UPPER CARLSON FLOODPLAIN RECONNECTION PROJECT
YEAR 3 (2017) MONITORING REPORT

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January 29 2018

Project Timeline:
Constructed: 2014
Planted: 2015
Monitored: 2013-2017+
Adaptive Mgmt: 2016

Project Team:
Project Supervisor: Diane Concannon
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Supervising Engineer: Will Mansfield, P.E.
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Ecologist: Cindy Young
Consulting Engineers: Ian Mostenko, P.E. and Brian Scott, P.E., Herrerra Env. Consult., Inc.
Basin Steward: Mary Maier

Funding:
National Oceanic and Atmospheric Administration via The Nature Conservancy;
Coordinated Investment for Puget Sound Floodplains Initiative sponsored by The Nature Conservancy and administered by the Washington Department of Ecology;
U.S. Environmental Protection Agency via the Snoqualmie Tribe;
King County Flood Control District via the Snoqualmie Watershed Forum’s Cooperative Watershed Management Grant Program; and
King County Department of Natural Resources and Parks.

Permits:
US Army Corps NWS-2013-946
Washington Department of Ecology 401 Water Quality Certification Order 10435
Washington Department of Fish and Wildlife Hydraulic Project Approval 131771-1
King County Department of Permitting and Environmental Regulation GRDE13-0096

Executive Summary

What is this report about?

This report presents the post-project monitoring results for the Upper Carlson Floodplain Restoration Project. The monitoring period for this report is pre-project to Year 3 (2017). Monitoring will continue to Year 10 and interim reports will be produced at Years 5, 7, and 10.

Where is the project?

The project is located on 50 acres of public land located on the right bank of the Snoqualmie River between River Miles 34 and 35, less than two miles downstream of the SR 202 bridge in Fall City.

What was the purpose?

The goal of the project was to restore natural floodplain functions and processes that create riverine habitat and promote salmon recovery. The project addressed high priority needs for the threatened Snoqualmie Chinook salmon identified in the Puget Sound Salmon Recovery Plan (2007) and for threatened steelhead and other species.

What actions were taken?

The project removed 1,600 feet of levee and revetment to allow the river to migrate. Trees growing on the levee were pushed into the floodplain to be captured by the migrating channel. A setback structure was installed along of 1,100 feet of Neal Road to protect property and infrastructure. It consisted of a 600-foot-long rock revetment, one large wood structure to catch floating wood from the project site, and three engineered log jams. Some of the native spoils were used at local farms to build ‘farm pads’. Over 20 acres of invasive vegetation was treated. Approximately 25,000 native trees and shrubs were planted.

Is the project meeting its goals?

Based on the first three years of observations, it appears that the Upper Carlson project is beginning to accomplish the overall goal of restoring natural floodplain functions and processes that create riverine habitat and promote salmon recovery.

The channel expanded by 2.6 acres in the first three years and is migrating faster than the downstream reference, but is expected to slow down over the next few years.

The river has deposited two to five feet of sand and gravel throughout most of the channel within the project site and up to 12 feet in some places. A new, one-acre gravel bar formed on the left bank, creating new types of fish habitat that were not previously there.

There was a net gain of approximately 0.54 miles of juvenile fish habitat in the project site, including gravel bars and woody banks, which support lots of fish. The amount of juvenile fish habitat at the project site is similar to that at a downstream reference site, after accounting for differences in reach length.

The river contains six new logjams and the overall quantity of instream wood increased by 111 pieces. Before the
project, there were no logjams and virtually no instream wood. Even though wood abundance has increased, the site only contains about 25% as much as the reference site. This gap is expected to close over time as more floodplain wood falls into the river.

Riparian forests are re-establishing around the 1936 channel, where plantings were installed. The plants are thriving in well-drained soils without watering. Weed control efforts have been effective but are ongoing to deal with repeated invasions of butterfly bush and blackberry. Most of the knotweed has been eliminated.

Juvenile Chinook salmon use of the project site has probably increased over baseline conditions, because the amount of edge habitat has greatly increased, and the types of edge habitats that have been formed are also those that support the largest numbers these fish

**What lessons were learned?**

We observed that juvenile Chinook salmon, coho salmon, and rainbow trout use a wide array of habitat types, so projects should focus on increasing both the amount and diversity of habitat.

When placing large wood in the floodplain, orient it so that the pieces fall into the river intact.

**Water and Land Resources Division**

Use hydraulic modeling results to identify, mitigate, and monitor changes in water velocity and flood elevations. Also invest heavily in an array of water level loggers in key locations.

Project effects are difficult to predict with precision so ‘buffer’ the site with additional land purchases or conservation easements to mitigate this risk, when possible.

Consider and plan for adaptive management needs; these may need to be designed and permitted ahead of time in case they are needed in a hurry.

Plan to regularly treat blackberry and other weeds in sunny areas with disturbed soils near the levee removal site. Even though these areas may be eroded by the river, then need maintenance to prevent major weed invasions.

**Summary**

Performance standards for every project goal are meeting or exceeding expectations,

Given the habitat gains, and the positive fish response to the project, King County should consider implementing similar projects to achieve salmon recovery goals in the Snoqualmie River. Future projects should capitalize on the lessons learned to ensure continuous improvement in project design.
1 Project Description

The Upper Carlson project site is located in the Fall City Natural area\(^1\), which is 50 acres of public land on the right bank of the Snoqualmie River between River Miles (RM) 34 and 35, two miles downstream of the SR 202 bridge in Fall City.

![Vicinity map](image)

Figure 1. Vicinity map.

By the 1930's, the project site was modified from its natural condition by human activities. To protect public and private property from flood and erosion damage, an existing side channel across the meander bend was dredged and levees where constructed along both banks. By the 1950's the Snoqualmie River relocated into the dredged channel and abandoned the former meander next to Neal Road.

Prior to restoration, the river channel was 100-200 feet wide and confined on both banks. Levees and revetments extended 1600 feet along the right (east) bank and over 3,000 feet on the left (west). These features disconnected the floodplain and impaired natural processes supporting productive fish habitat, including: channel migration, floodplain connections, and

\(^1\) NW quarter of Section 10 in Township 24, Range 7.
logjam formation throughout the project site. Most of the site was forested with native trees and shrubs, but invasive knotweed extended over 16 acres.

**Project goals**

The overall goal of the project was to restore natural floodplain functions and processes that create riverine habitat and promote salmon recovery (Table 1).

**Table 1. Project goals and objectives.**

<table>
<thead>
<tr>
<th>Goals</th>
<th>Objectives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Allow the river to expand and migrate toward the right bank at natural rates</td>
<td>Remove approximately 1600 feet of toe rock and revetment.</td>
</tr>
<tr>
<td>Promote channel aggradation and form bar habitat along the LB</td>
<td></td>
</tr>
<tr>
<td>Reconnect right bank floodplain with river at lower flows&lt;sup&gt;2&lt;/sup&gt;</td>
<td>Remove approximately 1400 feet of levee</td>
</tr>
<tr>
<td>Promote formation of complex, woody right bank edge habitat</td>
<td>Fell and stage 300 existing trees in the path of the migrating channel to form semi-stable jams. Construct large downstream ELJ that will trap additional wood over time to buffer new rock revetment and protect Rd.</td>
</tr>
<tr>
<td>Re-establish riparian forests</td>
<td>Install native plants and shrubs, allow for natural recruitment. Apply herbicide to 12+ acres of knotweed, as well as blackberry and Class A-C weeds.</td>
</tr>
</tbody>
</table>

**Design Features**

- **Levee removal and wood placement**: The project removed 1,600 feet of levee and revetment along the right bank. In addition, mature cottonwood trees growing on the levee were pushed over into the floodplain to mimic natural recruitment of trees from bank erosion (Figure 2).
- **Buried revetment**: The project constructed a setback protection structure along approximately 1,100 feet of Neal Road to protect property and infrastructure (Figure 2). It consisted of a 600-foot-long rock revetment, one large wood structure water ward of the revetment to recruit and retain wood, and three engineered log jams (ELJs).
- **Spoils**: The project distributed native spoils onsite in the following areas: unvegetated areas; areas with primarily invasive species; within placed log clusters; and at local farms in the form of ‘farm pads’.  

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<sup>2</sup> No performance standard was established for this goal because the certainty in the outcome was high and did need to be quantified.
• **Plantings:** The project controlled over 20 acres of invasive vegetation and plant approximately 25,000 native trees and shrubs to restore native plant communities throughout the floodplain.

![Figure 2. Project design.](image)

**Salmon Recovery Context**

The loss of rearing habitat quantity and quality along mainstem rivers, within the estuary, and in the nearshore environment is thought to be one key reason for the decline of Snohomish River basin Chinook salmon. Actions that improve the connection of floodplains to riparian forests and side channels, as well as those that improve habitat complexity in the vicinity of and downstream from Chinook spawning areas are predicted to be the most effective in improving population performance.

The project addressed high priority salmon habitat restoration needs for the threatened Snoqualmie Chinook salmon populations identified in the federal [Puget Sound Salmon Recovery Plan (2007)](https://www.nmfs.noaa.gov/pr/salm/recoveryplan/) as well as for threatened steelhead and other species. The Upper Carlson project was identified as a high priority project in the [Snoqualmie at Fall City (SAFC) Reach Restoration Assessment](https://www.kingcounty.gov/environment/landwater/water/waterways/restoration-assessment) (King County 2011). The project addressed four of the Snohomish Basin Salmon Conservation Plan's highest priority ecological actions in the Upper>Mainstem Snoqualmie River sub-basin:

- Reconnection of off-channel habitats;
- Restoration of shoreline condition;
- Restoration of hydrologic and sediment processes; and
- Riparian enhancement.
The Project was intended to make a significant contribution toward 10-year salmon recovery goals in the Snoqualmie River (Table 2).

## Table 2. Progress toward 10-year habitat goals in the Snoqualmie River.

<table>
<thead>
<tr>
<th>Watershed 10-year Goal</th>
<th>Amount to be achieved by project (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Restore 10.4 miles of habitat for juvenile salmon</td>
<td>0.4 miles (4%)</td>
</tr>
<tr>
<td>Recruit 41 large, natural logjams</td>
<td>4 to 6 (10-14%)</td>
</tr>
<tr>
<td>Restore 256 acres of riparian habitat</td>
<td>40 acres (16%)</td>
</tr>
<tr>
<td>Enhance 10 acres of off-channel habitat</td>
<td>Increase <em>(quantity not specified)</em></td>
</tr>
</tbody>
</table>

### 2 Performance Measures

The effectiveness of the Upper Carlson Floodplain Restoration Project was evaluated by comparing observed results with performance measures established prior to construction. Performance measures were generated either by environmental permit conditions (Table 3) or by the design team. Those established by the design team are presented in the following sections along with their corresponding goals and objectives. If the project is meeting performance standards, it is assumed to be meeting the project goals and objectives.

Some performance standards required the use of a reference site to put the observations into context. A true reference condition no longer exists anywhere on the lower Snoqualmie River. The reference site used in this study is simply one the most unmodified reaches of river and floodplain forest in the vicinity of the project (Figure 3). The downstream reference site was deemed suitable because it was only 9,000 feet downstream, the river bank was not armored or channelized, and the river was laterally migrating into a mature floodplain forest.

![Figure 3. Location of reference site relative to the project site.](image-url)
<table>
<thead>
<tr>
<th>Permit/Division</th>
<th>Condition</th>
<th>Report years</th>
<th>Reporting requirements</th>
<th>Monitoring Methods</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>KC DPER GRDE13-0096</strong></td>
<td>As stated in the monitoring and maintenance plan, vegetation management is proposed for 10 years after project completed.</td>
<td>2016-2026</td>
<td>The reports shall be submitted to DPER for life of the monitoring/maintenance period; unless DPER agrees to shorten the reporting period.</td>
<td>Not specified.</td>
</tr>
<tr>
<td><strong>Shoreline exemption</strong></td>
<td>The project shall be monitored for three years following the completion of the project. Particular attention shall be paid to prevention of or removal of invasive species on disturbed ground</td>
<td>2016-2018</td>
<td>An annual monitoring report shall be provided to DPER.</td>
<td>Site visits and weed inspections,</td>
</tr>
<tr>
<td><strong>KC Parks NRL SAP</strong></td>
<td>The plantings must be maintained in a condition of good health for a period of five years.</td>
<td>2016-2020</td>
<td>Spray records detailing dates of application, type of herbicide, and application rate must be submitted to David Sizemore and to Brett Roberts, Parks and Recreation Division (206-477-4583). A monitoring report must be submitted to Parks on the same schedule required by the other permitting agencies requiring reports.</td>
<td>Log dates of herbicide application, type of herbicide, and application rate. Site visits to evaluate health of plantings.</td>
</tr>
<tr>
<td><strong>USACE NWS-2013-946</strong></td>
<td>Plantings will be maintained as necessary for three years to ensure 50% herbaceous and/or 70% woody cover in year three, whichever is applicable. For all areas greater than 0.5 of an acre.</td>
<td>2018</td>
<td>A final monitoring report will be submitted to the Corps in year three. Failure to achieve [these standards] will require the applicant to submit a plan with follow up measures to achieve standards or reasons to modify standards. &quot;</td>
<td>Measure cover in planted areas using densitometer surveys in Year 3.</td>
</tr>
<tr>
<td><strong>WDOE 401 Certification ORDER #10435</strong></td>
<td>The Applicant shall plant and monitor vegetation at the site according to the Upper Carlson Project Draft Vegetation Monitoring and Maintenance Plan, dated December 11, 2013, or as revised and approved by Ecology</td>
<td>2016-2026</td>
<td>None</td>
<td>Not specified.</td>
</tr>
<tr>
<td><strong>WDFW HPA 131771-1</strong></td>
<td>Plantings shall be maintained as necessary for three years to ensure 80% or greater survival.</td>
<td>2016-2018</td>
<td>None</td>
<td>Not specified.</td>
</tr>
</tbody>
</table>
Goal 1: Allow the river to expand and migrate toward the right bank at natural rates.

<table>
<thead>
<tr>
<th>Performance Standard for Channel Migration</th>
<th>Documentation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1.</strong> By 2019 or after three 2-yr recurrence-interval floods, the channel margin will reach the estimated ‘rapid migration boundary’, then migrate at a slower rate resembling the downstream reference reach.</td>
<td>Maps of the top-of-bank location at the project site and reference site.</td>
</tr>
</tbody>
</table>

**Protocol for Measuring Bank Retreat:**

The average rate of lateral bank retreat—or channel widening—was measured by dividing the total area of retreat by the length of eroded bank. These measurements were made by digitizing the top of the bank from orthomagery and LiDAR and bathymetry-based bare-earth ground surface models (i.e., multi-source GSMs). The multi-source GSMs were created in 2011, 2013, 2015, and 2016. LiDAR surveys took place in March-April, before leaf-out, and produced bare-earth surface models with 3-foot resolution (ground surface distance or GSD) capable of generating one-foot contours. Bathymetric surveys were performed with boat-based echo sounders in the same year, before high flows could cause significant geomorphic changes, to create a multi-source ground surface model of the streambed and river banks. The bare-earth LiDAR GSMs were merged with the bathymetric surveys to create a multi-source, PLS-certified GSM for each survey year. The multi-source GSMs represented the floodplain in high-resolution, the bed of the mainstem river channel and side channel, including, submerged bars, pools, and visible grade breaks, secondary channels, backwaters, and/or the bank toe and slope. Supplemental measurements were collected with a field in GPS by walking at or near the top of bank.

Goal 2: Promote channel aggradation and formation of bar habitat along the LB.

<table>
<thead>
<tr>
<th>Performance Standard for Channel Aggradation and Bar Habitat along the Left Bank</th>
<th>Documentation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2.</strong> By 2019 or after three 2-yr recurrence-interval floods, a meander will form in response to bank retreat, with a point bar on the left bank and lateral scour on the right bank.</td>
<td>Maps of river channel planform and instream bar forms.</td>
</tr>
</tbody>
</table>

**Protocol for Measuring Channel Aggradation and Bar Habitat:**

Channel planform and instream bar forms were digitized from multi-source GSMs created before and after the project. Maps from each year were used to identify changes in bar margins, numbers, and total area. The GSMs were also used to quantify the magnitude of changes in
elevation (i.e., from scour or aggradation) and to estimate volumetric changes in sediment storage and erosion.

**Goal 3: Promote formation of complex, woody right bank edge habitat. (Four performance standards).**

<table>
<thead>
<tr>
<th>Performance Standard for Habitat</th>
<th>Documentation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>3.1.</strong> By 2017, there will be a minor increase in the amount and complexity of edge habitat, so that it increases above baseline and resembles the reference site. After 2017, a rapid increase will occur and become similar to the downstream reference by 2022 to 2024.</td>
<td>Maps of edge habitat by unit type at a variety of discharge levels.</td>
</tr>
</tbody>
</table>

**Protocol for Measuring Edge Habitat:**

At the site scale, edge habitats were mapped and classified as linear features using ultra-high-resolution (9-inch GSD) oblique imagery in the **ConnectEXPLORER** program. Edge habitats “effectively stratify microhabitat characteristics and seasonal abundances of juvenile salmonids”, and are “(1) sensitive to anthropogenic change and (2) reasonable predictors of juvenile salmonid abundances” (p. 727, Beechie et al. 2005). The ConnectEXPLORER program is a web-based imagery access and analysis software available to by King County. Every pixel in the imagery is georeferenced and viewable from four directions, and in orthoimagery format. Edge habitat length and type was interpreted imagery taken in 2013, 2015, and 2017. Measurement accuracy is reported by the vendor and was deemed suitable for the purpose of comparing changes in habitat availability.

Edge habitat types included the following (adapted from Beechie et al. 2005):

- **Gravel or Sand Bars**: Slow-water channel unit located where channel meets a shallow, gently-sloping shore;
- **Carlson (project site) bank**: Slow-water channel unit located where channel meets a deep, nearly vertical shore, where rip-rap/rock armor was removed.
- **Backwaters**: Slow-water, partially enclosed channel unit along a mainstem bank at the downstream end of a disconnected floodplain channel or secondary channel;
- **Side channels**: Either channelized flow of emergent hyporheic groundwater in flood channels, or channel units connected to the mainstem at both ends but containing less than half the discharge.

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3 Initially, we planned to map the low (<15 cm/s) and medium-(15-45 cm/s) velocity edge habitat (Beechie et al. 2005) on both banks of project site, nearby rip-rap banks, and at the reference site using a GPS. However, the methodology had to be adjusted owing to difficult access and deep, fast-moving streamflow's that prevented wading.
Figure 4. Examples of edge habitat maps created in the ConnectEXPLORER program from ultra-high resolution imagery.

<table>
<thead>
<tr>
<th>Performance Standard for Habitat</th>
<th>Documentation</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.2. Once the channel encounters the floodplain logs, at least four logjams are continually present. By 2020, overall large wood abundance will increase. By 2022-2024, the amount will meet or exceed the quantity at the reference site.</td>
<td>Maps and quantities of large wood and logjams in the project site and reference site.</td>
</tr>
</tbody>
</table>

Protocol for Measuring Large Wood Abundance and Position:

Wood quantities were estimated using field surveys and high-resolution (≤ 6" GSD) leaf-off orthoimagery at 1:300 scale. Pre-project wood surveys were not completed because there was virtually none present. Post-project field-based wood surveys were completed on June 25th, 2015. In the field survey, large wood pieces were classified by diameter and length categories (Montgomery 2008). The premise for this performance standard was that large wood adds complexity and roughness to the river and creates cover for juvenile fish. The benefits conferred by wood should be positively related to the amount of wood in the project site – particularly pieces interacting with flows.

For comparison, large wood was also mapped as lines in ArcGIS using 2015 orthoimagery. The length of each piece was calculated, but the resolution of the imagery was not fine enough to precisely measure log diameter. Results from the field survey were then compared with results from the orthophotos assessment.

The comparison of the field and imagery-based results indicated that field surveys underestimated the quantity of wood in the channel and floodplain (Figure 5), with the exception of pieces in the 1-2 m length class (B). These small pieces were underestimated in the
orthoimagery analysis. Field surveys identified 47 more pieces of wood in the B-size class (1-2 m long) than aerial surveys. Orthoimagery surveys identified between four and 175 large wood pieces that were missed in field surveys, depending on size class. The ‘C’ size class had the largest error rate in field surveys (159%). There was generally more consistency between field surveys and aerial surveys in the larger size classes (i.e., E, F, and G).

Table 4. Alphanumeric codes for length and diameter categories after Montgomery (2008).

<table>
<thead>
<tr>
<th>Diameter</th>
<th>Length</th>
<th>10-20 cm</th>
<th>20-40 cm</th>
<th>40-80 cm</th>
<th>80-160 cm</th>
<th>160-320 cm</th>
<th>320+ cm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3.9-7.9 in</td>
<td>7.9-15.7 in</td>
<td>15.7-31.5 in</td>
<td>31.5-63.0 in</td>
<td>63.0-126.0 in</td>
<td>&gt;126 ft</td>
<td></td>
</tr>
<tr>
<td>1-2 m</td>
<td>B2</td>
<td>B3</td>
<td>B4</td>
<td>B5</td>
<td>B6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2-4 m</td>
<td>C2</td>
<td>C3</td>
<td>C4</td>
<td>C5</td>
<td>C6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4-8 m</td>
<td>D2</td>
<td>D3</td>
<td>D4</td>
<td>D5</td>
<td>D6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8-16 m</td>
<td>E2</td>
<td>E3</td>
<td>E4</td>
<td>E5</td>
<td>E6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16-32 m</td>
<td>F2</td>
<td>F3</td>
<td>F4</td>
<td>F5</td>
<td>F6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt;32 m</td>
<td>G2</td>
<td>G3</td>
<td>G4</td>
<td>G5</td>
<td>G6</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Based on these findings, only orthoimagery was used to estimate large wood quantity by length class in 2015 and in 2016. Both the project and reference sites were mapped in 2015 but the reference site was excluded in 2016 to reduce costs.

![Figure 5. Comparison of estimated wood quantities in the channel (instream) and floodplain in 2015, based on counts from aerial orthoimagery, compared to field surveys.](image)
### Performance Standard for Habitat

<table>
<thead>
<tr>
<th>3.3. The engineered logjam will remain stable and engage the river sufficiently to trap large wood during floods with greater than a two-year recurrence interval, by the time placed wood starts to fall into the river from the levee removal area upstream.</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Documentation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Photo-documentation of the intact logjam and the proximity of the river channel.</td>
</tr>
<tr>
<td>Counts or measurements of wood trapping on the logjam after placed wood begins to be transported downstream.</td>
</tr>
</tbody>
</table>

### Protocol for Documenting Logjam Stability and Trapping Functions:

Orthoimagery interpretation was used to document the stability of the engineered logjam and measure the proximity of the river channel. Trapped wood, if present on the logjam, was also estimated from orthoimages.

### Performance Standard for Habitat

<table>
<thead>
<tr>
<th>3.4. Upon formation of new edge habitats, and increases in woody, submerged overhead cover along the right bank, juvenile Chinook salmon density will be higher in those habitats than along rap-rap banks.</th>
</tr>
</thead>
</table>

### Documentation

| Density or catch-per-unit effort estimates by habitat type. |

### Protocol for Measuring Fish Use:

Depending on the year, snorkeling or electrofishing was used to evaluate relative densities and species-specific habitat preferences. Fish were sampled at three or more edge habitat units of each type. Units were not randomized but were sampled without any known bias.

In 2014 and 2015, fish use was evaluated with snorkel surveys based on methods outlined by Thurow (1994). Two side-by-side snorkelers moved downstream while counting fish. Fish were visually tallied by species and length bins (e.g., 0-50mm, 51-100 mm, etc). They qualitatively evaluated turbidity and visibility distance (to 0.5 m) to estimate the width of the sampled area. Average density was calculated for each fish species in each habitat type across all sampled units and sampling events.

In 2016 and 2017, fish sampling was conducted using a custom-fabricated electrofishing cataraft specially designed for use at the Upper Carlson project site. This craft was built in response to the myriad challenges posed by snorkeling in a large, fast, turbid river. The electrofishing cataraft enabled sampling at a wider range of flows, regardless of turbidity levels, and provided added safety when sampling around instream obstructions. Captured fish were tallied by species and fork length (FL) was measured. The results were used to generate Catch-Per-Unit-Effort (CPUE) for each habitat type, species, and sampling event. On each sampling event, a standardized set of sub-reaches was electrofished within the project site. Catch-per-

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4 We could not calculate density for comparison with previous years because the effective capture distance of the e-fishing unit has not yet been determined.
unit effort (CPUE) was calculated for each sample by dividing the catch by the effort (seconds spent electrofishing).

Table 5. Summary of fish sampling by year and method.

<table>
<thead>
<tr>
<th>Method</th>
<th>Pre-project</th>
<th>Post-Project</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2014</td>
<td>2015</td>
</tr>
<tr>
<td>Snorkeling</td>
<td>Aug 12</td>
<td>June 8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Aug 18</td>
</tr>
<tr>
<td>Electrofishing via cataract</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td></td>
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<td></td>
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<td></td>
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</tbody>
</table>

Figure 6. Electrofishing cataract built specifically for fish sampling on the Upper Carlson Project.
Goal 4: Re-establish riparian forests, increase soil cohesion.

<table>
<thead>
<tr>
<th>Performance Standard for riparian forests</th>
<th>Documentation</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1. Native woody vegetation cover in planted areas shall not have large (&gt;1/4 acre) patches of dead plantings in 2016 or 2017.</td>
<td>Field-inspection based maps of any large patches of dead plantings.</td>
</tr>
<tr>
<td>In 2018, native woody vegetation cover in planted areas will exceed 30 percent.</td>
<td>Point-intercept surveys of cover in planted areas.</td>
</tr>
<tr>
<td>In 2020, native woody vegetation cover in planted areas will exceed 40 percent.</td>
<td></td>
</tr>
<tr>
<td>In 2022, native woody vegetation cover in planted areas will exceed 60 percent.</td>
<td></td>
</tr>
</tbody>
</table>

Protocol for Measuring Vegetation Cover:

In the first year of the full-scale planting (2016/17), field inspections were used to determine whether there are any large (e.g., >1/4 acre) areas of dead plantings.

From 2018-2026, average woody native vegetation cover will be quantified with point-intercept methods. This technique is preferred because it produces an unbiased estimate of cover and is more efficient than alternative techniques. One to three transects will be established at randomized locations across planting areas. Then cover\(^5\) along each transect will be estimated by sampling 100-250 systematically-spaced (e.g., 0.5-1 m apart) points along the transect with a densitometer\(^6\). The densitometer classifies each point as either a ‘hit’ (cover present) or a ‘miss’ (cover absent). When the densitometer records a ‘hit’, the species of the plant will be recorded. Cover for each transect is calculated as the mean of the binomial variable – or simply the percentage of the total number of points in which hits were detected. Variance is given by: \(c(1-c)/n\), where \(c\) is cover and \(n\) is the number of sampled points\(^7\). Pre-existing vegetation cover will not be counted toward performance targets.

---

\(^5\) Cover is defined as the proportion of the ground area covered by vertical projection of plant leaves, stems, and branches. Cover is measured vertically, not from an angle of view (canopy closure).

\(^6\) A sighting tube that allows the user to look directly upwards to see if crosshairs intersect a leaf, branch, or stem that obscures the sky (also known as a Canajus tube).

### Performance Standard for riparian forests

<table>
<thead>
<tr>
<th>Documentation</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.2. In 2021, 2023, and 2026, native woody vegetation diversity in planted areas shall exceed three species present at over 5% cover each.</td>
</tr>
<tr>
<td>From 2016-2026, Class A Noxious weeds are absent from planted areas.</td>
</tr>
<tr>
<td>From 2016-2026, Class B Noxious weed cover is less than ten percent in planted areas.</td>
</tr>
<tr>
<td>From 2016-2026, Class C Noxious weed cover is less than 25 percent in planted areas.</td>
</tr>
<tr>
<td>Expansive field inspections and point-intercept surveys of cover in planted areas.</td>
</tr>
</tbody>
</table>

**Protocol for Measuring Vegetation Diversity:**

From 2018-2026, woody native plant (tree and shrub) diversity and species-specific cover will be estimated from the point-intercept surveys used to measure cover.

**Protocol for Evaluating Class A Weeds:**

Class A noxious weeds, if present, were identified during annual inspections. Occurrences were mapped and flagged for removal and re-inspection, as needed.

**Protocol for Evaluating Class B & C Weeds:**

From 2018-2026, Class B & C noxious weeds will be measured visually and quantitatively using point-intercept sampling during surveys of native woody vegetation. When the densitometer records a ‘hit’, the species of the weed will be recorded and used to estimate percent weed cover by species in the sampled area.
3 Year 3 Results

This section summarizes the performance of the Upper Carlson Floodplain Restoration Project with voluntary performance standards and compliance with permit conditions (Table 6).

Table 6. Compliance with permit conditions.

<table>
<thead>
<tr>
<th>Permit</th>
<th>Year 3 Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>KC DPER GRDE13-0096</td>
<td>Compliant</td>
</tr>
<tr>
<td>Shoreline exemption</td>
<td>Compliant</td>
</tr>
<tr>
<td>KC Parks NRL SAP</td>
<td>Compliant</td>
</tr>
<tr>
<td>USACE NWS-2013-946</td>
<td>First survey in 2018</td>
</tr>
<tr>
<td>WDOE 401 Certification ORDER #10435</td>
<td>Compliant</td>
</tr>
<tr>
<td>WDFW HPA 131777-1</td>
<td>Compliant</td>
</tr>
</tbody>
</table>

Goal 1: Allow the river to expand and migrate toward the right bank at natural rates

<table>
<thead>
<tr>
<th>Performance Standard for Channel Migration</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1. By 2019 or after three 2-yr recurrence-interval floods, the channel margin will reach the estimated ‘rapid migration boundary’, then migrate at a slower rate resembling the downstream reference reach.</td>
<td><strong>Target met:</strong> Sufficient floods occurred to test this performance standard. At the project site, by January 2016, the top of the bank had reached the rapid migration boundary over the length of the levee removal area. The channel margin is currently migrating faster than the downstream reference. At the project site, from 2013-2016, approximately 113,000 square feet (2.6 acres) of bank retreat occurred over 1,700 linear feet, for an average lateral bank retreat rate of 22 feet per year. Bank retreat occurred over the whole length of the former levee, but was most rapid at the upstream and downstream ends. At the reference site, from 2011-2015, approximately 23,000 square feet of bank retreated over 1,100 linear feet, for an average lateral bank retreat rate of a length of five feet per year. The rate of bank retreat was relatively uniform along the length of the bank.</td>
</tr>
</tbody>
</table>

Bank retreat is predicted to slow down over time, but if it continued at the observed rates (22 feet per year), the 10-year prediction line could be reached by the fifth year (2019). For example, approximately 100,000 square feet of floodplain spread over 2000 linear feet remains between the top of bank in 2016 and the 10-year prediction line. On average, the 10-year line is 50 feet away from the current bank position.
Figure 7. Bank retreat relative to predictions. The background graphic represents the multisource ground surface model from 2016 ranging from low blues to high reds.

Goal 2: Promote channel aggradation and formation of bar habitat along the LB.

<table>
<thead>
<tr>
<th>Performance Standard for Channel Aggradation and Bar Habitat along the Left Bank</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2.1.</strong> By 2019 or after three 2-yr recurrence-interval floods, a meander will form in response to bank retreat, with a point bar on the left bank and lateral scour on the right bank.</td>
<td><strong>Target met:</strong> A one-acre point bar formed on the left bank, opposite the former levee. Lateral scour occurred on the right bank. Lateral scour and bank retreat caused right bank ground surface elevations to decrease by 10 to 20 feet, depending on the location.</td>
</tr>
</tbody>
</table>

Cross-section analyses performed at three locations illustrate how pattern of channel adjustment ranged from minor down cutting immediately upstream of the site to significant aggradation in the middle and downstream portion of the site (Figure 8). At the upstream bar location, the channel cross-section has changed significantly. The thalweg shifted right by 60
feet and became six feet more shallow. The left side of the channel aggraded by approximately 10 feet. Near the downstream end of the site, above the outlet of the 1936 channel, the channel widened by 80 feet and the bed aggraded by roughly five feet across the cross-section. These patterns are more apparent when illustrated by the multi-source GSM for each year (Figure 10).

Figure 8. Cross-section locations.
Figure 9. Changes in elevation at three cross-sections, 2011-2016.
Pre-project (2011) elevations. Levees appear as dark red lines on both banks. Deep pools are present along most of the right bank, represented as dark blue shapes.

Post-project (2015) elevations. Levee on right (northeast) bank is visibly absent, but dark red spoils piles remain visible. Scour on the left bank at the upstream end of the site is evident. Gravel bars are starting to form on the left bank opposite from the levee removal location. The deep areas that had been present along the right bank in 2011 are diminished in extent.

Post-project (2016) elevations. A pronounced bar extends from the left bank and the lateral scour pool on the opposite side of the river. Most of the spoils piles have been captured by the river. A deep pool persists along the right bank opposite the gravel bar. This appears to be the point at which the channel is migrating the fastest.

Figure 10. Pre- and post-project elevations in the floodplain and river channel.
Levee removal was followed by a significant but spatially-variable amount of aggradation (Figure 11). For example, up to 12 feet of aggradation occurred in the upstream end of the project site. The existing channel aggraded by two to five feet throughout the project reach. The reach immediately upstream from the levee removal location scoured relative to pre-project conditions.

Figure 11. Net change in elevations within the channel and the 1936 abandoned channel from 2011 to 2016.
Goal 3: Promote formation of complex, woody right bank edge habitat.

<table>
<thead>
<tr>
<th>Performance Standard for Habitat (Edge habitat)</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>3.1.</strong> By 2017, there will be a minor increase in the amount and complexity of edge habitat, so that it increases above baseline and resembles the reference site. After 2017, a rapid increase will occur and become similar to the downstream reference by 2022 to 2024.</td>
<td><strong>Interim target met:</strong> Each type of edge habitat increased from pre-project conditions. Gravel bar edge habitat and woody bank habitats, which did not exist prior to the project, now compose approximately 100 and 370 m of edge. Comparisons of habitat scaled to reach length show that the amount and composition of the habitat at the project site is becoming more similar to the reference site.</td>
</tr>
</tbody>
</table>

At the project site, both the amount and diversity of edge habitat increased after the project was completed (Figure 12). Gravel bar and woody bank habitats appeared for the first time. All habitat types increased, for a net gain of 864 m (2,835 feet) by 2017; total edge length increased from 564 meters (1,850 feet) on June 5, 2013, to 1,410 m (4,626 feet) on May 21, 2017. The trend of increasing edge habitat over time was the opposite of trend observed at the reference site.

![Figure 12](image)

**Figure 12. Changes in edge habitat at the project site over time by type.**

At the downstream reference site, both the amount and diversity of edge habitat decreased over time (Figure 13). At this location, backwaters had been present in 2013 but they filled in with sediment and were not reformed in 2015 and 2017. Regardless, gravel bars dominated.
Figure 13. Changes in edge habitats at the downstream reference site over time by type.

When the amount of edge habitat is normalized by the length of the channel reach, it is clear that the project site is now providing a similar amount of edge habitat as the reference site (Figure 14). Additionally, similar proportions are composed of woody and unarmored banks. The relative quantity of gravel bar habitat was much higher at the reference site, however. Prior to the project (in 2013), the relative quantity of edge length at the reference site was over three times higher than the project site; gravel bars and woody banks did not exist at the project site.

Figure 14. Comparison of the amount and type of edge habitat in the project site and the reference site, normalized by the reach length (meters of habitat per meter of channel).
<table>
<thead>
<tr>
<th>Performance Standard for Habitat (Large wood abundance and Position)</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>3.2.</strong> Once the channel encounters the floodplain logs, at least four logjams are continually present. By 2020, overall large wood abundance will increase. By 2022-2024, the amount will meet or exceed the quantity at the reference site.</td>
<td><strong>Interim target met:</strong> At the project site, there were two logjams—not four—in the channel in 2015, increasing to six in 2016, as the river encountered the placed wood. Overall quantities of instream wood increased from none to 44 (0.058 per 100 m) in 2015, and to 111 (0.146 per 100 m) in 2016. Approximately four times as much instream wood was observed at the reference site in 2015: 166 or 0.218 per 100 m).</td>
</tr>
</tbody>
</table>

A total of 719 pieces of large wood over one meter (3.28 ft) long were observed at the project site in 2015, declining slightly to 699 in 2016. This was equivalent to 94 pieces per 100 meters (328 ft) of channel length in 2015 and 92 pieces per 100 meters (328 ft) of channel length in 2016.

A strikingly different pattern of wood abundance was evident at the project and reference site; the vast majority of the wood at the project site remains in the floodplain—where it awaits interception by the migrating channel (Figure 16). At the downstream reference site, virtually all of the wood was in the river channel or ‘instream’. In both sites, the most abundant size class was ‘C’, which is four to eight meters long, noting that B class could be more abundant but is underrepresented due to sampling bias against very short pieces.

![Graph showing quantities of large wood at the project site by location and year.](image)

**Figure 15.** Quantities of large wood at the project site by location and year.

A strikingly different pattern of wood abundance was evident at the project and reference site; the vast majority of the wood at the project site remains in the floodplain—where it awaits interception by the migrating channel (Figure 16). At the downstream reference site, virtually all of the wood was in the river channel or ‘instream’. In both sites, the most abundant size class was ‘C’, which is four to eight meters long, noting that B class could be more abundant but is underrepresented due to sampling bias against very short pieces.
Figure 16. Comparison of large wood quantities per 100 meters of stream channel length in the project site and the reference site, by location.

By differentiating logs that were placed in the floodplain from those recruited to the site during floods, it is clear that the site is accumulating significant amounts of wood in the downstream half of the floodplain (Figure 17). This pattern persists in both 2015 and 2016. By 2016, many of the placed logs are over or in the bankfull channel of the Snoqualmie River. In many cases, however, the large placed logs are not sliding into the channel as had been hoped. Instead, many are cantilevered over the bank, far above the low-flow wetted channel. Some of the cantilevered logs have broken into pieces instead of sliding whole into the river.
Figure 17. Large wood maps of placed and recruited pieces of large wood. Upper map is from 2015 and lower map is from 2016. The background is the multi-source GSM for each year, in which low is blue and high is red.
### Performance Standard for Habitat (Engineered logjam stability and functions)

| 3.3. The engineered logjam will remain stable and engage the river sufficiently to trap large wood during floods with greater than a two-year recurrence interval, by the time placed wood starts to fall into the river from the levee removal area upstream. | Target not yet met: Jam not engaged except during overbank flows. |

The engineered logjam remains stable and can trap wood during overbank flows, but it has not yet been engaged by the river (Figure 18). Channel migration has not intercepted the structure. Because of this, the jam cannot effectively trap placed wood as it starts to fall into the river from the levee removal area upstream. The engineered logjam may yet function as intended as the channel continues to migrate but the timing will be different than expected. As a result, more of the placed wood is at risk of moving offsite than if the engineered logjam was fully engaged.

![Aerial photo of engineered logjam showing it remains stable and intact.](image)

**Figure 18.** Aerial photo of engineered logjam showing it remains stable and intact.

The ELJ structure at the downstream end of the project site is not yet engaged by the river channel. It remains stable and intact. It has not trapped any substantial amount of large wood since construction. That means that large wood that leaves the project reach upstream is not unlikely to be trapped by the ELJ, so its intended function has not been fully achieved yet.

### Performance Standard for Habitat (Fish use of edge habitats)

| 3.4. Upon formation of new edge habitats, and increases in woody, submerged overhead cover along the right bank, juvenile Chinook salmon density will be higher in those habitats than along rip-rap banks. | Target met: Juvenile Chinook salmon density and catch-per-unit effort was higher along non-rip-rap banks, including the new edge habitats that formed in the project area. |
Pre-project Snorkel Surveys (2014):

Pre-project snorkel surveys were completed late in the season, and so we did not expect to observed Chinook salmon juveniles; most have out-migrated by August. However, the results are reported here to illustrate differences between the sampled bank types (Figure 19).

- On August 12, 2014, two surveyors (H. Berge, D. Lantz) snorkeled 80 meters along right bank of the reference reach with 4.5-meter visibility for a total area of 360 m². The survey was completed in the daylight. One snorkeler surveyed submerged wood and another surveyed bare banks lacking wood. The entire surveyed area was classified as ‘banks’. Trout ranged from 100 to over 200 mm fork length (4-8 inches). Most (64%) of the coho salmon were >100 mm (4 inches). Fourteen adult whitefish were observed, and five juveniles. In addition to salmonids, three adult suckers were present. Suckers and whitefish were observed in the lowest part of the water column. Coho and trout were closely associated with large wood; actually within the root wads and small jams composed of sticks.

- On August 18, 2014, two snorkelers (C. Gregersen and H. Berge) surveyed two transects along the left bank opposite the levee removal site and one transect along the right bank at the project site, prior to levee removal. Both banks were covered in riprap. Visibility ranged from three to 4.5 m (10-13 ft) per transect. A total of 1,379 meters (4,524 ft) of riprap bank was surveyed. For analysis, each transect was treated as a sampling unit for a total sample size of three. Very few fish were observed in the sample; a total of 27 trout—and no salmon—were observed, plus six whitefish and 178 suckers.
Figure 19. 2014 comparison of fish density by bank types and dates by species, for coho and trout only (no Chinook salmon juveniles were observed).

No Chinook salmon were captured. Only rainbow trout were observed using riprap banks, and only at very low density (Figure 19). By comparison, fish density was higher at the woody reference bank, for both coho and rainbow trout (Table 7).

Table 7. Average fish density by species in 2014 snorkel surveys.

<table>
<thead>
<tr>
<th>Habitat Unit</th>
<th>Units sampled</th>
<th>Chinook</th>
<th>Coho</th>
<th>Rainbow trout</th>
</tr>
</thead>
<tbody>
<tr>
<td>Riprap</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0.003</td>
</tr>
<tr>
<td>Bank (ref)</td>
<td>1</td>
<td>0</td>
<td>0.13</td>
<td>0.014</td>
</tr>
</tbody>
</table>

Post-project Snorkel Surveys (2015):

In 2015, snorkeling was used to evaluate changes in fish use at the project and reference sites (Figure 20). The both sites were sampled in June 2015; only the project site was sampled in both June and August. Samples were averaged across events. On June 8 2015, two snorkelers surveyed four treatment transects. Visibility was 1.5 meters.
No Chinook salmon were observed in 2015 snorkeling (Table 8). Coho density was highest at the reference bank, but occurred at similar densities along the riprap banks and at the post-project Carlson bank. Too few rainbow trout were captured to support any meaningful inferences about habitat use, though slightly more were observed along the reference bank than the other locations.

Table 8. Average fish density by species in 2015 snorkel surveys.

<table>
<thead>
<tr>
<th>Habitat Unit</th>
<th>Units sampled</th>
<th>Average density (fish/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Chinook</td>
</tr>
<tr>
<td>Riprap</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>Bank (reference)</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Carlson Bank</td>
<td>8</td>
<td>0</td>
</tr>
</tbody>
</table>

Post-project Electrofishing Surveys (2016):

In 2016 electrofishing, Chinook CPUE was highest along gravel bars and the natural bank and were absent from riprap banks and backwaters (Figure 21). Variability in trout CPUE was similar to Chinook salmon, except that a small number of trout were observed using backwaters. Like Chinook and trout, coho salmon apparently avoided riprap banks, and were common along gravel bars and natural banks (Table 9). The use of the cataraft allowed for a larger number of habitat units to be sampled in 2016 than in the previous years. Unlike Chinook and trout, coho salmon juveniles were most abundant in the backwaters.
Figure 21. Comparison of catch-per-unit-effort from electrofishing samples by habitat type. Mean value across replicate samples collected in April, May, and June 2016.

The use of the cataraft allowed for a larger number of habitat units to be sampled in 2016 than in the previous years (Table 9).

Table 9. Average catch-per-unit-effort by species in 2016 sampling.

<table>
<thead>
<tr>
<th>Habitat Unit</th>
<th>Units sampled</th>
<th>Average catch-per-unit-effort (fish per second)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Chinook</td>
</tr>
<tr>
<td>Riprap</td>
<td>9</td>
<td>0.000</td>
</tr>
<tr>
<td>Backwater (ref)</td>
<td>3</td>
<td>0.000</td>
</tr>
<tr>
<td>Carlson Bank</td>
<td>9</td>
<td>0.018</td>
</tr>
<tr>
<td>Gravel Bar</td>
<td>7</td>
<td>0.028</td>
</tr>
</tbody>
</table>
Post-project Electrofishing Surveys (2017):

Sampling efforts in 2017 were more productive than in the past, primarily because the sampling effort was greatly increased, especially in the early part of the year when Chinook are more likely to be present (Table 10). Chinook and rainbow trout CPUE was highest along gravel bars—a newly-present edge habitat type, owing to the formation of a gravel bar opposite the levee removal area. Chinook used the Carlson bank and backwater areas at relatively similar levels. Coho CPUE was highest in the backwaters, but did not vary strongly between edge habitat types. Coho were found to be using all the edge habitat types. Riprap banks contained only coho and rainbow trout, but no Chinook.

![Figure 22. Catch-per-unit-effort in 2017 sampling.](image)

Juvenile Chinook salmon were 43 to 48 mm (1.7-1.9 inches) on average in April and May. Coho were larger, ranging from 78 mm (3 inches) in March to 50 mm (2 inches) in May, presumably as young-of-the-year composed a larger fraction of the sample later in the season. Rainbow trout ranged from 155 mm (6 inches) in April to 125 mm (5 inches) in May.

<table>
<thead>
<tr>
<th>Habitat Unit</th>
<th>Units sampled</th>
<th>Average catch-per-unit-effort (fish per second)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Chinook</td>
</tr>
<tr>
<td>Riprap</td>
<td>18</td>
<td>0.000</td>
</tr>
<tr>
<td>Backwater (trt)</td>
<td>5</td>
<td>0.003</td>
</tr>
<tr>
<td>Backwater (ref)</td>
<td>3</td>
<td>0.010</td>
</tr>
<tr>
<td>Carlson Bank</td>
<td>18</td>
<td>0.017</td>
</tr>
<tr>
<td>Gravel Bar</td>
<td>18</td>
<td>0.036</td>
</tr>
</tbody>
</table>
Goal 4: Re-establish riparian forests, increase soil cohesion.

<table>
<thead>
<tr>
<th>Performance Standard for riparian forests</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>4.1.</strong> Native woody vegetation cover in planted areas shall not have large (&gt;1/4 acre or 0.10 ha) patches of dead plantings in 2016 or 2017.</td>
<td><strong>Target met:</strong> No large patches of dead plantings, but two patches located along the north margin of the site. Plan to replant.</td>
</tr>
<tr>
<td>In 2018, native woody vegetation cover in planted areas will exceed 30 percent.</td>
<td>Future monitoring.</td>
</tr>
<tr>
<td>In 2020, native woody vegetation cover in planted areas will exceed 40 percent.</td>
<td></td>
</tr>
<tr>
<td>In 2022, native woody vegetation cover in planted areas will exceed 60 percent.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Performance Standard for riparian forests</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>4.2.</strong> In 2021, 2023, and 2026, native woody vegetation diversity in planted areas shall exceed three species present at over 5% cover each.</td>
<td><strong>Target met:</strong> Weed control is ongoing.</td>
</tr>
<tr>
<td>From 2016-2026, Class A Noxious weeds are absent from planted areas.</td>
<td></td>
</tr>
<tr>
<td>From 2016-2026, Class B Noxious weed cover is less than ten percent in planted areas.</td>
<td></td>
</tr>
<tr>
<td>From 2016-2026, Class C Noxious weed cover is less than 25 percent in planted areas.</td>
<td></td>
</tr>
</tbody>
</table>

4 Discussion

4.1 Are the project goals being met?

Based on the first three years of observations, it appears that the Upper Carlson project is beginning to accomplish the overall goal of restoring natural floodplain functions and processes that create riverine habitat and promote salmon recovery. All of the performance standards are being met. The project is compliant with requirements of environmental permits.

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8 The goal of reconnecting the right bank at lower flows is not addressed in this monitoring report because it was a simple outcome of removing the levee. The right bank is approximately five to six feet lower in elevation than before the project, so that the floodplain is necessarily connected more frequently and for longer durations.
Goal 1: Is the river expanding and migrating at natural rates?
The channel expanded by 2.6 acres (1.05 ha) in the first three years and is migrating faster than the downstream reference, but is expected to slow down over the next few years.

Goal 2: Is the channel aggrading and forming bars?
The channel has aggraded by two to five feet (0.6-1.5 m) throughout most of the project site and up to 12 feet (3.7 m) in some places. A new, one-acre (0.4 ha) gravel bar formed on the left bank, creating bar edge habitat and a backwater feature.

Goal 3: Is complex woody edge habitat forming?
There was a net gain of approximately 864 meters (0.54 miles) of edge habitat in the project site. Gravel bars and woody banks now compose approximately 479 meters (1,572 ft) of the total edge habitat. The amount of edge habitat per unit channel length is similar to the downstream reference site. Six logjams are present in the channel and the overall quantity of instream wood increased by 111 pieces, approximately 25% as many as at the reference site.

Goal 4: Are riparian forests reestablishing?
Riparian forests are re-establishing in the vicinity of the 1936 channel, where plantings were installed. Surprisingly, the plants are thriving in well-drained soils with little or no maintenance. Weed control efforts within the 1936 channel have been effective but are ongoing to deal with repeated invasions of butterfly bush. Most of the knotweed has been eliminated. The few areas with high mortality are being replanted. On the other hand, the disturbed soils and spoils piles along the right bank have not naturally revegetated with native woody species. Instead, these areas were quickly invaded by blackberry, which is now being subjected to intensive herbicide treatments.

4.2 How did juvenile salmon and trout respond to the project?
Juvenile Chinook salmon use of the project site has probably increased over baseline conditions, because the amount of edge habitat has greatly increased, and the types of edge habitats that have been formed are also those that support the largest numbers these fish. One key unknown is whether there more fish at the project site now than before, and whether they surviving at a higher rate. Though we surveyed fish use extensively, we cannot, and did not expect to be able to answer either of those questions. Instead, our findings allow us to confirm that a) critical habitat for juvenile salmonids has increased, and b) juvenile salmonids are using those habitats at a much higher rate than riprap banks. In combination, these observations suggest that the project has provided valuable benefit to juvenile salmon.

Based on our observations, the project likely benefits juvenile salmonids by providing a larger amount and a more diverse array of habitats for use by different species and life stages. For example, juvenile Chinook salmon numbers were consistently highest along gravel bar edges and unarmored banks, relative to backwaters. They were not found along riprap banks. Coho were widely distributed, but appeared to be most numerous in the backwater areas and least
numerous along riprap banks. Rainbow trout were numerous along gravel bars and riprap, but also found to be using other edge habitat areas too.

In some previous studies we have been able to estimate changes in habitat capacity, but we cannot in this case because CPUE does not directly translate into fish density. Even so, we can explore another method for estimating the relative magnitude of the potential impact of the project on juvenile Chinook salmon use (as an example). For example, we can use a simple index that is the produce of CPUE and the change in habitat length. We can take the product of the average habitat-specific CPUE for Chinook in 2017 and multiply these values by the net gain in the length of that edge habitat type (in meters). Since these fish were not captured along riprap banks, the index can be calculated from the baseline amount of backwater and unarmored bank. Accordingly, the baseline index value was 3.1. By 2017, the index increased to 17.4; a net gain of 14.4, or a 4.6-factor increase. This change suggests that the project has positively and significantly benefitted juvenile Chinook salmon (and other salmonids) at the site.

There are a few important caveats and limitations to acknowledge. The results of our study cannot be used to determine whether the project improved the survival rate of juvenile fish, relative to baseline conditions. We also have to presume that the electrofishing methods have equal capture efficiencies in each of the edge habitat types – future studies are planned to test and potentially revise this assumption.

4.3 Contribution to watershed-scale 10-year habitat targets?

The project has already achieved or surpassed its planned contribution toward the 10-year habitat targets established by WRIA 7.

- **Planned**: 0.4 miles of habitat added
  - **Achieved**: 0.5 miles of edge habitat added.
- **Planned**: Four to six logjams added
  - **Achieved**: Six logjams in the channel and more on the way.
- **Planned**: 40 acres of riparian habitat
  - **Achieved by levee removal**.
- **Planned**: Increased off-channel habitat
  - **Achieved**: New backwater formed behind one-acre bar on the left bank.

4.4 Were there any unexpected outcomes?

Every restoration project manager knows to ‘expect the unexpected’, but identifying unexpected outcomes—even if they could not be foreseen or avoided—provides a valuable reference for future project planning. A few of the key unexpected outcomes are listed here:

- The engineered logjam has not been engaged by the river yet. Consequently, placed wood may be lost from the site at a higher rate. No action is recommended because we still expect it to become engaged in the near future and relatively few placed logs have started to enter the river.
• Berm along right bank was not re-built to planned elevation, leading to excessive overbank flooding. Adaptive management was required and it is now fixed
• Disturbed soils and spoils along former levee were colonized by blackberry instead of native plants. Control efforts are underway. This area may need to be planted with a groundcover, even though it will be lost to future bank retreat.

4.5 What critical lessons were learned?

Lessons learned from the Upper Carlson project can be grouped into several categories and broken into issues and lessons. This list of lessons learned is preliminary in that more lessons and perspectives may be gained by continued monitoring.

Channel adjustments after levee removal:

• **Issue:** It is very difficult to predict future channel positions after a levee is removed.
• **Lesson:** Carefully illustrate and explain the range of potential outcomes that could occur with different hydrologic conditions (e.g., floods). Accommodate the uncertainty by making the project design be resilient to the uncertainty.

Large wood placement:

• **Issue:** Placed wood is breaking or cantilevering over the high streambank instead of falling in whole:
• **Lesson:** Place wood in the floodplain at a steeper angle to the channel to increase the chance it will fall into the channel intact.

Fish use of edge habitats:

• **Issue:** It is tempting to focus on identifying the most limiting habitat type and tailoring the project design to maximize the quantity of that habitat type.
• **Lesson:** Our observations suggest that projects should focus on increasing both the amount and the diversity of the edge habitats. By doing so, they can avoid pitfalls of managing for a single species, and instead provide a diverse riverine ecosystem that supports multiple species and life stages. Many channelized river reaches are dominated by riprap banks; our observations indicate that Chinook and coho use riprap banks very little or not at all.

Hydraulic Modeling:

• **Issue:** Impacts on the ground can happen even in small or isolated areas where hydraulic models indicate a ‘hot spot’ as measured by velocity (V) or changes in water surface elevations (WSE).
• **Lesson:** When hydraulic models indicate issues pay very close attention and invest more analysis of potential “on-the-ground” impacts in any and all areas where the hydraulic model indicates a ‘hot spot’ in terms of V or WSE.

**Sediment impacts:**

• **Issue:** Agricultural fields downstream of the project site experienced heavy sand deposition during overbank flows after the levee was removed.

• **Lesson:** Pay more attention to suspended sediment and how roughness changes in addition to how rapid channel migration may alter rates of sand deposition for properties immediately downstream.

**Adaptive Management/Maintenance:**

• **Issue:** Additional grading and planting was required to respond to problems with overbank flows and associated sedimentation. This required funding and planning resources.

• **Lesson:** Anticipate a routine need for adaptive management or large-scale maintenance in the first few years after large levees are removed from mainstem rivers. Budget enough for large the top three or four actions that may be necessary to mitigate risk. Create conceptual designs, cost estimates, and perhaps even get permits to construct them as they become necessary. Also consider building these large projects in phases that allow the design team to observe the riverine responses to the initial round of changes.

**Acquisitions/easements:**

• **Issue:** The project area was too limited to easily contain or mitigate off-site impacts.

• **Lesson:** Where possible, try to get a wider buffer between private property and areas within the project site that may be sensitive to project actions from a sediment, velocity, or changes in flood elevations. In particular, consider buying more land or easements in areas that may be prone to increased flooding, sedimentation, or erosion. It is probably wise to procure even more area than you think you need.

**Monitoring fish and edge habitats:**

• **Issue 1:** Snorkeling was relatively ineffective in the Snoqualmie River owing to difficult access, high velocities and low visibility from turbid water. Also wading and mapping edge habitats, such as been done at other project sites (Chinook Bend, Lower Tolt) is not feasible along most of the Snoqualmie River.

• **Lesson 1:** Boat-based electrofishing should be used instead of snorkeling when evaluating fish use of edge habitats. Edge habitat mapping should be done using aerial imagery and verified with field observations.
Flood level monitoring:

- **Issue:** Changes in flood surface elevations could not be precisely evaluated across the area of interest because there were too few water level monitoring loggers installed across the site and on nearby property. Monitoring channel changes and fish/habitat was overemphasized and more resources should have been put into water level monitoring.

- **Lesson:** For large river projects, both pre- and post-project risk assessments are critical should a major element in the monitoring plan. Project sites and surrounding areas should probably have four to eight continuous loggers deployed in strategically important locations, as determined by consultations with those involved in hydraulic modeling. Consider meeting earlier in the design process to discuss risk monitoring, even at the feasibility stage. Further detail is presented in Section 4.6. Adaptive Management.

### 4.6 Adaptive Management

King County has been evaluating the potential effects of the Upper Carlson project on flooding patterns and agricultural interests in the Fall City Area. In April 2016, King County staff hosted a public meeting to discuss the issues. Key observations that were relevant to this discussion are listed below:

- **Increased potential for gravel storage:**
  - Erosion of the sandy right bank and related channel widening and migration has created room to store approximately 10,000 cubic yards of coarse gravel in the project reach. That is six to 10 times the amount that accumulated in the reach before the project was completed.
  - Improving gravel retention in the project area reduces the amount of gravel that moves downstream and creates important habitat in the project area.
  - This gravel retention may be reducing the rate of growth of downstream gravel bars and the associated rates of erosion on adjacent riverbanks, providing a potential benefit to properties downstream already experiencing bank erosion.

- **Channel changes appear to be slowing:**
  - Within the project area, rates of change appear to be decreasing. Even during the record flood year of 2015-16, the rate of bank migration into the Upper Carlson project area slowed as a more natural channel pattern developed, and as the river encountered placed wood.
  - Sand erosion in the project reach caused by channel migration dropped by approximately half in the 2015-2016 water year, compared to the 2014-2015 water year—indicating that sand generated from the site and contributing to sand accumulation in the field downstream is returning to background levels.

After the meeting, King County completed several on-the-ground actions:

- **Berm:**
  - King County restored the ground surface elevation along the setback revetment in May 2016 by constructing a shallow berm in that area. While that berm was
not tested because of a lack of significant floods this winter, King County believes that much of the sand deposition and any elevated water surface elevation in that right bank area was due to this bank elevation being low.

- **Field repair:**
  
  - King County is working with the landowner on the right bank to restore fields damaged by project-related sand deposition.

- **Bank re-vegetation:**
  
  - King County continued to revegetate the right bank.

King County also engaged Dr. Ed McCarthy—an hydrologist and engineer—to conduct a technical third-party review to determine whether the project could have negative effects on downstream flooding patterns. King County will fully consider his recommendations and maintain a dialogue with neighbors as we move forward.

**Key Results of Third-Party Review:**

**Conclusions**

- “The Project was designed with due diligence, which included collecting comprehensive background information, developing the appropriate hydraulic models to evaluate alternative designs, and conducting post-construction monitoring and post-flood analysis.

- Although the Project had an adverse effect on the right river bank immediately downstream of it, the effect has since been acknowledged and repaired by the County.

- No other adverse effects have been identified to date. The Project-reach morphology that has occurred over the past two years is impressive, in a positive way.”

**Recommendations**

- “Continue the Project’s post-construction monitoring program for at least 10 additional years. The program currently monitors the rate of recession of the river’s right bank, measures channel geometry at reference locations, and measures continuous river stage at selected locations along the Project reach. In addition, because of the long-term anticipated significant changes in river geometry, the program should continue monitoring the rate of recession of the river’s right bank annually for 20 years from now. Furthermore, a general assessment of the conditions of the Project reach should be conducted subsequent to floods with a return period of greater than 10 years that occur

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during the next two decades. Such a monitoring program will ensure that adaptive management measures, if they are necessary, can be implemented in a timely manner. Collected data will help assess potential adverse effects of the Project that could become apparent over time. In addition, the data collected as part of the monitoring program can be used to inform the design of future floodplain restoration projects.

- Coordinate post-construction monitoring with ongoing efforts by the SVPA [Snoqualmie Valley Preservation Alliance]. Work with downstream landowners to perhaps develop a protocol for collecting data that can support a qualitative assessment of potential effects of the Project during flood conditions. This action could include obtaining photographs at specified locations during various flood stages, recording high water marks on landowners’ properties, and encouraging landowners to note and map the specific direction of flood flow paths. The Floodzilla Sensor project is currently in the process of installing 12 water level recording sensors along the river. The installation of 20 additional sensors is planned in the next two years. Coordinating this grass-roots data collection effort with the County’s post-construction monitoring program would be a benefit to all stakeholders.

- Based on both the post-flood analysis of the January 2015 flood and the results of future post-construction monitoring, refine the menu of contingency measures that would be implemented to mitigate potential adverse effects of the Project or to redirect the course of the Project.

- Use the January 2015 storm as an additional design hydrograph for future river restoration projects. The storm was unique in several respects, and it gives us a way to test, during the design phase, the robustness of a restoration project under a unique flow condition.

- Broaden the project selection criteria for future river restoration projects. The County’s current selection criteria focus on the removal of engineered structures and bank armoring from the river system. Consider projects along reaches of river that are susceptible to potentially devastating effects from natural river processes as well. As an example, a potential restoration project could be implemented to protect the eroding bank at the Richmond property, immediately downstream of the Project. Based on the County’s projections, continued bank erosion and channel migration at this location would increase the adverse effects of flooding within a large area of the left-bank floodplain, with potentially negative impacts on agriculture, property, and infrastructure.

- Increase flood storage as a design element. Increasing flood storage generally has the benefit of attenuating peak flood flow rates and should be incorporated as a restoration design element where possible.

- Include design elements that provide a direct benefit to agricultural resources. The floodplain restoration projects that have been constructed along the Snoqualmie River
have focused on improving salmon habitat. To build trust and to encourage participation from landowners, the needs of agricultural interests should be addressed as well. In addition, design elements related to floodwater management could provide a mutual benefit to agriculture and fish habitat. As an example, a significant area of agricultural land in the Valley would benefit from controlled drainage that could be accomplished with a network of ditches, subsurface drains, and flow control structures. This action would improve agricultural soil moisture conditions throughout the year and allow farmers to begin field operations earlier in the season. In addition, controlled drainage has been shown to improve water quality draining from agricultural fields. A study sponsored by SVWID [Snoqualmie Valley Watershed Improvement District] is soon to get underway, with the objectives of (a) identifying drainage needs for specific agricultural parcels and (b) developing a plan for implementing a drainage network to improve the viability of agricultural operations. Restoration projects could incorporate selected elements of the proposed drainage infrastructure as part of the overall restoration design and permitting package.

Next Steps

King County continues to monitor flooding patterns through a combination of water surface elevation gages, time-lapse video cameras, discussions with nearby landowners and collection of high water mark data after floods. We continue to see changes at the site, including changes in the elevation of the riverbed and floodplain.

King County remains committed to achieving project objectives, including the objective to maintain or improve current levels of flood hazard protection in the area. We are currently using new elevation data to re-run the hydraulic model to evaluate the new wider, shallower channel and predict any unexpected rise in water surface elevation or velocity during future, larger flood events. We will continue to share this and other new information about project performance and local flooding with the Fall City community.
References


King County. 2011. Snoqualmie at Fall City Reach Restoration Assessment. Prepared for King County Water and Land Resources Division by D. Eastman, T. Hurley, W. Mansfield, J. Latterell, C. Barton, T. Thinley, and M. Maeir. King County Department of Natural Resources and Parks, Seattle, Washington.


Appendix A. Experimental Planting in Year 1.

Introduction

The main planting area at the project site was a former river channel with sandy, droughty soil and was previously dominated by knotweed in the understory and relatively sparse deciduous trees like red alder and cottonwood. The existing canopy provided some shade to reduce solar radiation. There was considerable uncertainty about whether large-scale watering—which is very expensive—would be required. To reduce risk, the site was experimentally planted at a small scale in March 9, 2015.

Methods

Thirty plants were installed in each of 20 test plots. Each plot was spatially randomized. Corners were marked with steel posts.

Figure A1. Study plot locations.

The following plants were installed in each plot:

- *Symphorocarpus albus* (snowberry): 10 1-gal potted plants
• *Cornus stolonifera* (red-osier dogwood): 5 bare-root plants
• *Lonicera involucrate* (black twinberry): 3 1-gal potted plants
• *Fraxinus latifolia* (Oregon ash): 2 1-gal potted plants
• *Acer circinatum* (vine maple): 3 1-gal potted plants
• *Rubus parvifolium* (thimbleberry): 3 1-gal potted plants
• *Alnus rubra* (red alder): 2 1-gal potted plants
• *Picea sitchensis* (Sitka spruce): 2 bare-root plants.

Each plot was surveyed in the early part of the growing season (June 9th) to determine the number of live plants in each plot at the outset of the experiment. The watering treatment was then applied to selected plots. On August 17th, survival was assessed again in each plot to determine the effectiveness of the watering treatment. The results of the experiment were used to determine whether to proceed with the full-scale planting and as the basis for watering the new plantings or not.

**Results:**

Survival in the watered and unwatered plots was indistinguishable at p=0.05 (Figure A2). Survival was 90% or greater, on average, in both treatments, even though the 2015 growing season was extremely dry.

**Conclusion:** Watering was unnecessary to ensure survival rates exceeding 80%; even plants better suited for wet soils like twinberry and Oregon ash performed well. Accordingly, it was determined that watering was not cost-effective and the remainder of the 1936 channel was planted and watering was not subsequently used. Some of the plantings showed minor stress from the use of Imazypr in the prior year. Natural recruitment of bigleaf maple, salmonberry, and cottonwood seedlings was observed. Knotweed and blackberry also re-invaded the plots.