Lower Boise Creek Channel Restoration Project
2013 MONITORING REPORT

Monitoring Year 3 of 5

<u>REGULATORY PERMITS</u>
WSDOT #NWS-2010-582
Hydraulic Project Approval #11704-1
DDES Clearing and Grading #L09CG138
DDES Shoreline Exemption #L09SX026

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Constructed: Summer 2010
Planted: February 2011
Monitoring Period: 2011-2015

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Landscape Design: Laura Hartema

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King County

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Water and Land Resources Division
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Authors' Roles and Responsibilities

Laura Hartema was a primary author of this report. She designed and implemented the field experiments. She managed data collection and performed the analysis and interpretation. She was responsible for assessing and responding to maintenance needs related to plants and fences. She took photopoints of the site and managed maintenance crews.

Josh Latterell manages the ERES Monitoring & Maintenance Program and, accordingly, was responsible for decisions and on-the-ground actions related to flow, temperature, and wood management, as well as general oversight of monitoring activities. He was a primary author of this report. He was responsible for time-lapse cameras, temperature loggers, and underwater videography. He analyzed and/or summarized indicators not otherwise ascribed to other authors.

Hans Berge designed and implemented snorkel surveys for fish, and physical habitat surveys in the channel, and collected samples of the stream benthos. He reviewed a final draft of the monitoring report.

Dan Lantz and Chris Gregersen assisted Hans Berge with fish and instream habitat surveys and transcribed and summarized field data from those surveys. Dan Lantz reviewed an early draft of the monitoring report. Dan Eastman also participated in some early fish surveys.

Reviewers

This report was improved by thoughtful comments from Carolyn Butchart, Mason Bowles, Todd Hurley, and Will Mansfield. The authors wish to thank the design team for helpful input on site management decisions.

I. Setting and Location

Boise Creek provides important spawning and rearing habitat for salmonids, including threatened steelhead trout and Chinook salmon. However, habitat conditions near the White River confluence had been degraded for more than 80 years. In the 1930's the lower 500 feet of Boise Creek was relocated between the Northern Pacific Railroad and State Route 410. This shortened and steepened the creek, disconnected its floodplain, and turned it into a straight channel with high banks, a coarse bed, and virtually no wood. The road and railroad have since been removed, and the 15-acre property containing the project area is owned and managed by King County for recreational and habitat conservation. In 2009 and 2010, the project site was restored by King County (Fig. 1).

Figure 1. Aerial view of the project site in May 2013. Mud Mountain Road is on the left. White River is on right. The new channel is in the foreground. The old channel is in the background, mostly behind the trees. The upstream control reach is to the left of the bridge.

The project is located on Boise Creek at its confluence with the White River at river mile 23.25 (Fig. 2). It is southeast of the intersection of Hwy 410 at Mud Mountain Road, in SE ¼ Section 34, Township 20 North, Range 6 E, parcels #342006-9032, -9045, and -9086, in Enumclaw, Washington.

Figure 2. Vicinity map of the Lower Boise Creek Project.

II. Goals and Objectives

The goal of the restoration project was to relocate the lower reach and mouth of Boise Creek into a new channel configuration and alignment to restore the natural stream geomorphic structure, functions, and habitat-forming processes, while also protecting Tacoma Water's Pipeline (Table 1). The design approach was to establish an alluvial fan floodplain with large wood to provide roughness, allowing the creek to scour pools, form riffles, build terraces, and actively migrate, providing habitat for fish and wildlife, and an expanded riparian buffer (Tables 1 and 2; Fig. 3). The project targeted improvements in spawning, rearing, and refuge habitat for juvenile salmonids including summer and fall Chinook, pink, coho, and chum salmon, as well as native cutthroat and steelhead trout.

__Original Project 'Design Criteria' from Design Report__

- 1.01-year (effective) discharge = 137 cfs, 1.25 year (bankfull) discharge = 280 cfs.
- Range of spawning flows for Chinook salmon in Boise Creek of five to 60 cfs.
- Preferred spawning flow depths for Chinook salmon of one to three feet.
- Preferred spawning velocities for Chinook salmon of one to three feet per second.
- Preferred spawning depths should be associated with preferred spawning flows and velocities.
- Range of spawning substrate size preferred by Chinook salmon of 10 to 80 mm.
- Spawning substrate should begin to mobilize between the 1.01 and 1.25 year recurrence flow[1].

[1] Actually varies with time, location, roughness and other factors.

Table 1. Specific project goals, objectives from the design report, and monitoring indicators.

Specific Goals	Stated Objectives	Indicators
Create an alluvial fan floodplain and allow channel to actively migrate and build terraces[2]	1. Relocate existing channel and increase channel length to 600 feet (182 meters).	1a) Channel length and area
	2. Create approximately 2 acres of alluvial fan floodplain habitat[3].	2a) Floodplain area
Provide channel roughness to scour pools and form riffles and provide habitat for fish and wildlife	3. Place 150 pieces of large wood to create instream habitat	3a) Juvenile salmonids 3b) Pool: riffle ratio 3c) Residual pool depth 3d) Stream temperature 3e) Index of Benthic Integrity
	4. Establish a riparian buffer of native vegetation along each side of the channel that averages at least 150 feet wide (46 m).	4a) Riparian buffer width 4b) Woody native plant cover
	5. Provide fish passage at low flows	5a) Incidence of passage barriers
	6. Reduce velocities during bankfull flow and re-establish desirable spawning substrate.	6a) Redd density
Mitigate for WSDOT White River Bridge scour project by creating new instream habitat	7. Create two large wood structures that create a quiescent zone and function to provide year-round rearing habitat for fish: Structure 5 (four logs): 1,470 square feet; Structure 6 (five logs): 1,350 square feet.	7a) Summary of conditions of the mitigation site 7b) A list of the fish species observed during the monitoring site visit 7c) A quantification of the area of in-channel habitat created by Structures 5 and 6 7d) A summary of the habitat functions being provided by Structures 5 and 6 7e) Photo reference points for Structures 5 and 6

[2] In retrospect, this criterion should have specified complex, dynamic, alluvial fan topography.

[3] Alluvial fan floodplain habitat not defined in design report. Floodplains are often defined as depositional features composed of within-channel and overbank deposits, prone to regular inundation by floodwaters. Alluvial fans are conical depositional features with an apex at the point of emergence from the uplands and slopes that radiate away from the apex (Knighton 1998).

Construction activities spanned a two-year period (Table 2), including site preparation, soil clean-up, and project implementation.

Table 2. Timeline of project actions

Year	Action	Detail
2009	Site prep	Chemically treated, mowed and weed-trimmed five acres of non-native Himalayan blackberry (*Rubus armeniacus*) and regrowth.
2010	Treated invasives	Blackberry re-growth was spot sprayed in summer 2010, prior to construction.
	Removed contaminated material	9,000 yards of material and 800 tons of contaminated trestles, pilings, and soil from Burlington Northern Railroad (PAHs, arsenic, chromium, copper). Clean material disposed on site in buried setback revetment to protect Tacoma pipeline.
	Excavated 600-foot channel	Added 1.5 aces of new floodplain.
	Placed 150 pieces of wood	12 key pieces with rootwads; all salvaged from Mud Mountain Dam. Placed in both new and old channels. Six spanning logjams created in new channel.
	Placed 200 carcasses	Chum salmon carcasses placed along banks of new channel.
	Installed plants	>8,400 plants total , including 5,845 bareroot plants, 1,055 1-gallon native plants (Fig. 3; Table 3).
	Amended soil on berm	Added topsoil and mulched with 6-12” of animal-friendly hogfuel mulch to suppress weeds and retain moisture. West bench and left bank of new channel were not mulched.
	Staked floodplain	Staked with five to six-foot-long willow poles (3/4-1-1/2” diameter) at five to six feet on-center in late September .

Plantings were installed in order to establish native woody vegetation on both sides of the Creek (Table and Figure 3).

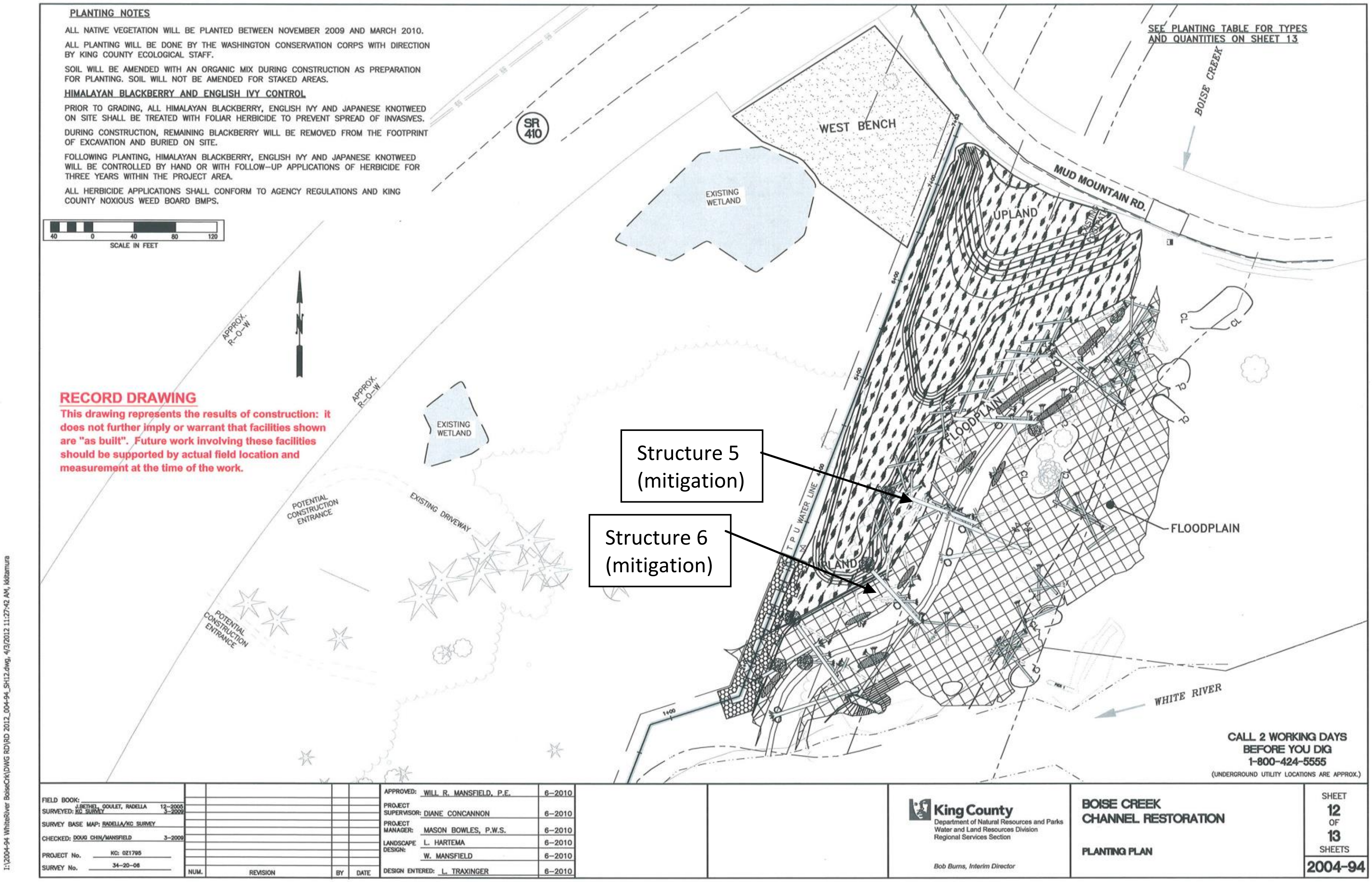


Figure 3. Planting plan for Boise Creek Channel Restoration Project.

Table 3. Plant list by type, species, common name, and location (FP is floodplain; UP is upland; WB is west bench; and UN is underplanting). O.C. refers to 'on-center'.

Type	Genus species	Common name	FP	UP	WB	UN	Qty	Size	Spacing (o.c. feet)
Trees	*Abies grandis*	grand fir		25	25		50	1 gal	10-15
	Acer macrophyllum	big leaf maple		150	150		300	1 gal	10-12
	Alnus rubra	red alder		200	200		400	1 gal	5-6
				350	350		700	bareroot	5-6
	Populus trichocarpa	black cottonwood		400	400		800	bareroot	6-8
	Picea sitchensis	Sitka Spruce		50	75	30	155	1 gal	10-15
	Pseudotsuga menziesii	Douglas Fir		100	50		150	1 gal	10-15
	Thuja plicata	Western red cedar			50	70	120	bareroot	15-25
Shrubs	*Corylus cornuta*	Western hazelnut		300	300		600	bareroot	3-4
	Holodiscus discolor	oceanspray		350	400		750	bareroot	3-4
	Rosa nutkana	Nootka rose		250	300		550	bareroot	3-4
	Salix lasiandra	Pacific willow	725				725	3-5' stakes	5-10
	Rubus parviflorus	thimbleberry		300	300		600	bareroot	3-4
	Salix scouleriana	Scouler's willow		250	250		500	bare root	4
	Symphoricarpos albus	snowberry		250	250		500	bareroot	3-4
	Salix sitchensis	Sitka willow	1500				1500	3-5' stakes	4-6

III. Permit Conditions

Four agencies stipulated performance targets in the permits that were granted for the construction of the project (Table 4).

Table 4. Permit conditions and requirements.

Agency	Permit type and number	Permit Requirements
Washington State Department of Transportation (WSDOT)	NWS-2010-582	Permittee implements and abides by mitigation memorandum "SR 410/White River Bridge Scour (WIN#A41001C/XL 3505) White River/Boise Creek Mitigation Memorandum" dated March 10, 2010. Mitigation monitoring reports (due in years 1, 3, and 5) that include: 1) Summary of conditions of the mitigation site 2) A list of the fish species observed during the monitoring site visit 3) A quantification of the area of in-channel habitat created in Boise Creek using the methodology described in the mitigation memorandum (hydraulic shadow of deflector structure; 17 degrees off perpendicular to the centerline of the structure from its tip to the bank downstream; flow re-attachment to the bank occurs 3 protrusion lengths downstream from structures that are arrayed in a series). 4) A summary of the habitat functions being provided by Structures 5 and 6 5) Photo reference points for Structures 5 and 6 *If the above required information is included in a comprehensive monitoring report for the Boise Creek Channel Restoration Project compiled by King County, then the permittee's submission of that report will meet this condition. All reports must be submitted to the Corps, Seattle District, Regulatory Branch and must prominently display the reference number NWS-2010-582.
Washington State Department of Fish and Wildlife (WDFW)	Hydraulic Project Approval (HPA), #11704-1, Provision 22	Plantings shall be maintained as necessary for three years to ensure 80 percent or greater survival of each species or a contingency species approved by the AHB.
King County (KC) Department of Development and Environmental Services (DDES)	Grading Permit #L09CG138, Condition 5	Monitoring shall be conducted for five (5) years after installation is complete. Monitoring reports shall be submitted to KC DDES, Senior Ecologist (Nick Gillen). Though the site will be monitored for maintenance purposes in all years, monitoring reports will be submitted in alternate years (2011, 2013 and 2015).
	Shoreline Exemption #L09SX026, Condition 5	Monitoring reports shall be submitted to KC DDES in alternate years (2011, 2013 and 2015).
KC Department of Natural Resources and Parks' (DNRP) Natural Lands Section	n/a	Monitoring reports shall be provided to KC DDES annually by December 31 for five years following acceptance of the as-built drawings. Though the site will be monitored for maintenance purposes in all years, monitoring reports will be submitted in alternate years (2011, 2013 and 2015).

IV. Monitoring Methods

A wide range of performance indicators were used to determine whether the project was meeting its objectives and performing as intended. These indicators were chosen on the basis of their relevance to project objectives, as well as their precision, cost to measure, and importance to regulatory agencies and stakeholders. The present tense is used in this section of the report because the monitoring activities are *ongoing*. Accordingly, this methods section is intended to serve not only as a record of what has been done, but what is to be done in future surveys. Indicators are grouped below according to the design objectives with which they are associated.

OBJECTIVE 1: Relocate existing channel and increase channel length.

Channel length indicates progress toward meeting project goals to create additional channel. Channel area is a complementary measure that takes into account changes in width.

Indicator 1a) Channel length and area

- Measure the length of the centerline of the old and new channel (Fig. 1).
- Measure width of the active (unvegetated) channel from 21 evenly-spaced transects in the new channel and 21 in the old channel. Use the same transects each year.
- Multiply centerline length by average channel width to estimate channel area.

OBJECTIVE 2: Create approximately two acres of alluvial fan floodplain habitat.

Floodplain area, defined here as a depositional feature consisting of within-channel and overbank deposits prone to regular inundation by floodwaters, can be approximated from topographic breaks and observations during floods.

Indicator 2a) Floodplain area

- Use topographic breaks (from post-project lidar) and field observations to estimate the area capable of flooding, for both channels combined.

OBJECTIVE 3: Place 150 pieces of large wood to create instream habitat.

Changes in instream habitat are indicated by increases in the density of juvenile salmonids, increased pool area, relative to riffle area, increased residual pool depth, and the absence of warming in stream temperature. Benthic indices of biotic integrity (B-IBI) are estimated from samples of the stream benthos, but these scores are not responsive to reach-scale conditions, rather indicators of the condition of the upstream watershed. Accordingly, it is not considered to be a good indicator of project-mediated changes to reach-scale habitat conditions. It is only being reported here to document that the work was done.

Indicator 3a) Juvenile salmonids

- Begin pre-project surveys in 2006 (Table 5) and survey at approximately the same time of year in subsequent years (2009, 2010) until the project is completed.
- Survey all channels present at the time, using pre-established transect locations located by Tetra Tech (contracted by Salmon Recovery Funding Board; SRFB) in old channel and the control reach.
- Flag and label SRFB transect locations A-K in the daytime.
- Survey fish after dark using two snorkelers; tally fish by species and size-class for each section or habitat unit.
- Perform habitat survey prior to fish survey (2013; repeat in 2015).
    - Measure channel width and length between each pair of transects (i.e., section).

  - Classify each section between transects as riffle, pool, run, glide.
  - Estimate average depth of each section.
  - Measure maximum and crest depth for each pool to calculate residual pool depth.
  - Visually classify substrate as a percentage of the total area using five size classes:
    - <2 mm; 2-16 mm; 16-64 mm; 64-256 mm; >256 mm)
  - Estimate surveyed area by multiplying section length by width and summing across all sections for each individual reach (i.e., new, old, and control).
- Tally total fish counted by species and size class for each channel
- Estimate density by area (fish per m^2 of wetted channel) and by reach length (fish per linear meter of stream channel).

Table 5. List of fish survey dates and flows (USGS 12099600) at the time of the surveys performed by King County staff. TetraTech also performed an electrofishing survey in 2006, which is not reported here.

			Control		Old Channel		New channel	
Survey	**Date**	**CFS**	**Length (m)**	**Area**	**Length**	**Area**	**Length**	**Area**
Pre-project	June 2 2009	16	-	-	156	1042	-	-
	May 11, 2010	29	152	-	152	-	-	-
	July 2, 2010	34	152	-	152	-	-	-
	August 12, 2010	9	152	-	-	-	-	-
Post-project	July 5, 2011	16	152	-	152	-	152	
	March 25, 2013	37	150	944	150	818	180	1473
	July 13, 2013	8	165	1117	135	514	163	1436

Indicator 3b) Pool: riffle ratio

- Estimate the total length of pool and riffle habitat from field surveys.
- Analyze old and new channels separately from one another.

Indicator 3c) Residual pool depth

- Measure the maximum and tail depth of each pool
- Calculate the difference and average across all pools.
- Analyze old and new channels separately.

Indicator 3d) Stream temperature

- Use Hobo ProTemp v2 water temperature loggers to measure the changes in water temperature (in degrees Celsius) as flow moves through the new and old channels, relative to the incoming temperature as measured in the control reach immediately above the project site.
- In 2011 and 2012, install loggers underwater at four locations (Table 6) throughout the project site in late May or early June (Table 6); use two zip ties to attach loggers to re-bar stakes driven into the streambed with a sledgehammer and cover each logger with a large rock to prevent loss or theft.
- In 2013, install loggers at five locations; same locations as in prior years with the addition of another logger upstream of the bridge to provide redundant measurements of incoming water temperatures (Inlet 2; Table 6).
- Remove loggers in October, after temperatures decline.
- Analyze by estimating the following metrics:
  - Daily maximum temperature measured by each logger in each year.
  - Daily maximum heat gain relative to incoming temperature, calculated as the difference between daily maximum of incoming water and the daily maximum at the location of interest.

- Seven–day average of the daily maximum temperatures (7DADMAX); the arithmetic average of seven consecutive measures of daily maximum temperatures.

Table 6. Water temperature loggers' location, name, description, and serial numbers by year.

Location	Name	Description of location	Serial numbers 2011	2012	2013
Existing channel	Inlet 1	Left bank downstream from the bridge, upstream from the confluence of both new and old channels	166398	10157518	10157555
	Inlet 2	Immediately upstream from bridge	n/a	n/a	10157518
New channel	Middle	1/3 the way downstream from the new channel inlet	67827	10144054	10157612
	Outlet	¾ the way downstream from the new channel inlet	706862	10120198	10120198
Old channel	Old channel	¾ the way downstream from the old channel inlet	678719	10157612	10144054

Indicator 3e) Index of Biotic Integrity

- Collect benthic invertebrate samples to document any changes in the benthos in response to changes in the condition of the Boise Creek watershed (not to the restoration project).
- Pre-project
    - Coordinate with King County Roads Services Division to sample the stream benthos according to the BIBI methodology for Puget Sound Lowlands.
    - In 2009 and 2010, collect three replicate samples of benthic invertebrates using a Surber sampler (1 foot^2) in August and combine (composite) all three samples for analysis (Table 7)
    - Submit all samples to a consulting laboratory for processing and identification.

Table 7. List of benthic samples by location, sampling group, and year.

Location	2009	2010	2011	2012	2013
Control reach[4]	KC-Roads (Aug 20)	KC-Roads (Sept 2)	KC-Roads? (July 5)	KC-DNRP	KC-DNRP
Old channel	KC-Roads (July 16)	KC-DNRP (July 2)	KC-DNRP (July 5)	*No riffles to sample*	KC-DNRP
New channel	n/a	n/a	KC-DNRP (July 5)	KC-DNRP	KC-DNRP

- Post-project
    - In 2011-2013, collect eight replicate samples and combine for analysis.
    - Sample all three locations, so long as there are riffles present to sample (e.g., in 2012 no sample was collected because no suitable sampling locations could be found).

OBJECTIVE 4: Establish a riparian buffer of native vegetation along each side of the channel that averages at least 150 feet wide.

Average riparian buffer width indicates the degree to which the project successfully established a riparian corridor. The site also provides an opportunity to inform future restoration projects through controlled experiments on the effectiveness of irrigation and mulch.

Vegetation performance can also be evaluated in the course of the experiment. An experimental approach is needed to gain a better understanding of when and where irrigation and weed suppression is required to ensure high plant cover and survival. Native tree and shrub species are planted to improve habitat in river restoration, mitigation or enhancement projects, particularly in disturbed areas where invasive species

[4] Sample located within 25 feet downstream of Mud Mountain Bridge.

dominate. Plants are often maintained through weed control, mulching and irrigation to promote survival. However, these treatments are expensive and may be unnecessary when site conditions are favorable. Though plant survival is routinely monitored, factors that affect survival remain poorly verified. Replicating similar studies across multiple sites and years will systematically improve our understanding of when and where to use irrigation and/or mulch on restoration sites. The study will also help project teams make better maintenance and budget decisions in the future.

Indicator 4a) Riparian buffer width

- Estimate the width of continuous woody native vegetation extending from the left and right margins of the active channel.
- Measure buffer width at 21 locations coincident with transects that were used to measure channel width; or delineate riparian area as polygon and divide area by length along the axis parallel to the channel.

Indicator 4b) Woody native plant cover and survival

- Estimate cover and survival in the context of restoration experiments that provide added value to future projects and meet permit conditions.

EXPERIMENT 1: EFFECTS OF IRRIGATION ON SURVIVAL AND COVER OF TREES AND SHRUBS

- Perform a controlled experiment in order to determine the effect of irrigation on the survival of native plantings on heavily sheet-mulched (6-12 inches of hogfuel), upland slopes at elevations ranging from 8-14 ft. (2-4 m) above the summer water surface elevation, under full sun exposure.

***Question**:* Does the irrigation protocol improve the survival of mulched plantings at the project site, and if so, to what degree?

- Null Hypothesis: Survival of native plantings is the same between wet (irrigated) and dry (non-irrigated) plots because hogfuel mulch helps to retain sufficient moisture in the soil to promote plant development during the period of observation. *(Irrigation has no effect on planting survival.)*
- Alternative Hypothesis: Survival of native plantings is higher in wet (irrigated) plots because hogfuel mulch alone does not retain enough moisture in the soil to promote plant development during the period of observation. *(Irrigation positively affects planting survival.)*

Design:

- Use a systematic random design with two treatments at a single level for a total sample size (*n*) of 12 plots (six irrigated/wet and six non-irrigated/dry).
- Randomly assign treatments (i.e., wet, dry) to each plot, so that treatments are equally divided between the east and west sides of the upland berm.

Plot layout:

- Establish potential starting points for plots systematically every 12 meters along the baseline (access road).
- Randomly choose 12 plots (36 m^2) along the upland berm; six to the west, and six to the east side of the berm.
- Plot dimensions are either 3 m x 12 m or 4 m x 9 m, depending on slope width. Plot size is designed to encompass approximately 16 trees each, to balance the need for statistical power with the cost of placing approximately 100 trees at elevated risk of mortality in dry plots.
- Orient plots east to west or west to east from the top of the slope towards the toe (Figure 4).
- Locate planted areas and plots at relatively consistent slope elevations from 8-14 feet (2-4 m) above the low-flow water surface elevation in the stream channel (approx.191 m or 626-633 ft based on Datum NAVD 88).
- Expose all plots to natural precipitation.

Plot Marking:
- Mark the south corners of each irrigation plot along the top of the berm with steel fence posts, plastic flagging, and label with an alpha-numeric code (e.g, 1WET).
- Locate each south corner post of the plot, along the top edge of the berm, with a global positioning system unit (GPS).
- Paint the south post at each plot and use it as the photo point reference, aiming diagonally at the opposite, corner post located down-slope.

Irrigation Protocol:
- In wet plots, water planted woody stems for approximately 30-45 seconds per plant with a hose and pump from a truck or withdrawn from the river.
- Irrigate wet plots between June and September as follows: 7 times in 2011, 3 times in 2012, and 2 times in 2013.
- Do not irrigate dry plots; encircle each dry plot with 16-gauge galvanized wire to clearly mark plot boundaries and to prevent accidental irrigation.

Sampling Protocol:
- Perform field surveys in May, prior to irrigation, and in August at the end of summer.
- Tally live stems by species, as well as naturally regenerating trees (e.g., alder).
    - In Year 2 (2012) and Year 3 (2013), tally all the alders regardless of source, because it is difficult to decipher recruited vs. planted alder.
- Plan to complete irrigation plot surveys in one to two days with one person.
- Take photographs from established photopoints, and repeat in each monitoring year to show site changes.
- Exclude planted stems that were dead by the first survey (May 2011) because factors other than irrigation were responsible for their mortality (e.g., dead nursery stock, transplant shock, vandalism, deer/elk browse).

EXPERIMENT 2: EFFECTS OF MULCH ON NATURAL TREE RECRUITMENT AND HERBACEOUS COVER
- A secondary study was conducted to determine the effects of hog fuel mulch on natural recruitment of native woody species and herbaceous plants.

Question 1*:* Does bark mulch reduce natural recruitment of native woody species, specifically, red alder and black cottonwood, compared to adjacent, bare (non-mulched) areas?

- Null Hypothesis 1**:** Native woody plants establish at the same densities in mulched and bare (non-mulched) plots because the mulch does not prevent germination, rooting, and growth of propagules. *(Mulch has no effect on natural recruitment rate of native woody plants.)*
- Alternative Hypothesis 1**:** Native woody plants establish greater densities in bare (non-mulched) plots because mulch reduces the ability of woody plants to germinate, root, or grow. *(Mulch reduces natural recruitment rate of native woody plants.)*

Question 2: Does hogfuel mulch reduce the occurrence of herbaceous/invasive plants, compared to adjacent, bare (non-mulched) areas?

- Null Hypothesis 2**:** Herbaceous/invasive plants establish at similar rates in mulched and bare plots because mulch does not prevent growth. *(Mulch has no effect on herbaceous plant establishment.)*
- Alternative Hypothesis 2: Herbaceous/invasive plants occur more frequently in bare (non-mulched) plots because mulch reduces the ability of herbaceous plants to germinate, root, or grow. *(Mulch reduces natural recruitment of herbaceous plants.)*

Design:

- Use a systematic random design with two treatments at a single level for a total sample size (*n*) of 51 quadrats (26 mulched and 25 bare/non-mulched).
- Randomly assign treatments – mulch or bare –to 1 m^2 quadrats.
- All quadrats were watered when the rest of the site was being watered.

Plot Layout:

- Establish quadrats every two meters along ten-meter long transects located six meters south and parallel to the irrigation experiment plots.
- Extend transects roughly east/west or west/east from the top of the slope towards the toe.
- Locate five transects west of the berm and five east of the berm (Figure 4).
- Locate all quadrats were located north of the transect line, in areas with similar planting schemes as in the irrigation experiment.

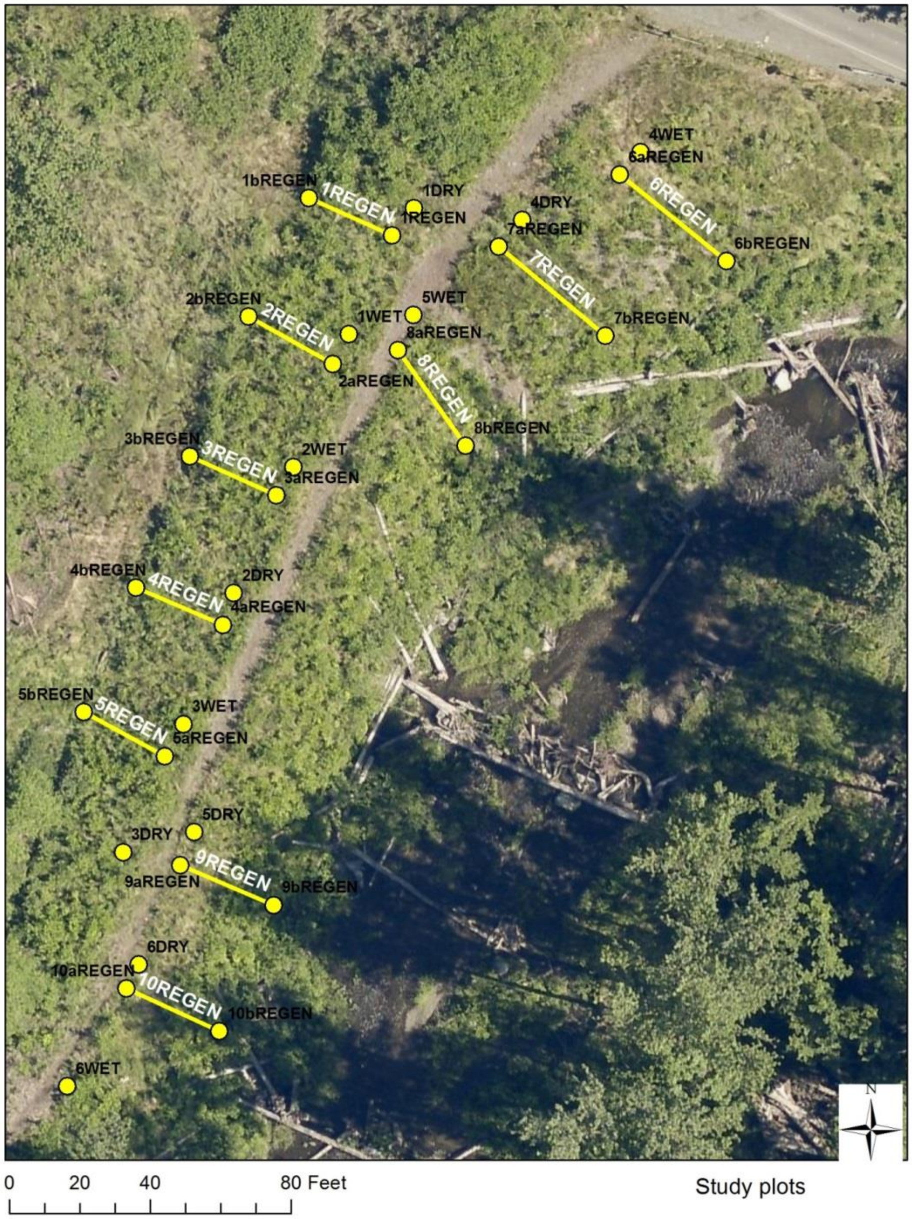


Figure 4. Vegetation study plot locations. Photo is from 2013.

Plot Marking:

- Mark each end of the natural recruitment transects with three-foot rebar sections, flag, and label (e.g, 1REGEN).
- Use the rebar at the top of the slope as the photo point reference, aimed diagonally at the opposite post located down slope.
- Assign each quadrat a label according to its distance from the starting point (e.g. 0, 2, 4...10 meters) and note the treatment type (e.g. 1-2M=Transect 1, 2 meters, mulched versus 4-4B; Transect 4, at 4 meters, bare).

Treatment Protocol:

- Initially, spread mulch over the entire site.

- Once quadrats are established, place a 1-m^2 sampling frame on the ground and used to manually remove mulch (in February 2011), and expose the underlying soils.
- In bare plots, periodically clear away and remove any mulch sloughs in from the sides.

Sampling protocol:

- Survey each quadrat in late August each year (2011-2013).
- Tally the number of live native woody plants by species.
- Estimate herbaceous cover (e.g., grasses and rushes) in each quadrat using a modified Daubenmire cover class scale (Table 8).
- Plan to complete the natural recruitment quadrat surveys in one to two days with one person.

Table 8. Cover classes used to quantify herbaceous cover in experimental quadrats. Adapted from Daubenmire (1959).

Cover class	0	1	2	3	4	5	6
% cover:	0 to trace	<5%	6-25%	26-50%	51-75%	76-95%	>96%

OBJECTIVE 5: Provide fish passage at low flows.

Passage barriers can manifest in different forms (e.g, thermal, physical, chemical) but monitoring for this objective is focused on effects of flow-splitting between the channels, and on informing and responding to concerns about debris accumulations that may form on installed logjams and form upstream passage barriers.

Indicator 5a) Incidence of passage barriers

- In March of each year, assess the connectivity of the new and old channels to surface flows, envisioning the outcome that would occur if discharge levels dropped below 10 cfs.
- Use a graduated wading staff to measure the relative difference in elevation of the thalweg in the new and old channels.
- If the old channel is deeper, begin or continue stakeholder consultations and make arrangements to install a decomposable gravel-based flow diversion structure to channel the majority of flow into the new channel in order to protect incubating steelhead embryos; rearing habitat in the old channel will be maintained by hyporheic upwelling.
- If the new channel is deeper, no further action is required.

OBJECTIVE 6: Reduce velocities during bankfull flow and re-establish desirable spawning substrate.

Redd densities in the project reach are indicative of the degree to which desirable spawning substrate is increased in the project reach. This objective overlaps with Objective 3, so any associated indicators that could be linked to both objectives are presented with Objective 3 only, for simplicity.

Indicator 6a): Redd density

- Obtain annual reports from Puyallup Tribal Fisheries (PTF), which surveys River Mile (RM) 0.0 to 4.5 (location of impassable falls) for steelhead and Chinook redds. Steelhead are surveyed each year, but Chinook redd counts are only reliable in even years because in odd years they are obscured by high densities of spawning pink salmon.

OBJECTIVE 7 (Mitigation): Create two large wood structures that create a quiescent zone and function to provide year-round rearing habitat for fish.

Indicators for the mitigation project were established in the agreements.

- 7a) Summarize conditions of the mitigation site.
- 7b) List the fish species observed during monitoring site visits.
- 7c) Quantify the area of in-channel habitat created by Structures 5 and 6 in Boise Creek using the methodology described in the mitigation memorandum. Specifically, estimate the hydraulic shadow of deflector structure: 17 degrees off perpendicular to the centerline of the structure from its tip to the bank downstream; flow re-attachment to the bank occurs three protrusion lengths downstream from structures that are arrayed in a series).
- 7d) Summarize the habitat functions being provided by Structures 5 and 6.
- 7e) Take photo reference points for Structures 5 and 6

Contaminant Monitoring (after site clean-up)

Contaminant concentrations are indicative of the effectiveness of clean-up efforts prior to project construction, and point to the need for any additional site remediation. This monitoring is not directly linked to a project objective but is included here to make sure it is documented.

- Measure background levels of arsenic, chromium and copper on November 13, 2009 (Shannon &Wilson, Inc., 2010); several contaminants of concern (COC) were identified on the Boise Creek site in 2010.
- After construction, collect samples (May 26, 2011) just downstream of the Mud Mountain Dam Road bridge (Samples 1-2) and downstream in the new channel (Samples 3-4).
- Collect samples at six-inch depths.
- Send samples to the Trace Metals Unit at the King County Water and Land Resources Division's (WLRD) Environmental Laboratory for analysis.
- Perform technical review of results (King County WLRD's Richard Jack, Water Quality Planner).
- If no COC's are discovered, discontinue sampling (in 2011).

V. 2010-2013 (Year 1 to 3) Monitoring Results

In general, riparian forests are re-establishing across the site, the channel is evolving, habitat has improved, and fish use has increased (Fig. 5).

May 17, 2011

June 22, 2013

Figure 5. Aerial oblique photos of the project site, looking downstream, in 2011 and 2013. The old channel is on the left behind the trees. The new channel is on the right. The control reach is not visible.

Objective 1. Relocated existing channel and increase channel length to 600 feet.

Indicator 1a) Channel length and area

- Length of the wetted channel centerline in 2013, measured from orthophotos:
    - Old Channel: **129** m (423 ft)
    - New Channel: **176** m (577 ft)
- Average width of active (unvegetated) channel
    - Old Channel: **9.4** m (6.8-16.8 m; SD 1.9; n = 21) or 31 ft
    - New channel: **18.6** m (9.1-28.0 m; SD 19.3; n = 21) or 61 ft
- Active channel area (as product of average width and centerline length)
    - Old Channel: **1,213 m^2** or 0.30 acres (0.29 as a polygon)
    - New channel: **3,273 m^2** or 0.81 acres (0.81 as a polygon)

Table 5. Results of 2013 post-project habitat surveys for control reach (control), enhanced old channel (old) and new channel (new). Note that the July 13th survey is affected by the flow diversion structure, which reduced the amount of flow in the old channel.

Factor	Metric	March 25 2013			July 13 2013		
		Control	Old	New	Control	Old	New
Wetted channel geometry	Avg channel width (m)	6.3	5.6	8.9	6.7	3.5	9.2
	Avg channel depth (m)	0.5	0.3	0.3	0.8	0.1	0.8
	Channel length (m)	150	150	180	165	135	163
	Channel area (m^2)	818	944	1473	1117	514	1436
Channel units	% Pool (by area)	15	2	12	13	0	30
	% Riffle, Riffle/Rapid, or Rapid	85	29	73	81	45	48
	% Glide or Glide/Run	0	69	15	0	55	17
	% Run	0	0	0	6	0	5
	Pool count	3	1	5	2	0	7
	Avg. res. pool depth (m)	0.5	0.5	0.5	0.1	0	0.4
Substrate size	Sand (<2 mm; %)	1	28	5	1	43	10
	Fine gravel (2-16 mm; %)	4	28	6	4	25	18
	Coarse gravel (16-64 mm; %)	9	22	59	8	13	35
	Cobble (64-256 mm; %)	50	21	28	51	17	26
	Boulder (>256 mm; %)	36	1	1	36	2	12

Objective 2. Create approximately two acres of alluvial fan floodplain habitat.

Indicator 2a) Floodplain area

- Construction of the new channel, including side channels, added approximately **one acre** in new floodplain area.
- The enhanced old channel area provides approximately **0.32 acres** of floodplain area; virtually all of which existed prior to the project.

Objective 3. Place 150 pieces of large wood to create instream habitat.

Indicator 3a) Juvenile salmonids

Salmonid abundances – particularly coho salmon – have increased in in the new and old reaches, relative to the control reach, which was located immediately upstream of the Mud Mountain Road bridge (Table 10).

July surveys can be reliably compared among years but comparisons of samples from different times of year are confounded by seasonal changes in fish size and species composition. For example, juvenile Chinook are commonly observed in March, May, and June samples, but surveys were not repeated in these months among years. In contrast, July samples located few or no Chinook. Accordingly, early samples (e.g., March) are preferable to July surveys in order to draw more inferences about project effects on Chinook salmon.

Table 60. Tally of all fish counted by species, size class, year, and location (CON – control; OLD – old channel; NEW – new channel). In 2010 and 2011 survey, fish were counted by species and age class. In 2013, salmonids were tallied by size class (fork length; FL).

		Pre-Project										Post-Project							
Common name	**Scientific name**		**2009**	**2010**					**2011**			**2013**							
		Age-class	**June 2**	**May 11**		**July 2**		**Aug 12**	**July 5**			**Size class**	**March 25**			**July 13**			
LOCATION			**OLD**	**CON**	**OLD**	**CON**	**OLD**	**CON**	**CON**	**OLD**	**NEW**	**(FL;mm)**	**CON**	**OLD**	**NEW**	**CON**	**OLD**	**NEW**
Chinook salmon	*Onchorynchus tschawytscha*	Fry	118	5	10	30	55	24	1	5	0	<50	0	25	209	0	0	0
												50-100	1	37	74	0	0	0
		Yearling	4	8	20	5	3	0	0	5	0	>100	0	0	0	0	0	0
Coho salmon	*O. kistuch*	Fry	84	474	384	188	158	400	132	812	1991	<50	8	969	1,023	117	192	398
		Smolt	16	253	65	28	11	36	4	66	18	50-100	2	83	27	171	319	809
												>100	0	40	0	8	10	126
Pink salmon	*O. gorbuscha*	Fry	0	20	0	0	0	0	0	0	0	n/a	0	0	0	0	0	0
Rainbow trout/steelhead & Coastal cutthroat trout	*O. mykiss & O. clarki clarki*	Fry	1	1	10	3	15	200	65	113	1933	<100	7	10	17	33	19	132
		Age-1+	33	46	35	19	36	48	18	41	12	100-200	29	43	66	60	2	74
		Age-2+	40	0	0	7	11	0	5	9	2	>200	27	15	37	9	0	13
Whitefish	*Coregonus* spp.	n/a	10	0	0	13	22	0	0	1	0	n/a	0	0	0	2	0	0
Char	*Salvelinus* spp.	n/a	0	0	0	0	0	0	0	0	0	n/a	1	0	0	0	0	0
Sculpin	*Cottuidae* spp.	n/a	22	0	0	63	76	23	1	2	0	n/a	2	0	5	0	0	3
Dace	*Rhinichthys* spp.	n/a	4	0	0	19	7	3	0	4	0	n/a	4	1	0	0	0	0
Sucker	*Catostomidae*	n/a	63	0	0	14	13	3	2	0	0	n/a	0	0	0	0	0	0
Lamprey	*Petromyzontidae*	n/a	3	16	2	9	18	1	0	1	0	n/a	1	0	0	0	0	0
Redside shiner	*Richardsonius balteatus*	n/a	0	0	0	0	0	0	20	0	0	n/a	0	0	0	0	0	0

- Observations from pre-project surveys in July 2010:
  - Similar numbers of coho, trout, and Chinook juveniles occurred in the control reach and the unimproved old channel.
  - Coho were the most prevalent, but abundances were generally low.
  - Large numbers of sculpin and whitefish in both channels.
- Observations from post-project surveys in July 2011:
  - Chinook juveniles found in control reach and enhanced old channel. None in new channel.
  - Coho fry and trout in all three reaches, but numbers in the new channel were far higher than in the others for both coho and trout.
  - Coho smolts most abundant in the old channel.
  - Relatively few sculpin, especially in old and new channels; most common in control reach.
  - Redside shiners observed for the only time.
- Observations from post-project surveys in July 2013:
  - No Chinook juveniles observed – notable because they were common in March 2013.
  - Coho and trout abundances were still highest in the new channel and old channel, relative to the control reach.
  - Abundance and diversity of non-salmonids was low, relative to previous years.

Over the period of record, eleven fish species have been observed in the vicinity of the project site, including a positively-identified bull trout (*Salvelinus confluentus*). Up to eight species were observed in some samples in the old channel and the control; the most number of species observed in any one sample in the new channel was four.

Photo 1. Juvenile salmonids (coho and Chinook salmon) using the new channel at the Lower Boise Project site (April 4, 2014).

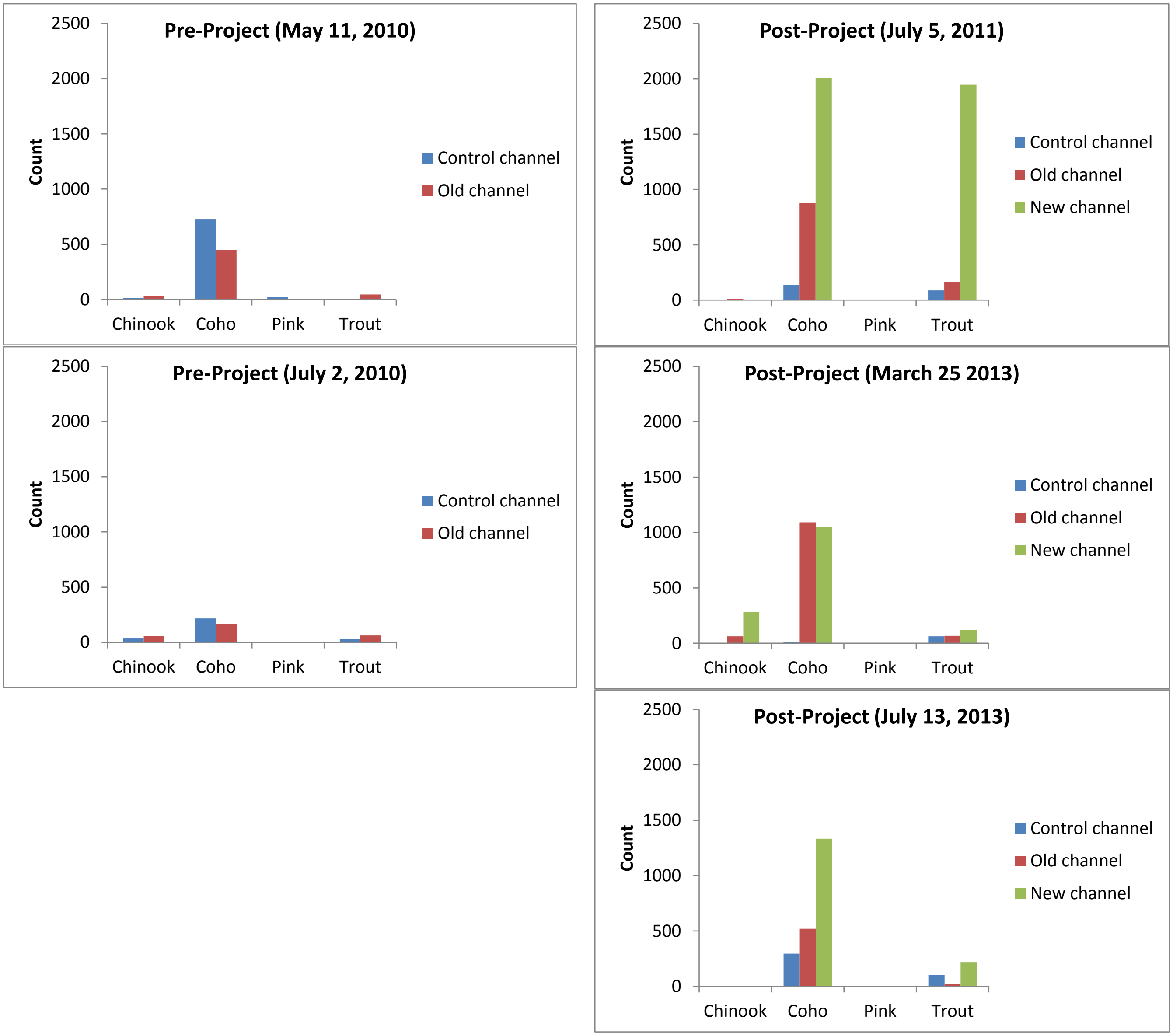


Figure 6. Fish tallies (salmonids only, not including whitefish or char), by location and year.

<u>Results of habitat surveys (July 2013):</u>

- The new channel was 2.5 meters wider than the control reach but the wetted channel was similar in depth (Table 9).
- By comparison, the new channel contained more pool area and less riffle habitat than the control reach.
- One-third of the wetted area in the new channel contained pools, and nearly half of the area (48%) was faster-moving water in the form of riffles, riffle-rapids, or rapids.
- The control reach contained only 13% pool area.
- The new channel contained approximately twice as many pools as the control reach (7 vs. 3) and the average residual pool depth was three times greater than that of the control reach.
- The stream substrate of the new channel was dominated by gravels (53%), in contrast with the control reach, where cobbles dominated and only 12% of the reach contained gravels. The old channel was dominated by sand, with 38% gravels.

Photo 2. Juvenile coho (fry and smolt) and trout at the Lower Boise project site on May 15 2013.

Indicator 3b) Pool: riffle ratio

- On March 25, 2013, pool:riffle ratios, by area, were **nearly equal** in the control and in the new channel. The ratio in the old channel was highest (Table 9).
    - New channel: **0.16**
    - Old channel: **0.42**
    - Control: **0.18**
- In July 13, 2013, the pool:riffle ratios (by area) were **3.9 times greater** in the new channel than in the control:
    - New channel: **0.63**
    - Old channel: No pools that that had sufficient residual depth to qualify.
    - Control: **0.16**

Indicator 3c) Residual pool depth

- On May 25, 2013, residual pool depth was estimated to be **0.5** meters in the control, and in the new and old channels (Table 9).
- In July 13, 2013, the residual pool depth was **four times** greater in the new channel than in the control reach. Pools were not recorded in the old channel.

Indicator 3d) Stream temperature

In 2011, maximum temperatures in the new channel were reached in early July, prior to the installation of a flow diversions (installed July 12 and 13, enlarged on July 27 and August 11 by Puyallup fisheries staff) and shade cloth (installed July 25^{h} and 26; removed September 15).

- INLET 1: Incoming stream temperatures first reached the annual maximum of 17 C^{o} on July 30 (Fig. 7; Table 11). The inlet logger was improperly launched on August 11th, so no temperatures were recorded until September 13th. The logger malfunctioned on September 15th and stopped recording.

- MIDDLE: The middle of the new channel reached a peak of 25 C° on July 10, after discharge dropped to very low levels and disconnected the new channel from surface flows (Fig. 7). On that day, temperatures in the new channel were 11 C° warmer than that of the incoming water measured at Inlet 1. The flows cut off on or around July 5th. Max daily temperatures at that location ranged from 21 to 25 C° for a week (July 5-12th), until the first small diversion was installed, which reduced the temperatures to match the incoming water (12 C°). The logger was stolen sometime after September 13, so measurements from after that date were lost.

- OUTLET: The outlet of the channel remained cooler than the middle, owing to hyporheic upwelling, which brought cooler water to the surface (Fig. 7). Peak temperature reached 22 C° on July 6th, which was 7 C° warmer than incoming temperatures at Inlet 1. The flow diversion successfully lowered the temperature at this location, as well. However, temperatures reached 20 C° on July 24th (3 C° warmer than incoming), owing to very hot weather, low flows, and a total lack of shade (i.e., air temperature was 28 C° (82 F°) at Sea-Tac). One day later, shade cloth was installed over the entire wetted portion of the new channel, and the diversion was expanded at the same time. As a result of those two actions, heat gain through the new channel was limited to less than 1 C°, thereafter.

- OLD CHANNEL: Peak annual temperatures were not recorded in the old channel because the logger was improperly launched. It began recording on July 26th.

Table 71. Results of water temperature monitoring by location, metric, and year. Max gain is measured as the magnitude of the temperature increase from Inlet 1 or 2 to the other locations throughout the site. Asterisk on old channel values indicates the dataset is incomplete.

Location	Name	Max Temp C°			Max gain C°			7DADMAX C°		
		2011	2012	2013	2011	2012	2013	2011	2012	2013
Control reach	Inlet 1	17	19	19	-	-	-	16	18	18
	Inlet 2	-	-	19	-	-	-	-	-	19
New channel	Middle	25	19	19	11	0.8	0.3	23	18	19
	Outlet	22	20	19	8	0.6	0.4	21	19	19
Old channel	Old channel	17*	15	-	-1*	-2.1	-	17*	13	19

In 2012, loggers were deployed on June 27, one day after a large sandbag flow diversion was built across the entrance of the old channel and covered with visqueen. The diversion ensured flows were concentrated in the new channel, and no disconnections occurred. No shade cloth was deployed. Maximum temperatures were reached in early August. Temperatures were nearly identical among loggers at the inlet and throughout the new channel; the old channel, which was fed primarily by hyporheic upwelling all summer, was much colder than the rest of the site (Table 11; Fig. 7).

- INLET 1: Incoming water temperature peaked at 19 C° for the first time on August 5, when flows were at 14 cfs. The logger was removed on September 19. The 7DADMAX of 18 C° was reached on August 12.

- MIDDLE: The middle of the new channel reached the maximum annual temperature of 19 C° on August 5, the same day as the incoming temperature peaked. On this day, heat gain was 0.2 C° from the inlet to the middle of the channel. Maximum heat gain 0.8 C° was observed on August 3rd, when flows were at 14 cfs. The 7DADMAX of 18 C° was reached on August 4.

- OUTLET: Temperature peaked at 20 C° for the first time, on August 5. The heat gain on that day was 0.5 C° warmer than the incoming water temperature (Inlet 1). The 7DADMAX of 19 C° was reached on August 13.

- OLD CHANNEL: The logger at this location was placed too high (owing to high flows on the day it was installed) and it went dry repeatedly from June 28 to July 12. The logger was relocated and resumed measuring water temperature on August 2. The maximum temperature was recorded that same day at 15 C^o, which was 2 C^o colder than the incoming water temperature measured at Inlet 1. The 7DADMAX of 13 C^o occurred on August 6. The temperature in the old channel dropped to 11 C^o on August 11 and remained at that level through September 19; averaging 5 C^o cooler than the temperatures at Inlet 1.

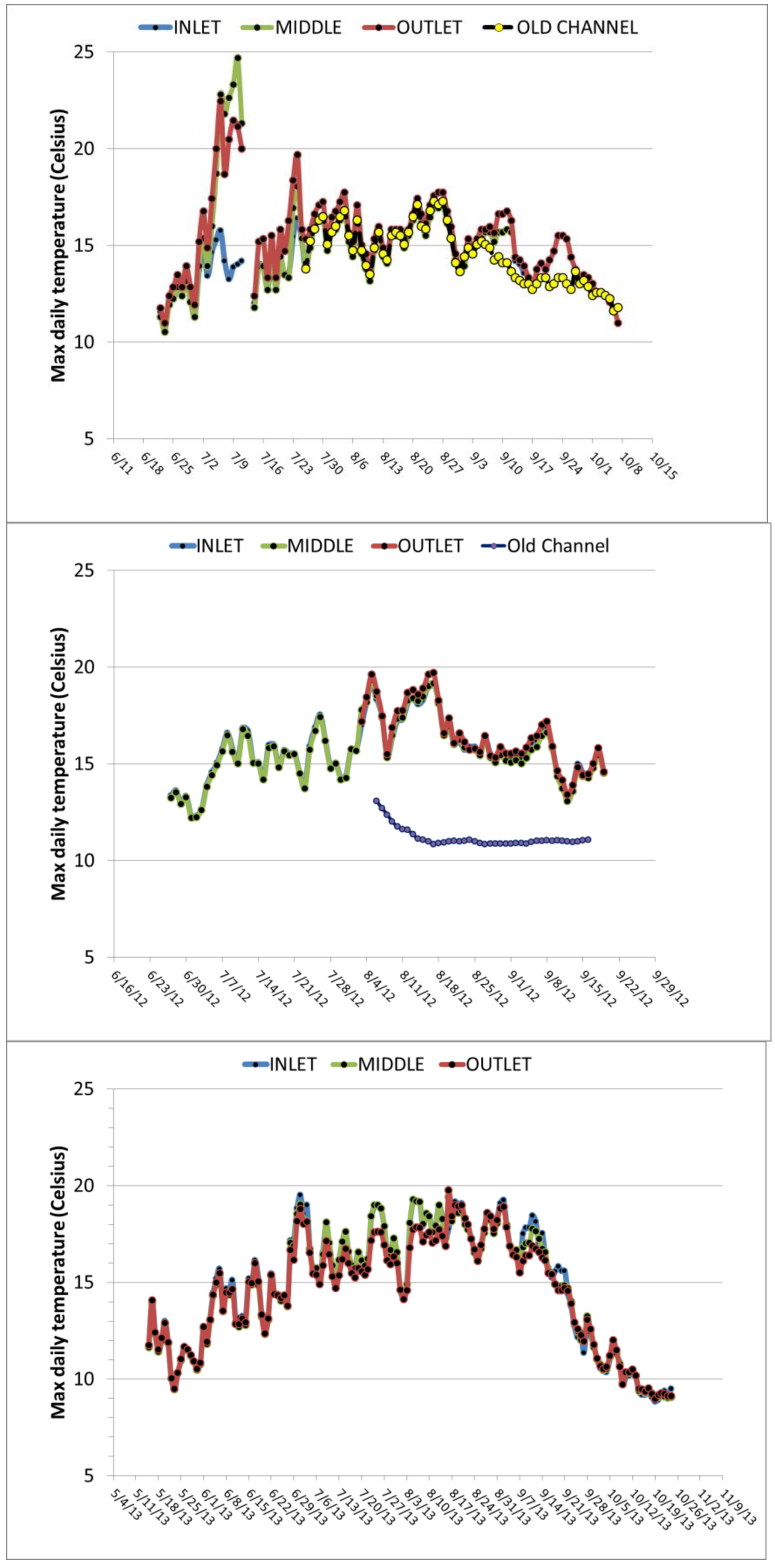
In 2013, loggers were deployed on May 15, including an extra logger in the control reach (Inlet 2). A sandbag flow diversion was installed on June 5th, diverting most of the flow into the new channel once again. No shade cloth was deployed. Maximum temperatures were reached in early July, contrasting with 2012. Temperatures were nearly identical across the site, as in 2012. Beginning in July, however, the outlet of the new channel was often approximately 1 C^o cooler than the inlet or middle, presumably because of hyporheic upwelling. No temperatures were recorded in the old channel because the logger was stolen before the data was downloaded (Fig. 7; Table 11).

- INLET 1: During a site visit on August 16 this logger was found floating on the surface, as it had been for some unknown length of time. This appeared to artificially elevate temperature readings by one or two degrees, owing to sun exposure. Recorded temperatures matched Inlet 2, which was nearby upstream of the bridge, until July 1. Accordingly, only values recorded after August 16 are considered to be reliable. After that date, maximum temperatures repeated reached 19 C^o and the 7DADMAX was 18 C^o on August 20.

- INLET 2: The peak temperature of 19 C^o occurred, for the first time, on June 30, and repeatedly thereafter. The 7DADMAX was also 19 C^o, and occurred on August 7th. The logger disappeared sometime after August 16th so observations after that date were lost.

- MIDDLE: The peak temperature of 19 C^o occurred, for the first time, on June 30, same as Inlet 2. There was zero heat gain on that day between the incoming water and the middle of the new channel. The 7DADMAX was 19 C^o, and occurred on August 7. The maximum heat gain occurred on September 22, but was only 0.3 C^o.

- OUTLET: The peak temperature of 19 C^o occurred on August 18, though heat loading that day was negligible (-0.2 C^o). Maximum heat gain was 0.4 C^o, occurring on October 6. The 7DADMAX was 19 C^o - identical to the other locations – and occurred on August 18, the same as the peak temperature.



2011

2012

2013

Figure 7. Daily maximum stream temperatures measured in the control reach (INLET), middle of the new channel (MIDDLE), outlet of the new channel (OUTLET), and in the old channel (OLD CHANNEL) in the summers of 2011-2013.

Indicator 3e) Index of Benthic Integrity

- Pre-project: King County Roads Services Division sampled the stream benthos in the control reach and the old channel in 2009 and 2010; the new channel had not yet been finished and so could not be sampled (Table 12).

Table 12. BIBI scores by location and year, using methodologies of the PugetSoundStreamBenthos.org.

	Pre-Project		Post-Project		
Location	**2009**	**2010**	**2011**	**2012**	**2013**
Control reach	64.7. (Good)	26.8 (Poor)	*No sample*	27.6 (Poor)	64.0 (Good)
Old channel	51.1 (Fair)	24.9 (Poor)	56.5 (Fair)	*No sample*	48.1 (Fair)
New channel	n/a	n/a	39.2 (Poor)	29.3 (Poor)	50.1 (Fair)

- Post-project: In 2011-2013, KC DNRP staff (H. Berge, lead) sampled the stream benthos at each location that contained suitable riffles.
  - No sample was collected in the control reach in 2011, nor in the old channel in 2012 because no suitable riffles were present in those locations and years.
  - The most recent samples indicate that the benthos in the control has a higher level of integrity (i.e., is in better condition) than in either the new or old channel. *As previously noted, the B-IBI is responsive to the condition of the upstream watershed, not to local reach conditions. Accordingly, it is not considered to be a good indicator of project-mediated changes to reach-scale habitat conditions. It is only being reported here to document that this work was done.*

Objective 4: Establish a riparian buffer of native vegetation along each side of the channel that averages at least 150 feet wide.

Indicator 4a) Riparian buffer width

- The average width of continuous (planted or recruited) woody native vegetation extending from right bank of the channel is **135 feet** (41 m); approximately 15 feet less than the target. The widest portion is to the northern side of the project site, and buffer width narrows farther downstream.
- However, there is only a 40-foot gap between the margin of the project plantings and the existing forest area on the right bank.
- Additionally, 260 feet south of the road, along the top of berm, the plantings flank existing vegetation, which in combination establish a continuous buffer much wider than 150 feet; the project is responsible for a smaller portion of that change than along the northern boundary.

Indicator 4b) Native plant cover

EXPERIMENT 1: EFFECTS OF IRRIGATION ON SURVIVAL AND COVER OF TREES AND SHRUBS

In 2013, all of the plot markers from two plots (5WET and 6WET) east of the berm were vandalized. It was not feasible to accurately relocate the two plots, so they were discontinued, and the power of the experiment was reduced.

Tree survival by species

Irrigation had no detectable effect on tree survival by 2013, so observations from wet and dry plots were combined for analysis of survival.

- Survival was less than 80% in three tree species: Grand fir (67%), big leaf maple (78%), and Douglas fir (76%);
- Survival exceeded 80% for two species: Sitka spruce and cottonwood survival.

More trees were present in 2013 than the total number originally planted, due to a peak in alder recruitment in the prior year. Planted alders could not be distinguished from naturally-recruited trees, so alders were analyzed differently from the other tree species. Instead of survival, the ratio of alder in August 2013 to May 2011 to was calculated and reported as a 'factor of change' (Table 13).

- The number of red alder was indistinguishable (i.e., the difference between them was statistically insignificant) between wet and dry plots in 2011 ($p = 0.63$; *t*-test) and in 2013 ($p = 0.84$; *t*-test), as were the factors of change from 2011 to 2013.
- All plots contained at least three times the amount of alder that was planted and observed in 2011. On average, the DRY plots had 10.3 times the amount and WET plots had 7.5 times the amount as observed in May 2011. Expressed as a percent change, the number of alder increased by 924% in dry plots and by 646% in wet plots, on average.

Table 8. Changes in red alder (only) quantities from May 2011 to August 2013.

Treatment	Plot	May 2011	Aug 2013	Factor of change	Percent change
Dry	1	6	25	4.2	317%
	2	6	43	7.2	617%
	3	4	65	16.3	1,525%
	4	6	22	3.7	267%
	5	2	53	26.5	2550%
	6	3	11	3.7	267%
Wet	1	4	57	14.3	1,325%
	2	6	32	5.3	433%
	3	4	29	7.3	625%
	4	6	18	3.0	200%

Alder recruitment peaked in 2012, and though the majority of recruits observed in 2012 died by 2013, quantities stayed well above what was originally installed (Figure 8). The average number of alders across the pooled plots was slightly higher in the DRY plots than WET plots (Figure 9), though this difference was small enough to be attributable to chance instead of the treatment.

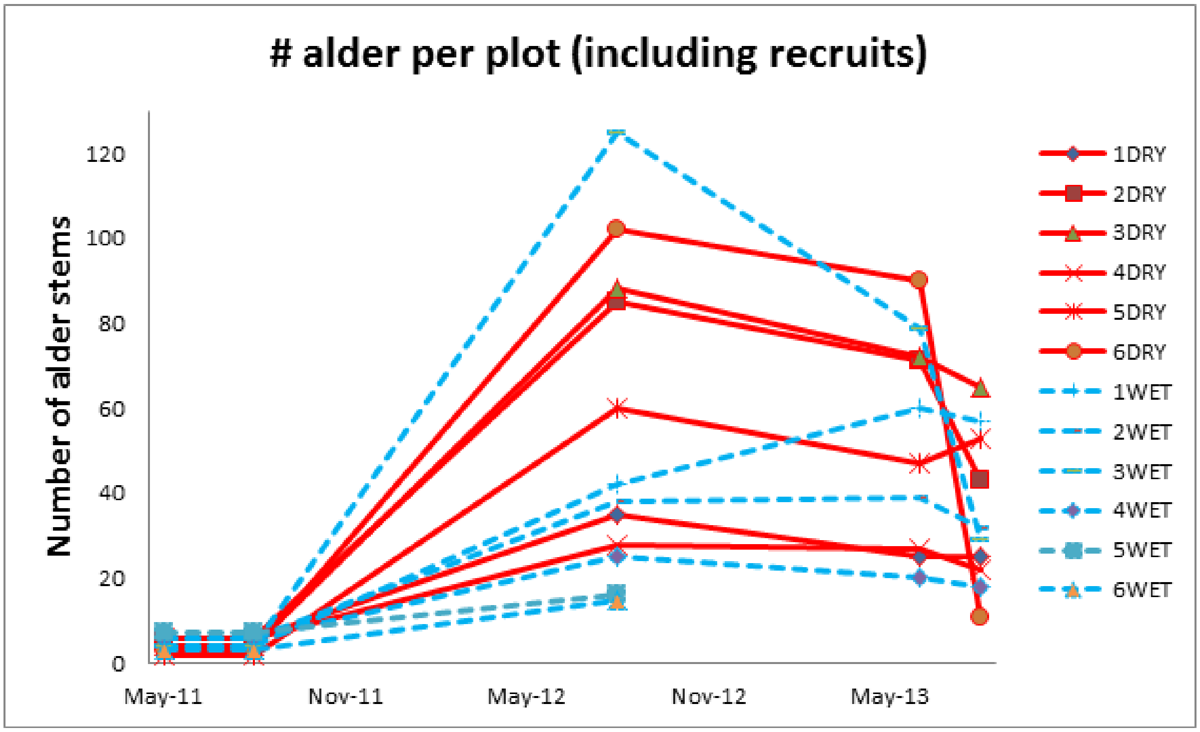


Figure 8. Changes in the number of alder stems in each plot over time by 2013.

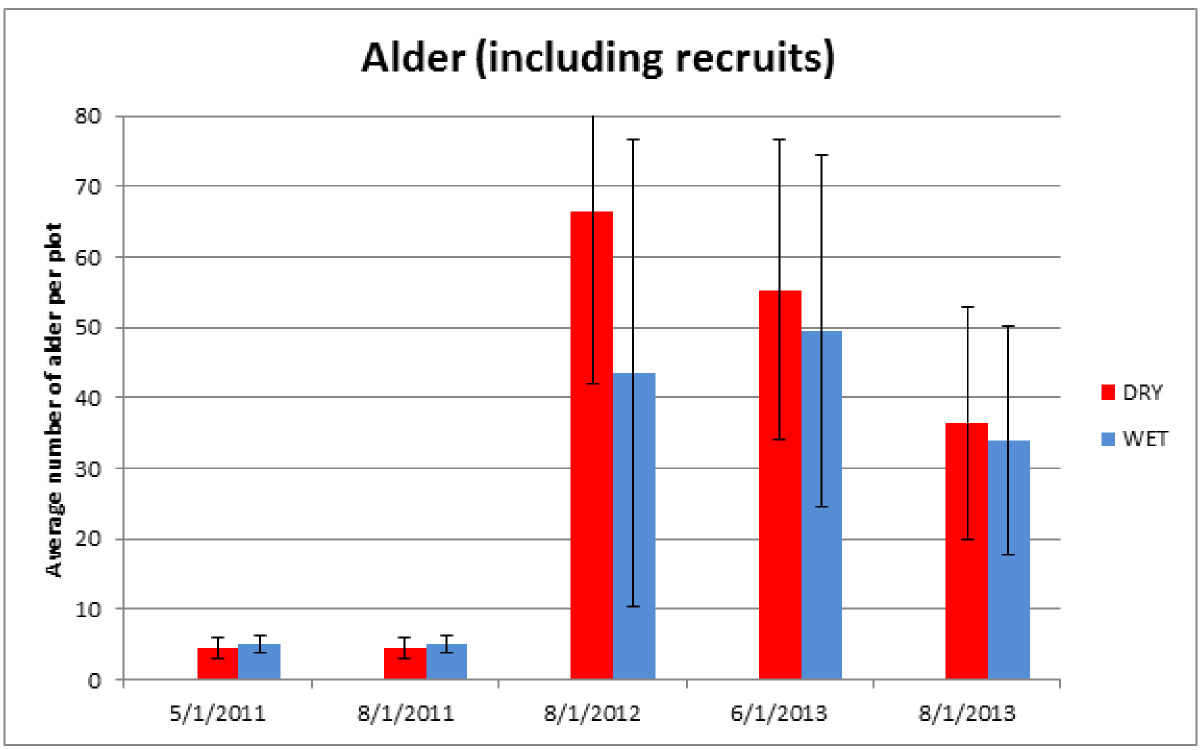


Figure 9. Average number of alder stems per plot by treatment by 2013. Error bars represent 95% confidence intervals.

The average factor of change for other trees (excluding alder) was 1.1 for DRY plots and 1.0 for WET plots (Table 14). The total number of trees exceeded that which was planted, and is attributed to naturally-recruited cottonwood (Figure 10). The number of tree (non-alder) stems was tallied per sample plot in May and August 2011, August 2012, and June and August 2013 (Figure 10).

Table 9. Changes in tree quantities (excluding alder) from May 2011 to August 2013.

Treatment	Plot	May 2011	Aug 2013	Factor of change
Dry	1	9	8	0.9
	2	12	12	1.0
	3	14	16	1.1
	4	9	18	2.0
	5	15	13	0.9
	6	16	12	0.8
Wet	1	9	8	0.9
	2	8	7	0.9
	3	16	23	1.4
	4	9	8	0.9

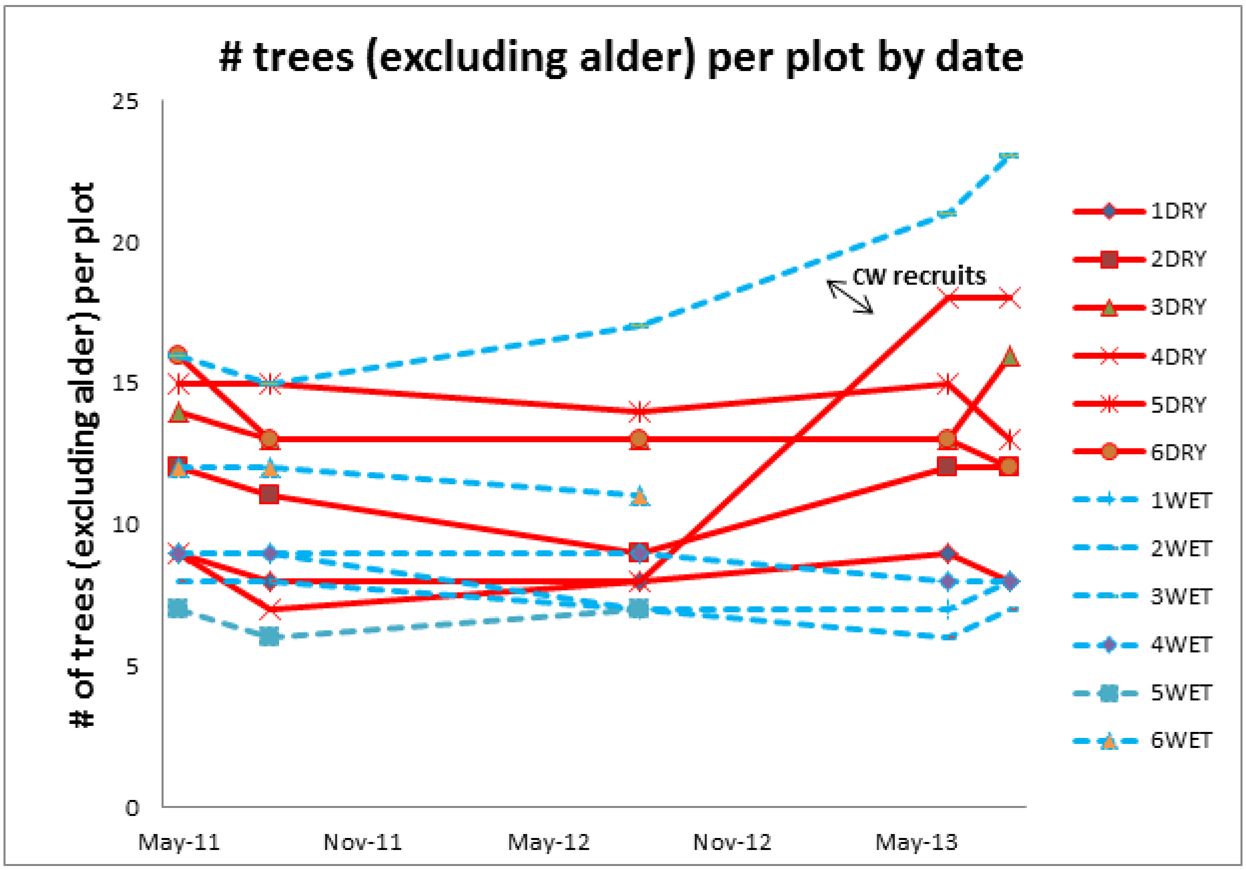


Figure 10. Number of trees (excluding red alder) per plot and treatment by 2013.

The survival of native trees (excluding alder) was indistinguishable between wet (irrigated) and dry (non-irrigated) plots in all monitoring years (Figure 11). Species-specific responses to irrigation could not be evaluated because there was insufficient room at the site to establish large plots with many more trees of each species.

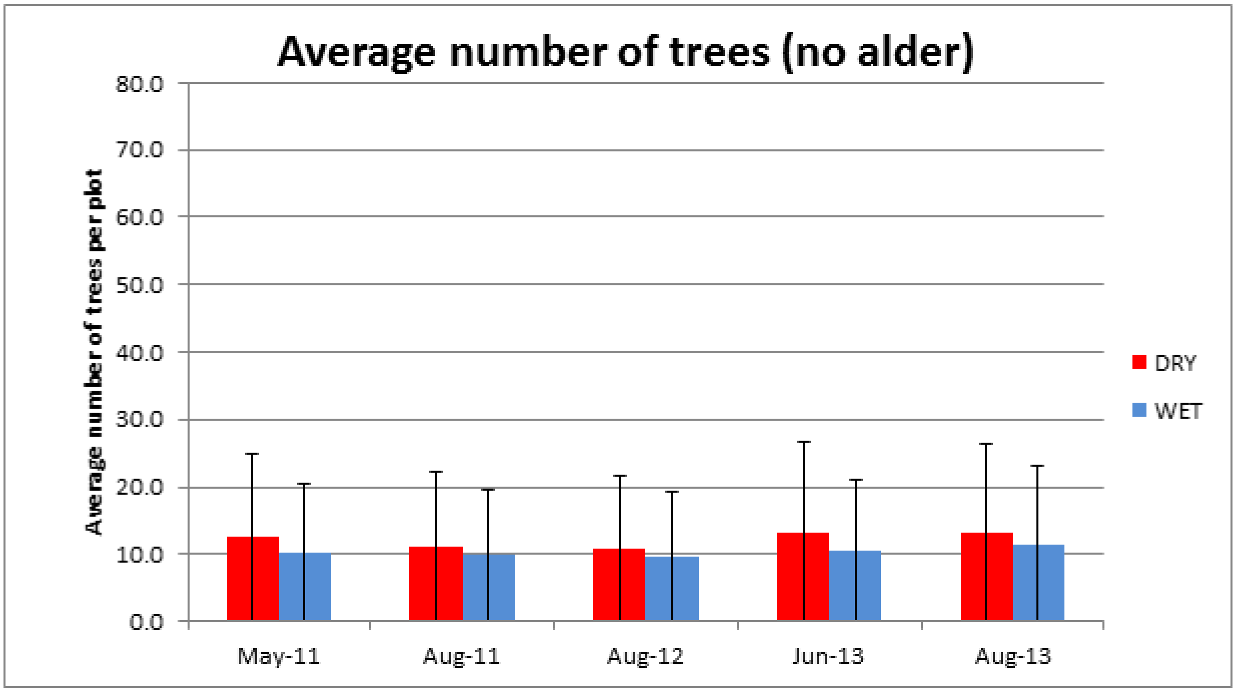


Figure 11. Average number of trees (excluding red alder) by treatment by 2013. Error bars represent 95% confidence intervals.

- *Fail to reject null hypothesis 2 for trees:*
    - Survival of native trees is the same between wet (irrigated) and dry (non-irrigated) plots because bark mulch helps to retain sufficient moisture in the soil to promote plant development during the period of observation. *(Irrigation has no effect.)*

Each study plot was numerically dominated by black cottonwood (all bareroot), red alder (36% bareroot, 64% potted), and big leaf maple (potted). In the initial survey (May 2011) prior to irrigation, all of the trees were alive, but three big leaf maples (8%) were stressed.

<u>Shrub survival by species:</u>
Irrigation had no detectable effect on shrub survival in 2013, which averaged 84% in both dry and wet plots. Wet plots consistently contained more shrubs on average, but that is attributable to a slight difference in planting density, not to treatments effects (Figure 12).

- Survival was less than 80% for three species: oceanspray (38%), thimbleberry (74%) and Scouler's willow (69%).
- Survival exceeded 80% in beaked hazelnut, Nootka rose, Sitka willow, and snowberry. Of the shrubs, Nootka rose showed the most growth and spread.

The number of shrubs was tallied in May and August 2011, August 2012, and June and August 2013 (Figure 13).

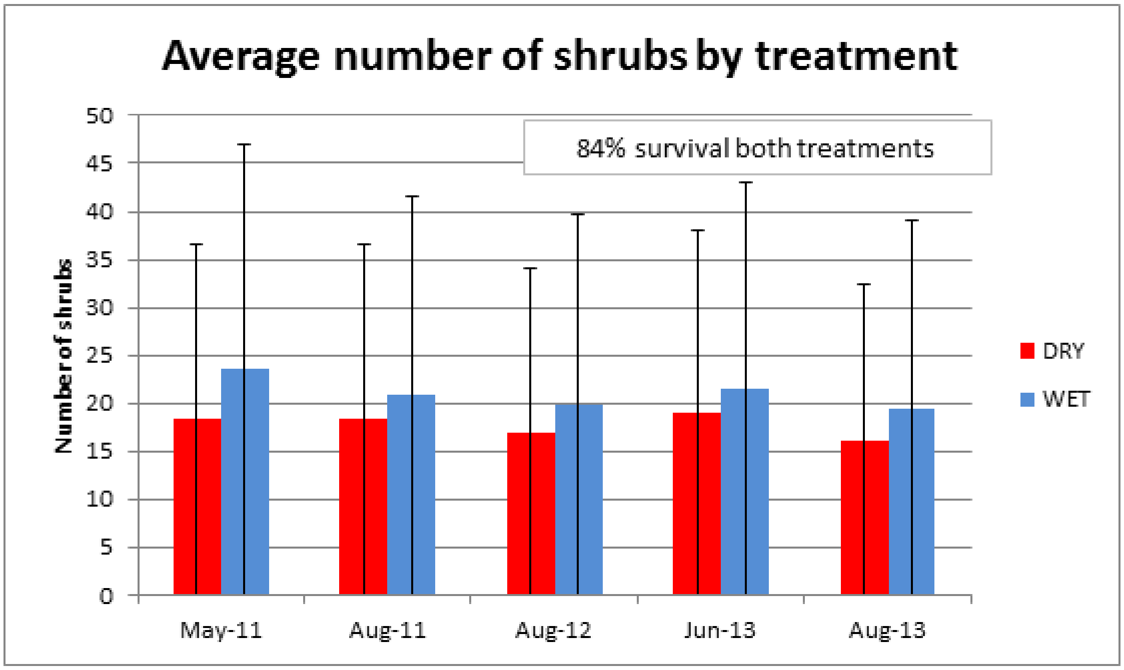


Figure 126. Number of shrubs by treatment, 2011 and 2013. Error bars represent 95% confidence intervals. Note that bars and error lines represent shrub numbers, not survival rates.

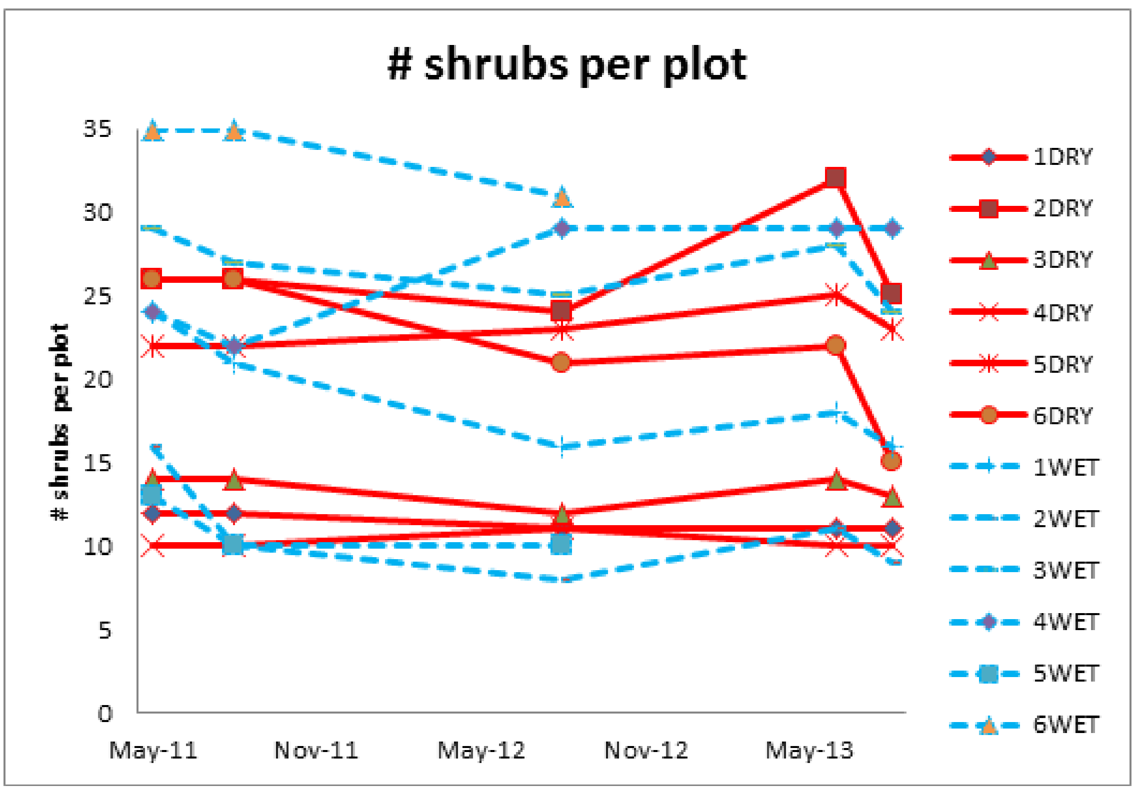


Figure 13. Number of shrubs per plot by treatment by 2013.

- *Fail to reject null hypothesis 2 for shrubs.*
  - Survival of native shrubs is the same between wet (irrigated) and dry (non-irrigated) plots because bark mulch helps to retain sufficient moisture in the soil to promote plant development during the period of observation. *(Irrigation has no effect.)*

Most shrubs were Western hazelnut or snowberry. As with the trees, species-specific effects of irrigation could not be evaluated on such a small site.

Representative photos of the site are included in the Appendix at the end of this document. Photopoints include Photopoint 1 (downstream to upstream) and Photopoint 12 (upstream to downstream). Vegetation plot photos include the irrigation study (Plot05DRY) and the natural regeneration study (Plot10REGEN).

EXPERIMENT 2: EFFECTS OF MULCH ON NATURAL TREE RECRUITMENT AND HERBACEOUS COVER

Woody vegetation

Although mulch clearly inhibited the occurrence (i.e., presence/absence) of alder seedlings in 2011, by 2013 that effect was no longer apparent (p=0.43; ordinal regression). A larger proportion of the bare plots contained alder (57%), and the average density was slightly higher than in mulched plots, but these differences were well within the range of what could be expected by chance, alone (Table 15).

- *Accept null hypothesis.*
    - By Year 3, native woody plants establish at similar densities in mulched and bare (non-mulched) plots because the mulch does not prevent germination, rooting, and growth of propagules. *(Mulch has no lasting effect on natural recruitment rate of native woody plants.)*

Table 10. Summary red alder recruitment in quadrats, by treatment in 2013.

Treatment	# plots	Plots with recruited alder	Percent of total	Number of recruited alder stems	Density of recruited alder (stems/m^2)
Bare	25	14	57%	35	1.4
Mulched	26	10	38%	26	1.0

Very few black cottonwood and big leaf maple established naturally; one big leaf maple seedling was observed in each of two mulched plots, and one cottonwood was observed in each of three bare plots and one mulched plot.

Herbaceous cover

The proportion of plots with extensive herbaceous cover increased over time, so that 48 out of 51 plots contained >50% cover by Year 3. A larger proportion of bare plots had high levels of herbaceous cover than the mulched plots in all years (Figure 14).

- By Year 3 (2013), herbaceous cover exceeded 95% cover in the majority (68%) of the bare quadrats (Table 16). In contrast, only 15% of the mulched quadrats contained >95% herbaceous cover.
- The majority 54% of the mulched plots contained 51-75% herbaceous cover (Table 16), though 88% of the plots exceeded 51% herbaceous cover.

The most common herbaceous plants were grasses, horsetail, clover, vetch, soft rush, willow herb, and buttercup.

Table 16. Percent of bare and mulched plots containing various levels of herbaceous cover at Lower Boise Creek in 2013.

Treatment	Plots	Herbaceous Cover Class						
		0 to trace	<5%	6-25%	26-50%	51-75%	76-95%	>95%
Bare	25 plots	0%	0%	0%	0%	20%	12%	68%
Mulched	26 plots	0%	0%	0%	12%	54%	19%	15%

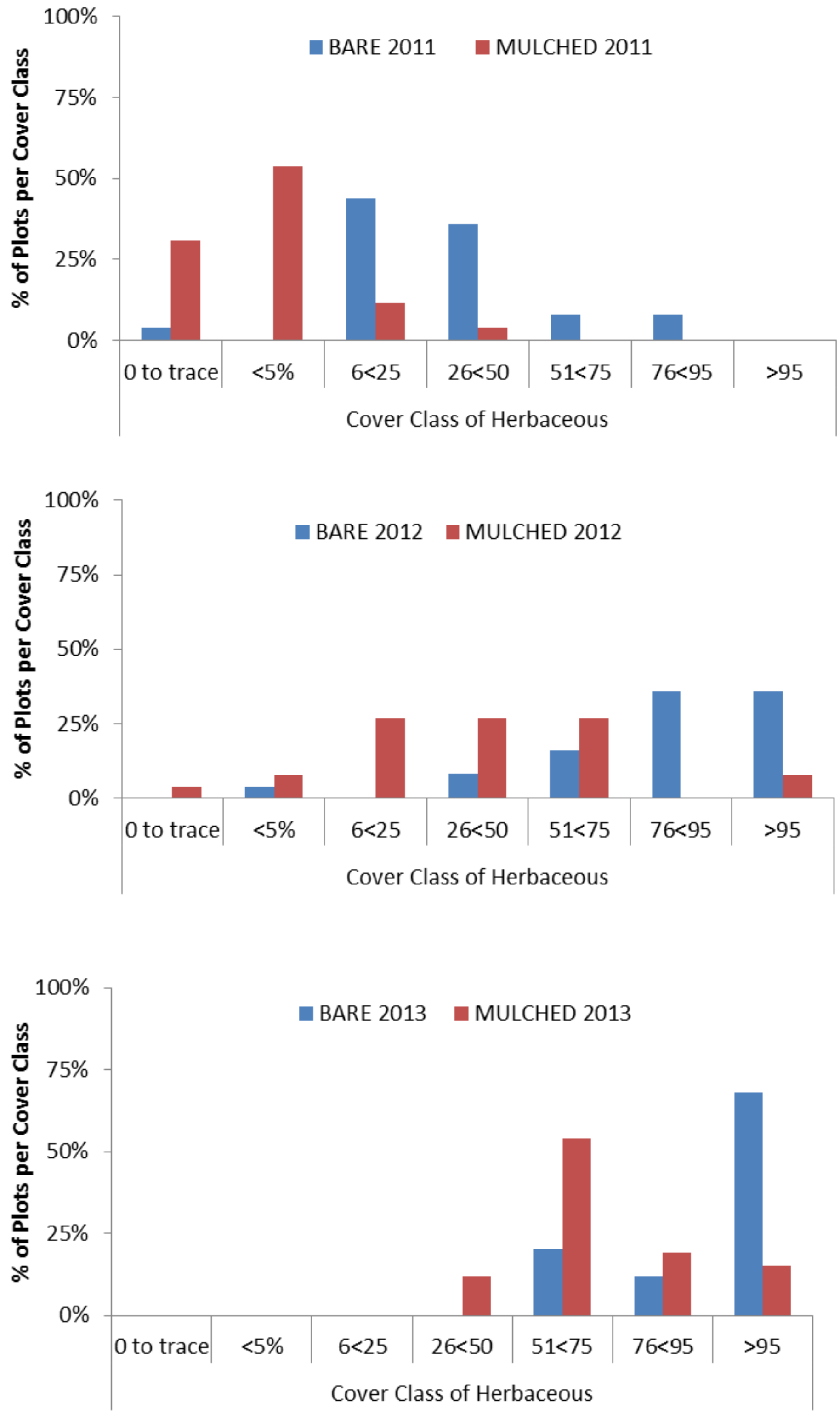


Figure 7. Herbaceous cover in bare and mulched quadrats at Lower Boise Creek, 2011-2013.

Invasive cover

Non-native species such as tansy, rabbit-tail clover, Himalayan blackberry, and reed canary grass were also observed.

- Blackberry was absent or only at trace levels in most of the mulched and bare quadrats (Table 17).
- The percentage of plots containing either <5% or 6-25% blackberry cover was greater in bare plots than in mulched plots.

There was no increased in blackberry cover in bare plots from 2011 to 2013. But more mulched plots were observed to contain <5% blackberry cover than in 2011. No quadrats had >25% blackberry cover, regardless of treatment, in any year. Reed canary grass was present in four bare plots and two mulched plots, but only at low levels (<10% cover). In 2013, 13 tansies were observed to be distributed among five bare plots and one tansy occurred in a mulched plot.

Table 117. Blackberry cover in bare and mulched quadrats at Lower Boise Creek in 2013.

Treatment	Cover Class							Plots
	0 to trace	<5%	6-25%	26-50%	51-75%	76-95%	>95%	
Bare	64%	28%	8%	0%	0%	0%	0%	25 plots
Mulched	73%	27%	0%	0%	0%	0%	0%	26 plots

Although mulch inhibited blackberry invasion and constrained herbaceous cover at this site in 2011, these benefits appear to have ended by Year 3.

- Fail to reject null hypothesis by Year 3.
  - Herbaceous/invasive plants establish at similar rates in mulched and bare plots because mulch does not prevent growth. *(Mulch has no lasting effect on herbaceous plant establishment).*

Objective 5: Provide fish passage at low flows.

Indicator 5a) Incidence of passage barriers

On or around July 5, 2011, water stopped flowing into the new channel; the elevation at the inlet to the old channel was lower and so it captured all of the discharge (Photo 3). Flows at that time were 16 to 17 cfs at Buckley (USGS 112099600). Many residual pools remained in the new channel, but temporarily became very warm and exceeded acute levels for steelhead fry and parr. As a consequence some steelhead redds were likely de-watered and juvenile salmonids that could not disperse and evacuate unsuitable habitats may have died.

Photo 3. View looking downstream in the new channel on July 14, 2011, approximately one week after a small diversion had restored some flow to the channel.

This unanticipated outcome triggered emergency actions to modify flow in 2011:

- July 6 KC excavated a small channel to allow some flow into the new channel.
- July 12/13, this channel was enlarged by PTF.
- July 27/August 11 PTF filled burlap sandbags provided by KC with stream gravels and placed them across the inlet to the old channel, forming an emergency flow diversion (Photo 4).
- August 23, KC relocated one to three cubic yards of gravel from the new channel into the old channel behind the upper logjam and placed brush and branches in front of the jam, in hopes of sealing off the jam during winter floods.

Photo 4. Flow diversion structure built by Puyallup Tribal Fisheries, with KC support. Photo taken September 12, 2011. Flow is moving from left to right, then toward the bottom of the picture. Diversion is visible on the right.

In 2012, the old channel thalweg remained lower in elevation than the new channel by approximately 0.5 m, so on June 26, a new flow diversion was installed after consultation with stakeholders and the KC design team (Photo 5). This diversion was more robust than in 2011, built from five hundred burlap sacks filled with pea gravel and covered with 6-mil plastic. It was effective at channeling the majority of flow into the new channel without de-watering the old channel, so that both areas provided optimal habitat value. The plastic was removed prior to winter floods, the burlap sacks disintegrated, and gravel was released into Boise Creek.

Photo 5. The 2012 flow diversion (left) routing discharge into the new channel (right).

In 2013, the old channel was still lower in elevation, so the flow diversion was re-installed, again after extensive consultation (Photo 6). This diversion was built in a similar fashion (on June 5, 2013) as in 2012, except that 700 bags were used and no plastic covering was applied. In addition, the entire structure was covered with branches and small woody material to provide camouflage, improved habitat value, and to prevent vandalism. Once again, it was effective and aquatic habitat in both channels was sustained.

Photo 6. The 2013 flow diversion (left) covered in woody material. The image was taken on June 5.

These actions were considered to be consistent with the project goal of providing habitat for fish and wildlife, and the objective of providing fish passage at low flows. The actions were also justified by the conclusion that the new channel could be functioning like an ecological trap, in which fish were disproportionately attracted to the high-quality habitat it provided, but in doing so, exposed themselves (or their progeny) to an artificially-elevated risk. Specifically, the constructed channel was going dry and getting too warm more frequently than a naturally-formed channel with established riparian forests. It became clear that having two channels at different elevations poses a challenge in Boise Creek, owing to the occurrence of low flows in spring and early summer during the period in which steelhead embryos and sac fry are sessile and can't disperse in response to declining flows and excessive temperatures.

In hopes of addressing this recurring problem, an adaptive management action was initially proposed for summer 2013; a plug of gravel, large wood, and slash would be placed in the upstream end of the new channel to better replicate natural conditions following an avulsion event on an alluvial fan, and more permanently divert low flows into the new channel. Permits from USACE were not granted in 2013, so the work was postponed until August 2014. We continued to stay in close contact with co-managers to adaptively manage the site.

In 2014, the key logs at the inlet to the new channel recruited a large amount of small woody material, including numerous willow shrubs. Over the course of numerous high flow events, this material formed a channel spanning jam that trapped a large upstream wedge of fine sediments and branches. The jam diverted approximately 95% of the discharge into the old channel. This posed an obstacle to the planned adaptive management action in the old channel, which would push 100% of the discharge back into the new channel. Co-managers (Puyallup Tribe, Muckleshoot Tribe, and WDFW) unanimously considered the three to four-foot tall jam to be sufficiently high and sealed from the upstream side so as to constitute a likely (>70% chance) passage barrier to upstream-migrating steelhead and salmon (*pers. comm.* M. Fox, R. Ladley, and L. Fisher). Although fish could swim upstream through the old channel as of March 2014, it would eventually be plugged by fine debris and sediments, and fish would have to contend with the logjam in the new channel.

The WDFW Area Habitat Biologist indicated that an enforcement action might be required if KC did not remove woody material accumulated on the logjam to improve passage. In direct response, staff from KC, Puyallup Tribal Fisheries, and Muckleshoot Tribal Fisheries modified the logjam on March 25th, 2014, just prior to the beginning of steelhead spawning season (Photo 7). Removal of small woody material and willow shrubs allowed the river to dismantle most of the jam, transport it to the next jam downstream, and to wash away the accumulated sediment wedge. As a result, the new channel headcut and captured virtually 100% of the discharge. The WDFW Area Habitat Biologist requested that one of the key logs be relocated to prevent an impassable jam from forming again in the future, but the Muckleshoot and Puyallup biologists did not endorse that strategy at this time, preferring to wait and monitor changes. Accordingly, KC is maintaining the structure as it currently exists, and plans to respond quickly to future changes as needed. If the log appears to cause a recurring problem, further action may be taken to reduce the need for ongoing maintenance.

BEFORE

AFTER

Photo 7. Channel-spanning logjam shown before and after modification to improve passage for adult steelhead and salmon, as unanimously directed by co-managers (WDFW, PIT, MIT).

Objective 6: Reduce velocities during bankfull flow and re-establish desirable spawning substrate.

Indicator 6a) Redd density

Redd densities at the project site have increased over pre-project conditions.

- Prior to the project, salmon and steelhead redds were not documented[5] in the project reach, but now Chinook salmon (Photo 8), steelhead trout (Photo 9), coho salmon, and pink salmon (Photo 10) consistently spawn at the project site (Table 18).
- In 2010 and 2012, three to 20% of the Chinook redds in Boise Creek occurred at the project site.
- Most of the Chinook redds had been constructed by September 20th.

Table 18. Salmonid redd counts observed by Puyallup Tribal Fisheries before (2008-2009) and after (2010-2013) the project in the project site (RM 0-0.2) and the watershed (RM 0-4.5) (Marks et al. 2014[6]). Chinook redds are not reported for 2009, 2012, or 2013 because the pink salmon runs prevent accurate identification of the redds. The first post-project year for steelhead is 2011, because they are spring spawners.

		Pre-Project		Post-Project			
Species	**Location**	2008	2009	2010	2011	2012	2013
Chinook	Project site	0	-	5	-	12	-
	Watershed (RM 0-4.5)	325	-	184	-	60	-
	Percent of total	0%	-	3%	-	20%	-
Steelhead	Project site	0	0	0	6	4	2
	Watershed (RM 0-4.5)	29	25	52	43	24	35
	Percent of total	0%	0%	0%	14%	17%	6%

- Numerous salmonids have been observed spawning in the project site, including Chinook, coho, and pink salmon, as well as steelhead trout.

[5] H. Berge reports seeing steelhead redds in the old channel prior to the project (*pers. comm*. 5/20/214).

[6] Marks, E. L., R.C. Ladley, B.E. Smith, A.G. Berger, J.A. Paul, T.G. Sebastian and K. Williamson. 2014. 2013-2014 Annual Salmon, Steelhead, and Bull Trout Report: Puyallup/White River Watershed--Water Resource Inventory Area 10. Puyallup Tribal Fisheries, Puyallup, WA. http://files.nwifc.org/tribaltechreports/

Photo 8. Female Chinook salmon digging a redd at Lower Boise project site on Sept 25, 2012. In total, 12 Chinook redds were established at the project site in that year.

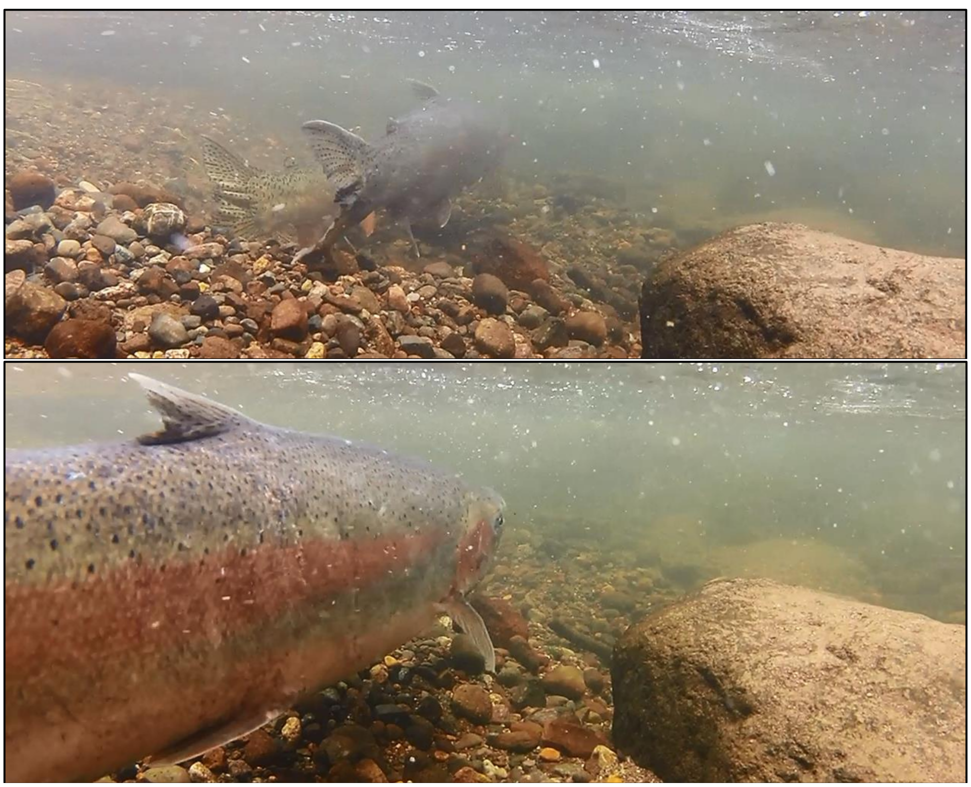


Photo 9. Pair of adult steelhead on a freshly-constructed redd in the Lower Boise Project site on May 15, 2013; one of two created at the project site in that year.

Photo 10. Spawning pink salmon pair at the Lower Boise Project site on September 9, 2013. The number of pink salmon redds has not been estimated for Boise Creek in any years, though they numbered over 100,000 in Boise Creek in 2009 (280,000 were counted; over 6200 per mile; just over one fish per linear foot of stream). Fewer were seen in 2011 and 2013.

Objective 7 (Mitigation): Create two large wood structures that create a quiescent zone and function to provide year-round rearing habitat for fish.

Indicator 7a) Summary of conditions of the mitigation site

Logjams installed at the mitigation site are intact and performing as intended. Scour holes have formed underneath or downstream of each structure. Additional small and large wood has accumulated on each structure. The structures are helping to trap gravel bedload and shape the new streambed.

Indicator 7b) A list of the fish species observed during the monitoring visit.

Juvenile salmonids have been observed using the instream habitats created by Structures 5 and 6 (Photo 11). These fish have been observed with snorkel surveys and incidental underwater video surveys. Adult salmon have also been observed using the associated habitat for resting, migration, or spawning, including Chinook salmon, pink salmon, and coho salmon (Photo 12).

Photo 3. Juvenile salmonids (mostly coho – darks shapes below the log near the streambed) using Structure 6.

Photo 4. Adult coho salmon holding in pool habitat created by Structure 5.

Indicator 7c) A quantification of the area of in-channel habitat created by Structures 5 and 6.

Structures 5 and 6 were expected to offset the loss of 1,320 square feet of potential rearing habitat and the temporal loss of large wood recruitment. Analysis of the two structures using the methodology described in the mitigation memorandum suggests that the total area of quiescent zone created by the structure exceeds 10,400 square feet, which exceeds the minimum expectations set forth in the memo (i.e., 2,820 square feet) (Fig. 14).

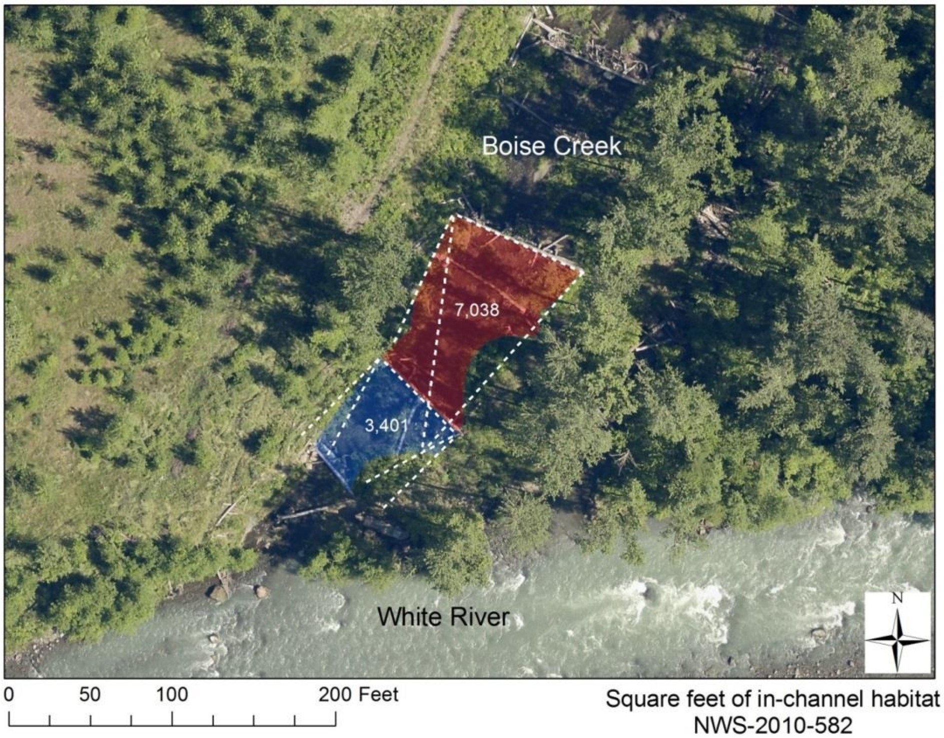


Figure 14. Quantification of in-stream habitat area (annotated in square feet; red denotes Structure 5 and blue denotes Structure 6) using hydraulic shadow methodology (reference lines and angles in white). The aerial photo was taken in summer 2013.

Indicator 7d) A summary of the habitat functions being provided by Structures 5 and 6.

- Structures are performing the following habitat functions:
  - Trapping woody material and creating larger logjams.
  - Dissipating hydraulic energy and creating scour pools that provide holding and resting habitat for migrating adults
  - Creating complex, slow-moving edge habitat in close proximity to overhead cover and submerged wood with interstitial spaces.
  - Trapping sediment upstream and contribute to the formation of downstream bars in their lee, as well.
- Geomorphic change has been progressing from the upstream end of the site toward the downstream end of the site and is expected to have an increasing, positive effect on the complexity (pool depth, edge length, hydraulic complexity and slow water habitat) of the mitigation area over time, but may reduce overall pool area.

Indicator 7e) Photo reference points for Structures 5 and 6.

Structure	2012	2013
5		
6		

Figure 15. Aerial photo reference points for Structures 5 and 6, showing conditions in 2012 and 2013.

Contaminants

- In 2011, arsenic, chromium and copper concentrations did not exceed chronic and acute surface water criteria in 2009 or 2011 (Table 19).
- Contaminants of concern (COC) have not increased in the Boise Creek project reach since construction finished.
- Water quality values were acceptable; roughly one-third the legal standard, or equivalent to background[7]. Fish olfactory impacts from copper are thought to occur within background levels (0.5 to 2.0 ug/L). However, the salmon returned for spawning and showed normal behavior with no evidence of chemical impairment.
- The 1.6 ug/L copper concentration value at the downstream end may indicate slight inputs of higher copper from groundwater, but may be a result from the changes in bed material. The increase is small and analytically impossible to trace it to a cause, and is likely a natural condition.
- No further water quality testing is suggested unless the channel cuts into un-remediated soils outside of the project area. Accordingly, contaminant monitoring was discontinued in 2011.

Table 12. Boise Creek water quality sample results (ug/L) from prior to (11/13/2009) and after (5/26/2011) the project, relative to U.S. Environmental Protection Agency's (EPA) chronic/acute thresholds based on hardness (standards).

COC	Chronic/Acute Stds	Pre-project	Post-project (sample 1 upstream)	Post-project (sample 2 upstream)	Post-project (sample 3 downstream)	Post-project (sample 4 downstream)
Arsenic	190/360	0.34	0.29	0.29	0.33	0.32
Chromium	69/213	0.29	0.23	0.24	0.25	0.24
Copper*	3.62/4.83	1.6	1.2	1.2	1.4	1.6

*Copper standards based on hardness of 26.3 mg/L.

[7] KCEL results reviewed by R. Jack, KC DNRP WLRD WQQ

VI. Maintenance

The project site has been intensively maintained each year since 2010. Actions include additional plantings, irrigation, flow and temperature management with shade cloth and temporary diversion, gate repair and replacement, and logjam modification (Table 20).

Table 13. Maintenance log.

Year	Action	Detail
2011	Installed plants on west bench	The two-acre west bench, west of the berm, and two acres of upland were planted with native trees and shrubs in February 2011 at 5’ densities on average.
	Staked floodplain	Staked with 5-6’ long willow poles (3/4-1-1/2” diameter) at 5-6’ on center in October.
	Irrigated plantings	Plantings were watered seven times, except inside the ‘dry’ plots.
	Installed flow diversion	Small sandbag diversion was installed by Puyallup Tribe staff to maintain flowing water in new channel. Action was a response to de-watering of the new channel as flows dropped and concentrated into the old channel, which maintained a lower thalweg elevation. Allowed to disintegrate in-situ.
	Installed shade cloth	King County crews installed approximately 500 feet of shade cloth to further reduce overheating of the stream as it flowed through the new channel.
	Removed shade cloth	Shade cloth was removed prior to winter high flows.
2012	Installed flow diversion	King County crews installed flow diversion (500 burlap sacks filled with pea gravel overlain with plastic) to route flows into the new channel and prevent de-watering. Allowed to disintegrate in-situ.
	Irrigated plantings	Plantings were watered three times, except inside the ‘dry’ plots.
2013	Staked floodplain and installed plantings in upland	Staked with 5-6’ long Sitka and Pacific willow poles, and cottonwood poles (3/4-1-1/2” diameter in December. Installed 150 potted trees and shrubs in upland.
	Installed flow diversion	King County crews installed flow diversion (700 burlap sacks filled with pea gravel overlain with small woody material, no plastic) to route flows into the new channel and prevent de-watering. Allowed to disintegrate in-situ.
	Irrigated plantings	Plantings were watered two times, except inside the ‘dry’ plots.

VII. Conclusions & Recommendations

This interim (Year 3 of 5) monitoring report focuses on reporting the status of each indicator in 2013 (Table 21), on making recommendations for site maintenance, and on preliminary recommendations for future projects based on lessons learned at the Lower Boise Creek project site. The final report will contain more in-depth examinations of each indicator, draw final conclusions, judge the strength of the evidence, and make final recommendations.

Table 14. Progress toward meeting specific project goals, objectives based on the status of monitoring indicators in 2013.

Specific Goals	Stated Objectives	Indicator Status
Create an alluvial fan floodplain and allow channel to actively migrate and build terraces	Relocate existing channel and increase channel length to 600 feet (182 meters).	• 577 feet of channel added, but the length varies and is within the margin of measurement error.
	Create approximately 2 acres of alluvial fan floodplain habitat.	• Approximately one acre of floodplain added to the site by the construction of the new channel.
Provide channel roughness to scour pools and form riffles and provide habitat for fish and wildlife	Place 150 pieces of large wood to create instream habitat	• Juvenile coho and Chinook consistently more abundant in new and old channel than in control • Pools compose 30% of the new channel; more than the control. • Pool depth is greatest in the new channel. • Stream temperature in new channel reached acute levels in 2011 (11 degrees over background), but heat loading in 2012 or 2013 limited to less than one degree Celsius. • BIBI scores in new and old channel are 'fair', lower than control, which was 'good' in 2013.
	Establish a riparian buffer of native vegetation along each side of the channel that averages at least 150 feet wide (46 m).	• Buffer width averages 135 feet. • Red alder density 3 times higher than planted because of natural recruitment. • >80% survival in Sitka spruce and cottonwood • <80% survival in Grand fir, big leaf maple, and Douglas-fir.
	Provide fish passage at low flows	• New channel disconnected in July 2011 but has been connected ever since then. Logjam in new channel modified March 2013 to improve passage.
	Reduce velocities during bankfull flow and re-establish desirable spawning substrate.	• Chinook and steelhead built multiple redds in the new channel each year since completion. Between 3 and 20% of all Boise Creek Chinook redds and 6 to 17% of all steelhead redds were found in project site.
Mitigate for WSDOT White River Bridge scour project by creating new instream habitat	Create two large wood structures that create a quiescent zone and function to provide year-round rearing habitat for fish: Structure 5 (four logs): 1,470 square feet; Structure 6 (five logs): 1,350 square feet.	• Logjams stable, growing, and are performing as intended. • Juvenile salmonids and adult salmon and trout are using the created habitat. • Rearing habitat area is over 10,000 square feet. • Structures are trapping wood, dissipating energy, scouring pools, providing complex, slow-moving edge habiat and contributing to bar formation.

<u>Is the project meeting its goals and objectives?</u>

As of Year 3, the site is starting to develop a more complex channel, some floodplain features, and some characteristics of an alluvial fan (Table 21). Riparian vegetation has established substantial cover, and plantings have survived at high rates; generally over 80%. The channel is evolving in response to new inputs of stream sediments and the hydraulic complexity created by the logjams. Lateral migration has occurred in several places along the left bank of the new channel, and numerous side channels exist near the margins of the channel-spanning logjams. No terrace construction has been seen yet. Most importantly, multiple species of both juvenile and adult salmonids are in higher abundance at the site than before the project was completed, which indicates that the project is providing improved habitat. In addition, mitigation goals are being met. In spite of those successes, there were significant problems with temperature and channel de-watering in 2011. These problems were quickly resolved and carefully avoided in subsequent years.

Important lessons are emerging from our experience and may inform the design, implementation, and monitoring of future projects on Boise Creek:

- **If a new flow-through channel is excavated and the old channel is left intact and connected to discharge, consider plugging the old channel with gravel and wood or slash instead of leaving it 'as-is'**. Under natural circumstances, new channels may form when the existing channel fills in with alluvium, or is blocked by wood or sediments. As a result, the as-built condition of the project site did not closely mimic a natural occurrence. Gravels did not accumulate in the old, pre-existing channel according to expectations, in spite of experiencing multiple high flow events. Instead, most of the gravels were routed into (or deposited in) the new channel. As a result, the new channel kept plugging up and the old channel was prone to capture the low flow channel.
    - Placing logs at grade in the old channel, instead of suspended above the bed, may have prevented this from happening.
    - Bedload transport rates were likely overestimated, which serves as a reminder to design the project to be resilient to errors in technical reports – especially with respect to parameters that can't be reliably estimated.
    - In restoration projects that blend together a 'process-based' approach with the establishment of substantial amounts of new, excavated habitat, a prudent approach may be to leave the site in a condition that simulates a more natural chain of events.

- **Extend the scope of permits** (e.g., HPAs and NW27s) to cover potential maintenance actions and to extend the permit duration to cover as much of the maintenance period, including placement of fill (e.g., sandbags) and additional wood. This allows for more timely responses and is more cost-effective than applying for separate permits.

- **Use scenario-planning in advance of project implementation** to evaluate potential ecological risks (e.g., overheating, de-watering, stranding) and inform pro-active maintenance. Discuss the outcomes with stakeholders if possible, and use the results to inform the monitoring and maintenance plan.

- **Creating multiple channels in Boise Creek carries ecological risks and rewards.** The presence of steelhead, combined with a high frequency of very low discharge in the summer and fall, makes Boise Creek a risky place to use multiple channels in project design – especially if they are at similar elevations.
    - Steelhead embryos may remain in the gravel into July and August, when summer flows may reach very low levels. In combination, these factors create a strong possibility for redd de-watering if low flows abandon one or more of the channels that hosted redds.
    - Dividing the lowest discharges among multiple channels could also create upstream passage barriers that would not otherwise exist.
    - Consider these issues when making decisions about grading and the relative elevations of each channel; avoid making two or more channels with equal elevations.
    - The acceptability of such risks, relative to the potential benefits, should be evaluated through consultation with co-managers prior to finalizing project designs.

- **Set aside funding** that can be used on short-notice to mobilize responses to unaccepted project outcomes.

- **Develop monitoring and maintenance plans collaboratively** with project design teams to better anticipate potential risks and improve the timing of problem detection.

Were permit conditions met?

- NO, but amended in 2013 to exceed losses.

Three tree species did not meet the HPA's "80% survival of each species requirement." However, an additional 925 woody plants (450 trees and 475 shrubs) were planted in December 2013 to amend any losses on the site. Plants were installed outside of irrigation or recruitment study plots to avoid the potential for error in future data collection. Also, the high amount alder recruited exceeds the original number of plants installed. Monitoring will continue on schedule.

VIII. Maintenance Findings and Recommendations

Does the irrigation protocol improve the survival of mulched plantings at the project site, and if so, to what degree?

- NO for trees.
- Test was inconclusive for shrubs.

This study showed that irrigation did not improve overall tree survival. There was no indication that irrigation improved overall shrub survival, though the study had low power to detect one (β = 0.25 in 2012, less in 2013); basically, the study only had a one in four chance of detecting an irrigation effect on shrubs. The variability in shrub survival among plots suggests that other factors – besides soil moisture – are preventing some of the plants from establishing successfully. The wire strung around dry plots may have some effect on deer browsing or human trampling, but the role of these factors is unknown.

These findings mean that, from 2011- 2013, at this site, irrigation was not necessary to achieve performance standards. However, watering may have contributed to better vigor and growth = higher woody cover. Monitoring will continue to track survival and density over time to see if irrigation in the first three years has any effect over a longer time period.

Several factors may have contributed to the lack of a stronger treatment effect: a 2011 wet spring climate, topsoil amendment, and the use of hogfuel mulch. These findings should be interpreted with caution, however, as results may differ in drier springs or at sites with more droughty soils, or in sites without hogfuel mulch. These findings will contribute to the development of evidence-based guidelines on when irrigation and mulch are needed.

Does hogfuel mulch reduce natural recruitment of native woody species, specifically, red alder and black cottonwood, compared to adjacent, bare (non-mulched) areas?

- YES for alder.

In 2013, hogfuel mulch inhibited natural alder establishment, relative to bare quadrats at this site. Too few black cottonwood and big leaf maple established to test the effect of mulch. The establishment patterns at the bare quadrats suggest that red alder might have colonized roughly 56% of the berm by Year 3 if mulch had not been used. Instead, the mulched quadrats suggest about 38% of the berm was colonized.

The use of mulch may have precluded the establishment of an additional 3,000 red alder stems on the two acre berm. If red alder had established at 1.4 stems/m^2 over 56% of the berm – as was observed in the quadrats in 2013 – this would total roughly 11,000 alder stems. If alder establishment followed the example of the mulched quadrats, establishing 1.0 stems m^2 over 38% of the berm, this would total roughly 8,000 stems. This demonstrates the tradeoffs involved in applying mulch to the entire site.

Comparing the two types of study plots, the amount of alder recruitment was the same (1.0 stems/m^{-2}) after three years (2013) in both the mulched and watered plots (WET “irrigation plots” and “recruitment” plots), showing the same recruitment response across the site.

Does hogfuel mulch reduce the occurrence of herbaceous or invasive plants, compared to adjacent, bare (non-mulched) areas?

- YES.

Hogfuel mulch inhibited establishment of herbaceous and invasive plants; less cover of herbaceous or weedy cover was observed in mulched plots than bare plots. Not only did herbaceous weeds occur in more of the bare plots, they typically covered more of the plot than in mulched areas. These findings reinforce the notion that mulch effectively inhibits weeds. However, as hogfuel mulch breaks down over several years, it has a lower effect on weed control.

Maintenance Recommendations

1. Irrigate trees and shrubs as needed, instead of by default. Early inspections can determine which species or individuals are stressed and should be targeted for watering. From 2011-2013, irrigating the two-acre upland cost approximately $4500 to $6500K per summer. The experimental results show that performance standards could have been met without this expenditure.

2. In future monitoring experiments, compare the effects of irrigation on cover and vigor of woody species. Though irrigation did not appear to increase tree survival in this study, irrigation may increase vigor and cover of woody plants.

3. Use hogfuel mulch rings on trees instead of mulching bare areas between plants. Results indicate that mulch provides weed control, but also limits natural recruitment of red alder and other desirable volunteers. Consider using mulch rings to provide weed control and retain moisture, while also allowing for higher natural recruitment on bare ground between plants. The cost of hand labor to spread mulch rings may be higher, but partly offset by cost savings from reducing mulch volume.

4. Focus on restoration goals when determining the need for or selection of erosion control measures. It is typically required that a slope adjacent to a stream channel have some form of erosion control. Though mulch helps water infiltrate into the soil instead of sheet flowing off the slope and potentially eroding the bank or depositing sediment, it also limits natural recruitment of desirable species. Dense grass seed or hydroseed with tackifiers also reduce/prevent natural recruitment. Consider options according to project goals, site conditions and likelihood of erosion.

5. In future monitoring, compare the survival between trees with mulched rings versus no treatment on bare sites. Mulch retains moisture and inhibits weeds, but it is expensive. Mulch may be unnecessary on sites with decent soil that are bare or void of competitive grasses (e.g., reed canary grass). Experiment with mulch rings versus no mulch treatment.

6. In future monitoring, compare the survival between potted trees versus bare root stock.

Bareroot plants cost 50-60% less than potted stock. Bare roots are more easily transported on site and planted faster (in decent soil conditions), which saves on labor costs. However, if bare root stock does not flourish and provide as fast cover as potted plants, cost savings may be insignificant.

7. <u>Test the effect of irrigation on natural recruitment in bare (unmulched) plots.</u>
Though a site's soil may be ripe for recruitment, moisture is a limiting factor in survival of naturally recruited species. Use a controlled experiment to see if irrigating bare plots helps promote the survival of recruited species through dry periods in spring and summer. In some cases, it may be more cost-efficient to irrigate portions of a project site, in support of natural regeneration, than to install potted or bareroot plants.

IX. References

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X. Appendix - Photopoints

Photopoint 1: Looking upstream at Lower Boise Creek from top of railroad abutment at confluence with the White River.

2010

2011

2013

Photopoint 12: Looking downstream from top of bridge at Mud Mountain Road.


2010 August


2011 February


2012 August


2013 August

Irrigation Study Plot 5DRY: 2011-2013


2011 May


2011 August


2012 August


2013 August

Regeneration Study Plot 10: 2011-2013

2011

2012

2013