 1 complete, or sites with Barrier = Yes, Passability = Unknown
>0 and ≤0.2211	4	multiple partial barriers w/ at least one that's 33% passable; or more than 3 barriers that are 67% passable
>0.2211 and ≤0.4489	7	one 33% barrier or 2-3 barriers that are 67% passable
>0.4489 and ≤0.67	10	no more than one barrier that's 67% passable
>0.67	15	No downstream barriers

Table 6 shows the scoring framework for the barrier cluster parameter. The barrier cluster parameter reflects streams with a localized cluster of barriers that adversely affect the ability to realize upstream habitat gains from a single barrier remedy. Barriers within or upstream of a defined barrier cluster would get fewer points and score lower than barriers that are downstream of all barrier clusters.

Table 6. Scoring for the Barrier Cluster Parameter.

Barrier Clusters	
Barriers that are not within or are downstream of a barrier cluster receive points. Barriers within or upstream of a barrier cluster do not receive points. *Barrier clusters are defined as:* • *A group of at least 3 barriers; and* • *At least 15 barriers per mile (determined by the distance between the most upstream and most downstream barrier); and* • *Maximum distance between any two barriers is 704' (twice the avg. separation for 15 barriers/mile).* *OR* • *A barrier with a total pipe length of >1,000'.*	
Criteria	**Score**
No cluster or downstream of any cluster	5
Within ***OR*** Upstream of a barrier cluster	0

Table 7 shows the scoring framework for the subbasin barrier density parameter. The subbasin barrier density is a parameter that quantifies the density of barriers in individual subbasins and provides a subbasin-wide metric of system connectivity. All barriers within the same subbasin receive the same score for this parameter, with subbasins with a lower barrier density getting higher scores.

The value for the subbasin barrier density parameter is based on the number of barriers per stream length in the subbasin upstream of the most downstream county barrier blocking salmon access from salt water (the controlling county barrier). The county calculated the subbasin barrier density for each discrete stream subbasin that has one or more county barriers. Within the subbasin the parameter counts the number of barriers of any type and ownership within the basin upstream of the controlling county barrier and quantifies the stream length within the subbasin. The subbasin barrier density value

equals the number of barriers divided by the stream length. This subbasin barrier density value is then scored from 0 to 5 points as shown in Table 7. If there are multiple county barriers within a given subbasin, each will have the same value and score for this parameter.

Table 7. Scoring for the Subbasin Barrier Density Parameter.

Subbasin Barrier Density		
This is a metric based on the barriers/stream length in the subbasin upstream of the most downstream barrier blocking salmon access from salt water. The calculation is based on: • *Determining the most downstream county barrier (the controlling county barrier) on each discrete stream subbasin containing a county barrier;* • *Counting the number of barriers of any type and ownership within the subbasin upstream of the controlling county barrier;* • *Totaling the length of IP watercourse (feet) w/in the subbasin upstream of the controlling county barrier;* • *Dividing the # of barriers by the length of IP watercourse in the subbasin.*		
Barrier Density	**Score**	**Notes**
less than 25 density	5	*Barrier density values (barriers/feet) are multiplied by 100 to provide non-decimal values. Across the inventory, the upstream barrier density ranged from 0-125. The scoring bins for the barrier density values provide a reasonable spread of the scores for this parameter.*
≥25 and <50 density	3	
≥50 density	0	

1.1.4. Species Presence and Status

Table 8 shows the scoring for barriers in potential habitat for Chinook or Lake Sammamish kokanee. All stream reaches in the County that Chinook or Lake Sammamish kokanee are known to use based on WDFW and County fish distribution data were manually delineated with polygons that represented the stream and its 100 year floodplain. In addition, the lower 100 meters of streams that entered Puget Sound or Lake Washington or Lake Sammamish were assumed to be accessible for non-natal Chinook juvenile rearing and were also delineated as potential habitat.

Table 8. Scoring Framework for Chinook or Kokanee Habitat Benefits.

Species	
Potential Habitat for Chinook or Lake Sammamish Kokanee	**Score**
Yes	5
No	0

1.1.5. Calculating Prioritization Scores

The total barrier prioritization score is the sum of the individual metric scores for each category. The maximum possible score is 100.

$$Total\ Score\ = Stream\ Habitat\ Quantity\ \&\ Quality + Watershed\ Habitat\ Quality + Connectivity + Chinook/Kokanee$$

The scoring formula provides up to 55 points for Stream Habitat Quantity and Quality and up to 45 points for all other metrics. Barriers that score high in all but Stream Habitat Quantity and Quality could have scores as high as 45 points. All barriers in the inventory occur on streams that meet physical

criteria as potential salmon habitat, but a number of barriers have very little actual upstream fish habitat (as reflected by the Stream Habitat Quantity and Quality score).

The program goal is to provide salmon access to upstream habitat that county barriers currently block. If the barrier does not have meaningful upstream habitat, then high scores on the other categories can result in misleadingly high total scores (as high as 45). This artifact of the scoring system was identified during the workshops and became fully evident when the county evaluated the initial scoring for the full county barrier inventory. Some barriers scoring in the low forties had essentially no upstream habitat, while others had fairly high Stream Habitat Quantity and Quality scores. To avoid an improper equating of the priorities for barriers like these, the county developed a scoring adjustment for barriers not meeting a minimum threshold for upstream Stream Habitat Quantity and Quality values and distance.

For barriers meeting the following criteria for upstream habitat, the score from the priority formula is divided by four:

1. Sites score zero for Chinook or kokanee benefits; AND
2. The upstream habitat distance is less than 657 feet (200 m); OR the upstream Stream Habitat Quantity and Quality value is no more than 0.2 (even if the Stream Habitat Quantity and Quality distance value is at least 657 feet).

For example, FPS-150 on a small unnamed stream under SE David Powell Road had a Stream Habitat Quantity and Quality score of zero and the scores for other categories totaled to 40 points. The barrier does not occur on a stream reach that has potential use by Chinook or kokanee, so it meets the first criteria above. While there is 697 feet of upstream habitat distance, the value for Stream Habitat Quantity and Quality is less than 0.2, so it meets the second criterium above. Since it meets both criteria for dividing the total score by four, the adjusted final score for FPS-150 is 10.

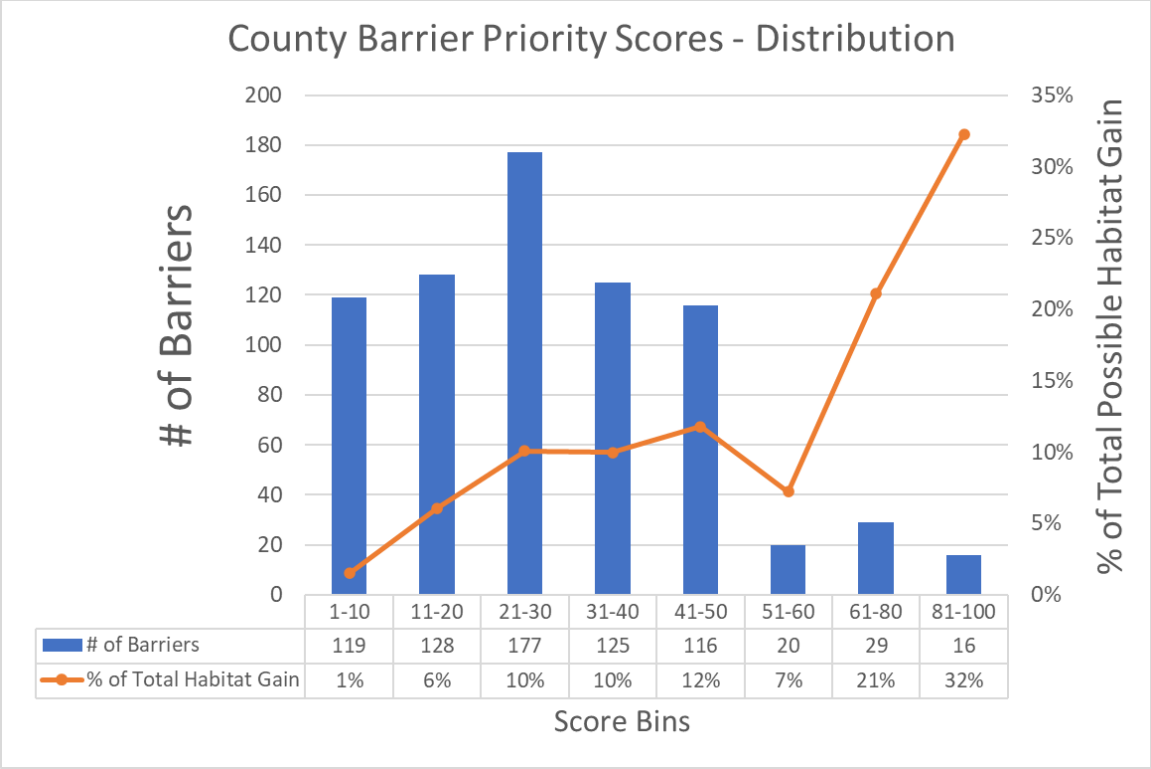
79 barriers met the criteria related to low upstream habitat gain and therefore had their prioritization scores adjusted.

6. Prioritization Results

The county analyzed 946 sites assessed as full or partial barriers. Of these, 730 barriers have complete prioritization scores since all of the metric categories have data that can be scored. The remaining 216 barriers have incomplete scores due to missing data in one or more categories (most often this is due to lack of coho intrinsic potential analysis since the stream on which the barrier occurs is not yet mapped). The discussion below focuses on the 730 county barriers with complete scores.

Scores range from 1 to 95 (out of a maximum total score of 100). Figure 2 provides a chart of the distribution of priority scores and habitat gain for county barriers.

Figure 2. Distribution of Priority Scores and Habitat Gain for King County Fish Passage Barriers



The prioritization formula intentionally "weights" the Stream Habitat Quantity and Quality metric highly, with a potential 55 out of 100 total points. The relatively high weighting aligns with the program goal of restoring fish passage to allow salmon to access actual salmon habitat that a barrier blocks. All other metrics being equal, a barrier that blocks access to more habitat should have a higher priority than a barrier blocking less habitat. As seen in Figure 2, the distribution of potential habitat gain across the inventory of county barriers is very skewed to a relatively few barriers having very large amounts of upstream habitat gain. The prioritization scores reflect this skew with relatively few county barriers with high scores. This is driven primarily by the metric for Stream Habitat Quantity and Quality.

A total of 65 county barriers score higher than 50 points. These barriers receive at least 10 points for the Stream Habitat Quantity and Quality metric (and 25 barriers receive the maximum of 55 points for the Stream Habitat Quantity and Quality metric). These barriers average 40 points for the Stream Habitat Quantity and Quality metric. Remedy of these 65 barriers cumulatively would provide 61% of the total possible habitat gain from all county barrier remedies.[16]

The 241 barriers scoring between 31 and 50 could result from very high scores for all metrics but Stream Habitat Quantity and Quality, or high scores for Stream Habitat Quantity and Quality and lower scores from other metrics. Cumulatively, remedy of these barriers would provide 22% of the total possible habitat gain from all county barrier remedies. The lower cumulative habitat gain for so many more barrier remedies is a result of the generally lower Stream Habitat Quantity and Quality scores for

[16] Habitat gain is measured based on the total Stream Habitat Quantity and Quality value upstream to the next county barrier, or to the end of coho intrinsic potential if there are no upstream county barriers.

barriers scoring in this range. The Stream Habitat Quantity and Quality metric scores range from zero to 38. These sites average 8 points for the Stream Habitat Quantity and Quality metric.

The 177 barriers scoring between 21 and 30 generally result from mid-range scores for all metrics. Stream Habitat Quantity and Quality metric scores in this group range between 1 and 21 and the average Stream Habitat Quantity and Quality score is 5 points.[17] Cumulatively, remedy of these barriers would provide 10% of the total possible habitat gain from all county barrier remedies.

The 247 barriers scoring no more than 20 points universally have low scores for all metrics, or have extremely low scores for the Stream Habitat Quantity and Quality metric and have had their scores adjusted to reflect little or no potential upstream habitat gain from a barrier remedy. The Stream Habitat Quantity and Quality metric scores range from zero to 13. These sites average 2 points for the Stream Habitat Quantity and Quality metric. Cumulatively, remedy of all 247 of these barriers would provide 7% of the total possible habitat gain from all county barrier remedies.

The prioritization results will inform development of county plans for fish passage restoration in the coming years. The results show that remedies of the high scoring barriers will restore salmon access to most of the habitat blocked by county barriers and the county is planning to accomplish this by 2032.

7. Availability of Fish Passage Barrier Inventory and Prioritization Data

The King County barrier database, including prioritization scoring, is available for download at the King County GIS Open Data website (https://gis-kingcounty.opendata.arcgis.com/) under "Fish Passage Sites/fp fishpassagesites points." Attributes that can be displayed include location and severity of assessed fish passage sites, barrier type, the overall priority score of King County fish passage barriers, and the barrier-specific values and point scores of each prioritization parameter.

8. Next Steps

Over time, the county plans to update the prioritization to reflect new and improved information. New information includes identification of newly assessed barriers and barrier remedies that would affect the Stream Habitat Quantity and Quality and Connectivity scoring.

The prioritization currently applies only to county-owned barriers.[18] Broader application to all barriers, regardless of owner, may be pursued to better inform decisions on fish passage projects and programs by all barrier owners.

The initial prioritization provides incomplete scores for 216 barriers that field assessment identifies with potential salmon habitat upstream, but that are not mapped with streams and therefore do not have

[17] This score range demonstrates the value of normalizing the Stream Habitat Quantity and Quality scores on 30 rather than the highest Stream Habitat Quantity and Quality value of 509. If normalized based on 509, the highest Stream Habitat Quantity and Quality score in this group would have been 1 point, and 144 barriers would have had zero Stream Habitat Quantity and Quality points. This would mean that the entire score for 144 of the barriers in this group would have been comprised of only the metric scores for Connectivity, Habitat Quality, and Chinook/kokanee benefits.

[18] Note that the prioritization scoring for Connectivity is based on all known barriers on the stream, including non-county barriers. Remedies of non-county barriers would increase the Connectivity scores for the remaining county barriers in the same stream system.

coho rearing intrinsic potential values calculated at this time. The county is working to improve the accuracy of its mapped stream network to connect all identified county barriers with the larger stream network. This includes adding accurate stream locations where they exist on the ground but have not previously been accurately mapped, removing stream segments where they are mapped but do not actually occur, and revising stream alignments where field conditions differ from mapped locations. The updated stream network will be incorporated into updates to the analysis of coho rearing intrinsic potential (and eventually into the National Hydrography Dataset). With more complete coho rearing IP, the prioritization will better reflect the relative priority of the full barrier inventory. As most of the unmapped streams are very small watercourses, most of the barriers on these streams will likely have relatively low priority scores. The county is also evaluating options to expand the coho intrinsic potential analysis to lakes, ponds, and wetland areas so that these waterbodies are captured in the Stream Habitat Quantity and Quality metric.

Updates to the prioritization are planned in late 2022 to reflect planned work on the stream network and coho intrinsic potential. Thereafter, updates would be at least every 2 years to reflect updated barrier data. Updates will include new information that's available on all metrics, including where barriers have been remedied to make them fully passable.

Barrier remedies have the potential to change scoring for Stream Habitat Quantity and Quality and Connectivity. Changes in scoring for Stream Habitat Quantity and Quality have the most potential to re-order overall barrier priority. After remedy of the 24 barriers receiving the maximum 55 points for Stream Habitat Quantity and Quality, the normalization of the scores for Stream Habitat Quantity and Quality will be based on the remaining county barrier with the highest Stream Habitat Quantity and Quality value. Currently this is FPS-2498 on an unnamed tributary to the White River, with a Stream Habitat Quantity and Quality value of 28.8. After remedy of the 24 barriers with higher Stream Habitat Quantity and Quality values, FPS-2498 would have the highest Stream Habitat Quantity and Quality value in the barrier inventory, and its Stream Habitat Quantity and Quality score would jump from 53 to 55.

Other barriers scoring less than FPS-2498 would see similar increases in the points for Stream Habitat Quantity and Quality metric since their habitat value will be a greater relative proportion of 28.8 than the 30 that is currently used for normalization. For example, FPS-1751 on Big Soos Creek under SE 192nd has a Stream Habitat Quantity and Quality Value of 11.6. Using 30 to normalize to points results in a Stream Habitat Quantity and Quality score of 21 points:

$$(11.6 \div 30) \times 55 = 21.3$$

With normalization based on a value of 28.8, the Stream Habitat Quantity and Quality score for FPS-1751 increases to 22 points:

$$(11.6 \div 28.8) \times 55 = 22.1$$

As the county remedies higher scoring barriers, the "re-normalization" of the Stream Habitat Quantity and Quality scoring will result in more differentiation between barriers currently receiving lower total prioritization scores. For example, FPS-442 on Tuck Creek under NE Woodinville-Duvall Road has a Stream Habitat Quantity and Quality value of 24.6, the 29th highest Stream Habitat Quantity and Quality

value for county barriers. After remedy of the 28 barriers with higher Stream Habitat Quantity and Quality values, the Stream Habitat Quantity and Quality points will be generated by normalizing based on the FPS-442 value of 24.6.

If FPS-442 is the basis for normalizing Stream Habitat Quantity and Quality scoring, the Stream Habitat Quantity and Quality score for FPS-1751, would then increase from 21 to 26:

$$(11.6 \div 24.6) \times 55 = 25.9$$

Table 9 summarizes the changes in metric scoring after remedy of barriers with higher Stream Habitat Quantity and Quality values. The resulting cascading effect on prioritization scores as higher gain barriers get remedied will contribute to focusing priority and future effort on remedy of the barriers that have the relatively high values for the Stream Habitat Quantity and Quality metric.

Table 9. Changes in Stream Habitat Quantity and Quality Score After Remedy of Barriers with Higher Stream Habitat Quantity and Quality Values

Stream Habitat Quantity & Quality (HQ) Normalization Formula	FPS HQ Score = (FPS HQ value/HQ value used for normalization) x 55 pts.			
Scenario	Highest HQ Value in County Inventory	HQ Value Used for Normalization	FPS-1751 HQ Value	FPS-1751 HQ Score
Original Scoring	477.5	30[a]	11.6	21.3
After remedy of 24 barriers w/ HQ values >30	28.8	28.8[b]	11.6	22.1
After remedy of barriers with 28 highest HQ values	24.6	24.6[c]	11.6	25.9

[a] *In the original inventory, there are 24 barriers with HQ values more than 30 and they all get 55 HQ points.*
[b] *After remedy of all barriers with HQ values greater than 30, the next highest HQ value is 28.8 for FPS-2498.*
[c] *After remedy of barriers with the 28 highest HQ values, the next highest HQ value is 24.6 for FPS-442.*

Barriers with low values for the Stream Habitat Quantity and Quality metric will have stable priority scores in the middle to low range since they will always get few points for the Stream Habitat Quantity and Quality metric.

Scores for the Connectivity metric will also change with barrier remedies. For example, a barrier like FPS-2499 on Pussyfoot Creek under 196th Ave SE has a score for downstream connectivity of 4 due to one 33% passable barrier downstream at FPS-1754 (which receives the full 15 points for downstream connectivity). FPS-1754 is slated to be remedied by 2024 and, once that occurs, the downstream connectivity score for FPS-2499 will increase from 4 to 15 points. Barrier remedies can also increase the scores for barrier clusters and subbasin barrier density (each worth a maximum of 5 points). Changes to Connectivity metric scores will be greatest when total barriers are remedied in the same stream system.

While the factors for prioritization have been finalized, scoring for the barriers will constantly evolve as the program develops and barriers are corrected.

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