Bull Run Water Supply
Habitat Conservation Plan

Annual Compliance Report 2019—Year 10

Final · September 2020

Portland Water Bureau
From Forest to Faucet

City of Portland, Oregon 1851

Under penalty of law, I certify that, to the best of my knowledge, after appropriate inquiries of all relevant persons involved in the preparation of this report, the information submitted is true, accurate, and complete.

Steve Kucas, Environmental Compliance Manager, PWB Resource Protection

9/4/2020

Date

Contents

Appendixes

Tables

Figures

Acronyms and Abbreviations

cfs	cubic feet per second
DO	dissolved oxygen
EDT	Ecosystem Diagnosis and Treatment
ESA	Endangered Species Act
HCP	Habitat Conservation Plan
JOM	juvenile outmigrants
LCR	Lower Columbia River
LW	large wood
MSL	mean sea level
NMFS	National Marine Fisheries Service
O&M	operations and maintenance
ODEQ	Oregon Department of Environmental Quality
ODFW	Oregon Department of Fish and Wildlife
PGE	Portland General Electric
PHP	Portland Hydroelectric Project
PWB	Portland Water Bureau
RM	river mile
TDG	total dissolved gas
TMP	Temperature Management Plan
TMDL	total maximum daily load
USGS	U.S. Geological Survey
VSP	viable salmonid population
7DADM	7-day average of daily maximum temperature

1. Executive Summary

2019 is the 10-year point of HCP implementation, and the City is quite proud of what is has accomplished in the Sandy River Basin during that time. All major HCP measures have been implemented ahead of schedule, and there are not large habitat projects left to complete. A new appendix in this report (Appendix A) describes all of the City's accomplishment through 2019.

The habitat goals of only one conservation measure (HCP Measure T-2--Post-infrastructure Temperature Management) were not fully met in 2019 or previous years. The City provides an analysis in Appendix A indicating that, even with the water temperature performance to date and considering the extreme water temperatures from 2014 to 2019, fish production has not been negatively impacted and the beneficial uses have been protected. The City will continue to monitor water temperatures in the lower Bull Run River in 2020 and work with the National Marine Fisheries Service, the Oregon Department of Environmental Quality, and the Oregon Department of Fish and Wildlife, starting in the spring, on operational measures to address water temperature performance for the lower Bull Run River.

Only three conservation measures could not be implemented from 2010 to 2019 because of unwilling landowners. The projected benefits of those original HCP measures have been compensated by the implementation of other measures.

The HCP conservation easement program has been very successful. The projected fish habitat benefits associated with the easement program meet or greatly exceed the projections for the original HCP. The City does not intend to pursue additional conservation easements.

All instream habitat measures have been implemented. The projected fish habitat benefits from those measures either approximate, or exceed, those benefits projected by similar HCP measures.

The City also provides an analysis of the project effects on Sandy River fish populations from the measures implemented in the first 10 years the HCP has been in effect, using EDT modeling and a comparison of Viable Salmonid Parameters, in the same way it was done in the original HCP. EDT model predications indicate that for the four primary HCP fish species considered, there will be significant habitat benefits from the conservation measures already implemented from 2010 to 2019. These projected benefits either meet or exceed those originally described in the HCP commitments.

The Bull Run Water Supply Habitat Conservation Plan (HCP) is a 50-year plan to protect and improve aquatic habitat while continuing to manage the Bull Run River watershed as a water supply for the City of Portland (City), Oregon. The City created the HCP, with technical assistance from the Sandy River Basin Partners, to minimize and mitigate the effects of covered activities associated with the Bull Run water supply operations on listed and unlisted Endangered Species Act (ESA) species and their associated habitat. The primary focus of the HCP is protection for ESA-listed anadromous fish under the jurisdiction of the National Marine Fisheries Service (NMFS), but the plan also includes other species. In 2009, NMFS issued an Incidental Take Permit to the City pursuant to Section 10(a)(1)(B) of the Endangered Species Act and signed an Implementing Agreement with the City. The HCP and each of its provisions are incorporated into those agreements.

In addition, in 2008 the Oregon Department of Environmental Quality (ODEQ) approved the City's Temperature Management Plan for the Lower Bull Run River (Appendix H of the HCP). The City's plan addresses temperature requirements for the lower Bull Run River that are articulated in the Sandy River Basin Total Maximum Daily Load (TMDL) report.

In 2016, PWB chose to begin monitoring water temperature and toad breeding site selection to determine whether Measure R-3, Reed Canarygrass Removal, was having the desired outcomes for western toads (*Bufo boreas*) and northern red-legged frogs (*Rana aurora*). Appendix I summarizes the results of the monitoring.

The HCP includes 49 conservation measures to protect and improve habitat and to avoid or minimize the impacts of the Bull Run water supply system. Annual reports from the City are required to document compliance with the conservation measures, monitoring requirements, research efforts, and adaptive management actions that are implemented.

The tenth year of the HCP was 2019, referred to as Year 10 throughout this document. This is the ninth Annual Compliance Report.

Changing circumstances and conditions have required modifications to some of the original HCP measures. The changed measures were implemented with target amounts or locations that accounted for other measures that could not be implemented (for example, canceling a large wood (LW) project in one location and increasing the number of large wood pieces in a second location). These changes are noted in this report and documented in an appendix of key correspondence with NMFS (Appendix J).

The City met the terms and conditions of every HCP conservation measure for 2019, with the exception of downstream water temperature targets. For 52 days, the temperature of the Bull Run River exceeded the HCP temperature target. The City presented the 2019 water temperature information to the Oregon Department of Environmental Quality, the National Marine Fisheries Service, and the Oregon Department of Fish and Wildlife. The City will continue to monitor water temperatures in the lower Bull Run River in 2019 and to work with ODEQ, starting in the spring, on operational measures to improve performance of the system for temperature control.

2. Introduction

2.1 Habitat Conservation Plan Background

In April 2009, the National Marine Fisheries Service (NMFS) signed a Permit for Incidental Take of Threatened Species number 13812, granting the City of Portland (City) authorization to operate its Bull Run water supply subject to the provisions of the implementing agreement for the Bull Run Water Supply Habitat Conservation Plan (HCP). The Incidental Take Permit covers four anadromous fish species listed under the Endangered Species Act (ESA) of 1974—Lower Columbia River (LCR) Chinook Salmon *(Oncorhynchus tshawytscha)*, Columbia River Chum Salmon *(O. keta)*, LCR Coho Salmon *(O. kisutch)*, LCR steelhead *(O. mykiss)*—and Pacific Eulachon *(Thaleichthys pacificus)*.

The Bull Run HCP includes 49 habitat conservation measures that are expected to minimize and mitigate, to the maximum extent practicable, the effects of take on the covered fish and wildlife. The measures are designed to improve habitat conditions for the fish and 18 additional wildlife species in the Bull Run subbasin and the Sandy River Basin, watersheds that are part of the lower Columbia River Basin in northwest Oregon. The Sandy River Basin was included in the plan in order to fully address the Incidental Take Permit requirements.

Measures in the Bull Run include modifying water supply infrastructure, implementing seasonal flow regimes and downramping rates, placing gravel and large wood, establishing fish passage in certain streams, removing invasive species, and defining operational standards to avoid or minimize the effects of operations on the covered species. The measures in the Sandy River Basin, called offsite measures, include large wood and log jam placement, channel redesign and reconstruction, establishing fish passage in certain streams, establishing easements and making improvements in riparian zones, and acquiring land parcels and water rights.

The HCP measures are being implemented and monitored over the course of 50 years. Measures in some reaches are being implemented early in the term of the HCP to provide the greatest improvements over time. Not every measure was implemented in the first year, however. Other measures slated to be implemented later in the HCP time frame are mentioned by name in this report but are not extensively discussed. By necessity, the terms of some measures have changed in response to changes in the Sandy River watershed. The City has maintained full records of measure adjustment terms, including correspondence with NMFS documenting approval of the changes. Correspondence is summarized in this compliance report appendix each year.

A key element of the HCP involves improving water temperature conditions for spawning and rearing salmonid fish. Compliance with this objective also fulfills the temperature objectives for the lower Bull Run River that are articulated in the Oregon

Department of Environmental Quality's (ODEQ's) Sandy River Basin Total Maximum Daily Load (TMDL) report (ODEQ 2005). The City's Temperature Management Plan for the Lower Bull Run River, approved by ODEQ in 2008, is Appendix H of the City's HCP.

2.2 Annual Report Organization

This report is organized to provide the status of work and planned accomplishments for HCP monitoring, the research efforts, and the Portland Water Bureau's adaptive management program. The monitoring section is divided into compliance and effectiveness monitoring. Within each of these monitoring subsections, information is provided for the Bull Run Watershed measures and for the offsite measures in the Sandy River Basin, respectively. Measures that share similar objectives (such as large wood placement or obtaining riparian easements) are grouped together. The introductory subsections titled Measure Commitments are taken directly from the HCP and are characterized by a font that is different from the rest of the report text.

The HCP outlines a specific program of monitoring, research, and adaptive management to evaluate habitat improvements resulting from the measures. The monitoring component includes both compliance and effectiveness monitoring. This ninth yearly report of accomplishments includes compliance monitoring information in Section 4.1, effectiveness monitoring information in Section 4.2, and a summary of the planned research in Section 4.3. Reports describing the monitoring, research, and results in detail are available as Appendixes A through I. Appendix J summarizes key correspondence between PWB and NMFS on obtaining authorization for changes to measures, including adjustments to the terms of selected measures.

Table 13, beginning on page 58, provides summary information for the status of each measure. The table outlines the measurable habitat objective, the method of compliance monitoring described in the HCP, the years in which the measure is planned to be implemented, and a description of the status. Table 13 also indicates where the effectiveness monitoring reports and the research reports are relevant to measures in this annual report. Measures that are not relevant to the current reporting year are shown with a gray background. Measures that are due to be started in future years are blank in the "Status" column.

3. HCP Monitoring, Research, and Adaptive Management Programs

3.1 Monitoring Program

The monitoring program for the HCP is designed to document compliance and verify progress toward meeting the goals and objectives outlined in Chapter 6 of the HCP. The monitoring program comprises both compliance and effectiveness monitoring. Compliance monitoring tracks progress implementing the HCP measures. Compliance monitoring reports focus on the work completed and planned for the following calendar year. Effectiveness monitoring, described in detail in Appendix B, is provided for those measures for which the habitat outcomes are somewhat uncertain. Effectiveness monitoring data will enable an assessment of whether the measurable habitat objectives have been met.

3.2 Research Program

The research program for the HCP focuses on four components in the Bull Run River Watershed and one component in the larger Sandy River Basin. In the Bull Run Watershed, the City is studying the placement of spawning gravel, the concentrations of total dissolved gases at certain locations, and the abundance of spawning Chinook adults. For the Sandy River Basin, the City is collaborating with other organizations doing research to measure the number of juvenile salmonid outmigrants at the reach and basin levels. See Appendixes C–F for detailed reports on the research and results.

3.3 Adaptive Management Program

Adaptive management is an approach that involves monitoring the outcomes of a project and, on the basis of the monitoring results, improving the way the project is managed. The City anticipates that, over the course of its 50-year HCP, scientific understanding of the issues relating to salmonid habitat will improve and some conditions will change such that some reconsideration and adaptation of its approach will be appropriate. The adaptive management program provides for ongoing evaluation of individual measures as well as milestones for evaluating the HCP as a whole. A key measure for adaptive management is the Habitat Fund, described in Section 4.4.

4. Monitoring Measures Status and Accomplishments

4.1 Compliance Monitoring

Most of the HCP measures pose very little uncertainty as to whether implementing the measures will meet the objectives. For these measures, the City is conducting compliance monitoring to track implementation and document completion.

4.1.1 Bull Run Measures

The City is using established United States Geological Survey (USGS) sites on the lower Bull Run River and Little Sandy River to monitor river flow and water temperature. River flow compliance will be measured at USGS Gage No. 14140000 (at river mile [RM] 4.7 on the Bull Run River). This gage will also be used to determine compliance with the downramping rate. Compliance with temperature measures will be based on the temperature data recorded at USGS Gage No. 14140020 on the lower Bull Run River (at RM 3.8, the Larson's Bridge site) and at USGS Gage No. 14141500 on the Little Sandy River (at RM 1.95, the Little Sandy Dam site), as shown in Figure 1.

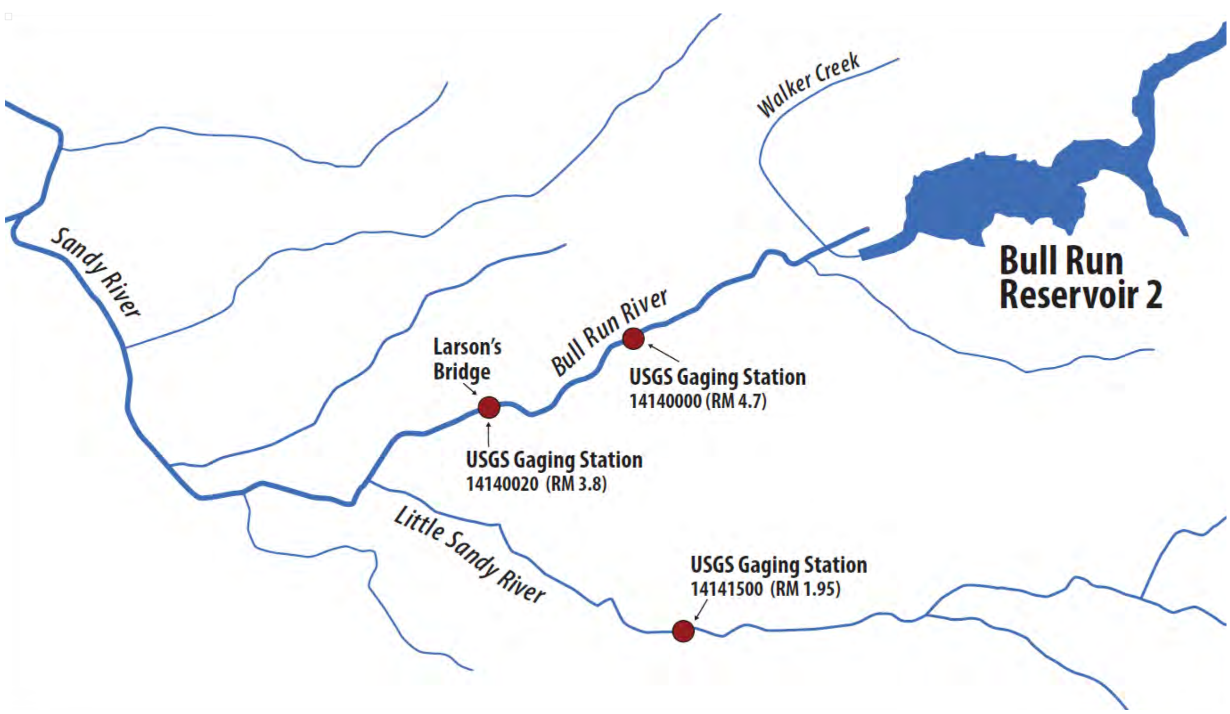

Figure 1. USGS Gaging Stations for Compliance Monitoring

Measure F-1—Minimum Instream Flow, Normal Water Years

Location: Bull Run Watershed

Benefits: Bull Run River flow

Contact: Kristin Anderson, Hydrologist, PWB Resource Protection

Primary Objective

Measure F-1 describes minimum instream flows to improve fish habitat conditions in the lower Bull Run River during normal water years. The measure includes guaranteed minimum flow amounts and other criteria that will maintain flow levels for spawning, rearing, and migrating salmonids and other aquatic species.

Measure Commitments

Measure F-1—Minimum Instream Flows, Normal Water Years: For HCP Years 1-50, the Bull Run water supply will be operated during normal water years to achieve the guaranteed flows in the lower Bull Run River specified in Table 1 (expressed in mean daily flows in cubic feet per second, cfs).

Table 1. Flow Commitments for the Lower Bull Run River during Normal Water Years, Measured at USGS Gage No. 14140000, RM 4.7

Time Period	Guaranteed Minimum Flow (cfs)	Required Percent of Inflow	Maximum Required Flow (cfs)
January 1–June 15	120	n/a[a]	n/a
June 16–June 30	Gradually decrease flows over 15 days from minimum of 120 cfs to a minimum of 35 cfs. If reservoir drawdown begins before June 30, decrease flows at no more than 2 inches/hour to reach the 20–40 cfs operating range; see below.		
July 1–September 30	Vary flow from 20 cfs to 40 cfs to manage downstream water temperature[b]		
October 1–October 31	70	50%	400
November 1–November 30	150	40%	400
December 1–December 31	120	n/a	n/a

[a]n/a = not applicable
[b]See Measure T-1.

For the period from June 16 to June 30, the guaranteed minimum flow of 120 cfs will be decreased by 5 cfs per day until the minimum of 35 cfs is achieved at Gage No. 14140000.

Variable flows will be implemented in summer (July through September) of normal water years. Water temperature is a key management concern during this season, and the reservoirs will be operated to take advantage of the limited amount of cold water that can be stored. Releases from the reservoirs will vary with weather conditions to better manage use of the available cold water. During mild weather, when temperatures in the river are naturally lower, less cold water will be released from the reservoirs. During warm weather, when cold water from the reservoirs is needed to moderate river temperatures, more cold water will be released. The resulting average summer flow in normal water years is expected to be 35 cfs.

Flow releases in October and November are defined as a percentage of reservoir inflow, with both upper and lower bounds as shown in Table 1. The City will provide a "floor" or minimum flow levels for the lower Bull Run River. The City will also cap the maximum flow level in October and November to allow the reservoir to refill to reduce the potential for unacceptable turbidity. The percentage of inflow released is higher in October than in November, but the total amount of water released will be higher in November because (1) the floor for the November minimum flow is higher than the floor for October, and (2) inflow is generally higher in November than October.

Basing water release on a percentage of inflow will ensure that fall flow in the lower river is determined by flow into the reservoirs, not by the amount of water stored in the reservoirs or the amount diverted for municipal supply. Reservoir storage and diversions are both affected by water demand. Inflow is not affected by water demand.

The City will control streamflow releases below Dam 2 at Headworks (RM 6.0 on the Bull Run River), and the lower Bull Run River flow will be measured at USGS Gage No. 14140000 (RM 4.7). For purposes of determining streamflow releases in October and November, reservoir inflow will be measured and totaled for four USGS Gages (No. 14138850, Bull Run River at RM 14.8; No. 14138870, Fir Creek at RM 0.6; No. 14138900, North Fork Bull Run River at approximately RM 0.2; and No. 14139800, South Fork Bull Run River at RM 0.6). The daily mean flows of the four gages will be added and then multiplied by 1.2 to account for the ungaged area of reservoir inflows in the Bull Run Watershed.

City staff will determine the week's reservoir inflows once a week and determine the following week's flow target based upon the inflow data. The first determination of reservoir inflow levels will occur prior to October 1. The flow releases to meet the targets will be implemented starting on October 1. Flow release targets will be set each week through the end of November.

Through the term of the HCP, the flow releases in the lower Bull Run River may exceed the guaranteed minimum flows in Table 1 if the reservoir inflows exceed demands for drinking water and the guaranteed minimum flows for fish.

The minimum flow requirements may not be met during the days that the Chinook surveys occur. Flows will be held to less than 150 cfs, as measured at USGS Gage No. 14140000, to allow safe surveying. The surveys are expected to occur approximately once per week from August through November. See Appendix G of the HCP for more details on the Chinook survey procedures.

Status of Work for Calendar Year 2019

The City met the minimum instream flow requirements of HCP Measure F-1 in 2019. Guaranteed minimum flows for normal water years were used as the flow targets January through May and July through December in 2019. See Measure F-2 for June flow requirements for 2019.

During October and November, guaranteed minimum flows were based on a percentage of total inflow to the Bull Run reservoirs during the previous week. Table 2 summarizes the dates and flows used to derive these calculations.

Table 2. Dates, Inflow, and Flow Targets for October and November 2019

Flow Target Period		Index Period		Average Inflow (cfs) During Index Period	Flow Target (cfs)
From	To	From	To		
1-Oct	1-Oct	17-Sep	23-Sep	205	102
2-Oct	8-Oct	24-Sep	30-Sep	292	146
9-Oct	15-Oct	1-Oct	7-Oct	227	113
16-Oct	22-Oct	8-Oct	14-Oct	335	168
23-Oct	29-Oct	15-Oct	21-Oct	1172	400
30-Oct	31-Oct	22-Oct	28-Oct	889	400
1-Nov	5-Nov	22-Oct	28-Oct	889	356
6-Nov	12-Nov	29-Oct	4-Nov	222	150
13-Nov	19-Nov	5-Nov	11-Nov	141	150
20-Nov	26-Nov	12-Nov	18-Nov	151	150
27-Nov	30-Nov	19-Nov	25-Nov	271	150

Releases from Bull Run Reservoir 2 were reduced on October 2, 9, 16, and 29–30; November 5–6, 13, 20, and 27; and December 4, 2019, to allow Portland Water Bureau (PWB) fish biologists to conduct spawning surveys safely in the lower Bull Run. On these days, the mean daily flow at USGS Gage No. 14140000 was less than the guaranteed minimum level, a reduction in stream flow that is allowed under the terms of the HCP measure. Figure 2 shows several days in late May when flows were slightly below the minimum 120 cfs. During that time period, USGS Gage No. 14140000 was reporting streamflow values above 120 cfs. A subsequent re-rating of the stream site by the USGS resulted in a revision of the streamflow data to be below 120 cfs. Lower Bull Run River flows at USGS Gage No. 14140000 are depicted in Figure 2.

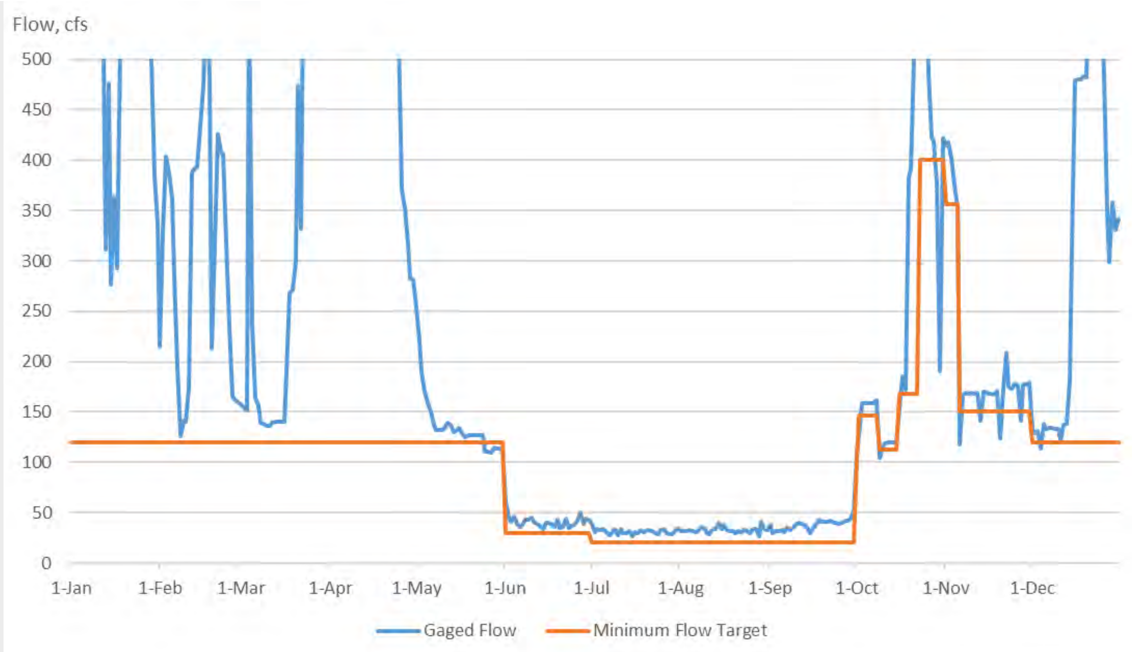

Figure 2. Lower Bull Run River Minimum and Actual Flows[a] in 2019

[a]Flows exceeding 500 cfs are not shown.

Planned Accomplishments for Calendar Year 2020

The City will continue to set the minimum flow levels early each day so that the daily averages meet or exceed the HCP minimum flow targets. Flow levels will be monitored in 2020 and compared to the guaranteed minimum flows. Normal-year or critical-year flow criteria will be applied as appropriate.

Measure F-2—Minimum Instream Flows, Water Years with Critical Seasons

Location: Bull Run Watershed

Benefits: Bull Run River flow

Contact: Kristin Anderson, Hydrologist, PWB Resource Protection

Primary Objective

Measure F-2 describes minimum instream flows that will be used during water years with critical seasons. These minimum flows will be used to achieve the guaranteed flows in the lower Bull Run River.

Measure Commitments

Measure F-2—Minimum Instream Flows, Water Years With Critical Seasons: During HCP Years 1–50, for any years that have a critical spring or fall season, the Bull Run water supply will be operated to achieve the guaranteed flows in the lower Bull Run River specified in Tables 3 and 4 (in mean daily flow in cfs). Fall flows in Table 3 will not be implemented more frequently than two years in a row and will not be implemented 4 years after a previous season of critical fall flows has been implemented (to avoid affecting the same age cohort twice). If a year does not have a critical spring or fall season, all flows will be the normal water year flows described in Measure F-1.

The triggers for a critical spring or fall season are defined in Table 3.

Table 3. Critical Spring and Fall Season Triggers

Critical Season	Trigger
Spring	Drawdown occurs prior to June 15
Fall	August and September inflows within lowest 10% of historical record (1940 to current HCP Year)

The response to a critical spring season is outlined in Table 4.

Table 4. Flow Commitments for the Lower Bull Run River during Water Years with Critical Spring Seasons

Time Period	Guaranteed Minimum Flow[a] (cfs)	
June 1–June 30	30	If critical spring season trigger is met, decrease flow after drawdown begins, but no earlier than June 1. Maintain downramping rate described in Measure F-3, from 120 cfs to 30 cfs.

[a] Measured at USGS Gage No. 14140000 (RM 4.7)

In any year of the HCP when a critical spring season has been triggered, there may be additional rain that temporarily raises reservoir inflow levels above outflow levels. The City may elect, in such circumstances, to raise the flow of the Bull Run River higher than the critical-period guaranteed minimums indicated in Table 4. Also, the City may elect to release more flow than the guaranteed minimum to the lower Bull Run River during critical spring seasons to meet water temperature objectives as described in Measures T-1 and T-2.

The trigger for the critical fall season is based on whether the mean daily flow for the August and September inflows to the Bull Run reservoirs are within the lowest 10 percent of historical flows for that time period. Throughout HCP Years 1-50, the 10th-percentile flow level will be updated annually to include new years of record.

The response to a critical fall season is outlined in Table 5.

Table 5. Flow Commitments for the Lower Bull Run River during Water Years with Critical Fall Seasons[a]

Time Period	Guaranteed Minimum Flow[a] (cfs)	Required Percent of Inflow (cfs)	Maximum Required Flow (cfs)
October 1–October 15	20	If critical fall season trigger is met, continue to vary flow from 20–40 cfs to manage downstream water temperature	
October 16–October 31	30	50%	250
November 1–November 15	30	40%	250
November 16–November 30	70	40%	350
December 1–May 31	120	n/a	n/a

[a]Measured at USGS Gage No. 14140000 (RM 4.7)

The percentage of inflow and maximum flow requirements might not be met during the days that the Chinook surveys occur. Flows will be held to less than 150 cfs, as measured at USGS Gage No. 14140000, to allow safe surveying. The surveys are expected to occur approximately once a week from August through November. See Appendix G for more details on the Chinook survey procedures.

The City will control streamflow releases at Headworks (RM 5.9 on the Bull Run River), and the lower Bull Run River flow will be measured at USGS Gage No. 14140000 (RM 4.7). For purposes of determining streamflow releases in October and November, reservoir inflow will be measured and totaled for four USGS Gages (No. 14138850, Bull Run River at RM 14.8; No. 14138870, Fir Creek at RM 0.6; No. 14138900, North Fork Bull Run River at approximately RM 0.2; and No. 14139800, South Fork Bull Run River at RM 0.6). The daily mean flows of the four gages will be added and then multiplied by 1.2 to account for the ungaged area of reservoir inflows in the Bull Run Watershed.

City staff will determine the previous week's reservoir inflows once each week and establish the next week's flow release target based on that inflow data. The first determination of streamflow level will occur prior to October 1. The flow releases to meet the targets will be implemented starting on October 1. Additional flow release targets will be set each week through the end of November.

Status of Work for Calendar Year 2019

The critical spring trigger was met in 2019. Naturally occurring drawdown commenced on May 7, 2019. Downstream flows were decreased below 120 cfs starting on June 1.

The lowest 10 percent of total reservoir inflow during August and September from 1940 through 2018 was 3.52 billion gallons. Total reservoir inflow during August and September 2019 was 4.61 billion gallons; therefore, critical fall conditions did not occur. Lower Bull Run River flows at USGS Gage No. 14140000 are depicted in Figure 2 on page 10.

Planned Accomplishments for Calendar Year 2020

The critical spring and fall triggers will be assessed in 2020. If one or both triggers are met, the City will implement the appropriate guaranteed critical-year minimum flows per the conditions of the HCP.

Measure F-3—Flow Downramping

Location: Bull Run Watershed

Benefits: Bull Run River flow

Contact: Glenn Pratt, Hydroelectric Project Manager, Portland Bureau of Hydroelectric Power

Primary Objective

The City is committing to a low downramping rate to reduce effects on covered fish in the lower Bull Run River and the Sandy River.

Measure Commitments

Measure F-3—Flow Downramping: For HCP Years 1–50, the City will release flow into the lower Bull Run River, below Dam 2 as a result of hydropower operation, at a maximum downramping rate of no more than 2 inches/hour (0.17 ft/hour), as measured at USGS Gage No. 14140000 (RM 4.7). City staff will monitor recordings at USGS Gage No. 14140000 to ensure that the decreases adhere to this downramping rate.

This maximum downramping rate will not apply to events beyond the control of system operators, such as unexpected power grid interruptions, downed power lines, equipment failures, emergency responses at the Headworks as required to ensure compliance with federal safe drinking water standards, the mandatory annual testing of the powerhouse, and other circumstances that preclude the use of the North Tunnel or Diversion Pool at the City's water supply Headworks. The maximum downramping rate will also not apply when naturally occurring high flows, as measured at USGS Gage No. 14138850 (Bull Run RM 14.8), decrease by more than 2 inches/hour.

Status of Work for Calendar Year 2019

The City was in compliance with Measure F-3 in 2019.

Downward-stage fluctuations in the lower Bull Run River, as measured at USGS Gage No. 14140000, were maintained at or below a rate of 2 inches/hour for 99.77 percent of the time in 2019. Downramping exceedances occurred for 20 hours, or 0.0023 percent of total operating hours during the monitoring year.

The effects analysis outlined in the HCP was based on predicted flow exceedances of 0.4 percent of total operating hours per year—a level of downramping flow exceedances that was determined to have minimal effects on covered fish species in the plan.

While downramping exceedances occurred for 20 hours in 2019, all of the exceedances were excluded from the fluctuation limit as allowed by Measure F-3. Even though the exceedances were allowed, the City analyzed the flow data to determine why the exceedances occurred and to improve future operations. Accounting for each hour of the allowed downramping exceedances follows:

- 15 hours were associated with the excessive flow rates coming into both Reservoir 1 and Reservoir 2 due to extreme precipitation from April 7 to April 12, 2019. During this time, both powerhouses were running at maximum capacity (P1 = 24 MWh production, and P2 = 12 MWh production). During this 6-day period, the flows at both reservoirs were spilling over both spillways despite the maximum production at both powerhouses. At this time, flows would fluctuate beyond the ability of the powerhouses to modulate and control them.

- 4 hours were associated with the failure of the USGS 14139900 gage (elevation gage for the Reservoir 2) between December 14 and December 15 in 2019 when the USGS gage bubbler system ran out of nitrogen and reported the same elevation for intervals two days in a row. This gage error caused the operator unknowingly to miscalculate the flow rate between Reservoir 1 and Reservoir 2. Subsequently, the operator reduced the flow from Reservoir 1 at a faster rate than necessary to maintain the elevation at Reservoir 2 and the flow rate downriver as measured by the 14140000 gage.
- 1 hour (January 6, 2019) was associated with the disruption of service to the hydroelectric plants as a result of trees falling into the high-voltage line and causing the plants to trip off-line.

When these allowed exemptions are factored into the years output, the City was compliant with this measure of the HCP during all hours.

Downramping data for the 2019 calendar year is maintained in City of Portland Water Bureau files at J:\Engineering\Hydro Power\Hydro Restricted\ACTIVE PHP FILES\Morning Reports\PHP 2 Inch Per Hour\2019

Planned Accomplishments for Calendar Year 2020

Flow downramping will continue to be monitored in 2020.

Measure T-2—Post-infrastructure Temperature Management

Location: Bull Run Watershed

Benefits: Bull Run water temperature

Contact: Kristin Anderson, Hydrologist, PWB Resource Protection

Primary Objective

The City has altered its water supply infrastructure and its water supply operations to reduce water temperatures in the lower Bull Run River. The City's strategy relies on sharing the available cold water in the Bull Run reservoirs for drinking water and fish flow needs. The City stores cold water in the reservoirs in spring and early summer when overall temperatures are lower and will release the water throughout the summer and early fall when river temperatures are warmer. The multilevel intakes already existing at Dam 1 are used for this purpose. With the multilevel intakes at Dam 2, the City's target is to maintain the 7-day moving average of the maximum daily water temperature (7DADM) of the lower Bull Run River below either the numeric stream temperature criteria or the 7-day moving average of the maximum water temperature of the Little Sandy River, whichever is greater, with additional air temperature and calendar exceptions. Compliance with this measure fulfills the objectives of the City's Temperature Management Plan (TMP) for the Lower Bull Run River (Appendix G of the HCP).

Measure Commitments

Measure T-2—Post-infrastructure Temperature Management: Within HCP Years 1-5, the City will design, permit, and complete two significant changes to Bull Run water supply infrastructure to implement this conservation measure:

The Dam 2 intake towers will be modified to allow taking water from the reservoir at different levels.

The spillway rock weir in the Bull Run River immediately downstream of the Dam 2 spillway will be modified to allow rapid movement of flow through the spillway stilling basin.

After the infrastructure changes are made to the Dam 2 intake towers and the spillway rock weir, the City will manage flow to meet Oregon state water quality standards in the lower Bull Run River, as established in ODEQ's Sandy River Basin TMDL (ODEQ, 2005) and the ODEQ-approved Temperature Management Plan. The City will use the Little Sandy River water temperature (measured at USGS gauge 14141500) as a surrogate for the natural thermal potential of the lower Bull Run River. Water temperature compliance will be measured at Larson's Bridge on the main stem Bull Run River (USGS site 14140020). All water temperatures will be expressed as the 7-day moving average of the daily maximum temperature (Table 6).

Per the Sandy River Basin TMDL, Bull Run River water temperature target will be maintained

- at or below the appropriate biologically based numeric temperature criteria shown in Table 6 when the Little Sandy River temperature is below the criteria

Table 6. Appropriate Numeric Temperature Criteria

River Reach	Time Period	Habitat Use	Numeric Criterion (7-Day Average Maximum)
River Mile 0 to 5.3	June 16 to August 14	Salmonid rearing	16 °C
	August 15 to June 15	Salmonid spawning	13 °C
River Mile 5.3 to 5.8	June 16 to October 14	Salmonid rearing	16 °C
	October 15 to June 15	Salmonid spawning	13 °C

Source: ODEQ 2005

or

- at or below the Little Sandy River temperature (as adjusted, see below) when the Little Sandy River temperature is above the numeric criteria

Also, per the TMDL, the Bull Run water temperature target will be adjusted above the actual measured Little Sandy temperatures as follows:

- Between August 16 and October 15, allowances will be made for a 1.0 °C departure above the Little Sandy temperature.
- If the 7-day moving average of daily maximum air temperature is above 27 °C, the lower Bull Run water temperature target will be the lower Little Sandy River water temperature plus 1 °C.
- If the 7-day moving average of daily maximum air temperature is above 28 °C, the lower Bull Run water temperature target will be the lower Little Sandy River water temperature plus 1.5 °C.

The ODEQ temperature standards [OAR 340-041-0028(12)(c)] provide an additional exception if the maximum daily air temperature exceeds the 90th percentile of the 7-day average of the daily maximum air temperature calculated in a yearly series over the historical record. If this situation occurs in the lower Bull Run River, the numeric criteria and natural condition criteria (Little Sandy water temperatures as adjusted above) would not apply.

Daily maximum air temperatures will be recorded at the Water Bureau's Headworks facility below Dam 2 (approx. RM 6).

The Bull Run water temperature criteria also will not apply to events beyond the control of the water system operators, such as unexpected power grid interruptions, downed power lines, equipment failures, loss of computer contact with the Dam 2 intake towers, emergency responses at Headworks as required to ensure compliance with federal Safe Drinking Water standards, the mandatory annual testing of the protection devices at the powerhouse, and other circumstances that preclude the use of the intake towers or diversion pool at the City's water supply Headworks.

Status of Work for Calendar Year 2019

Infrastructure changes (the addition of multilevel water intake gates on the north tower at Bull Run Reservoir 2) were completed in 2014, and the multilevel intakes were placed into operation for temperature management. 2019 was the sixth year of using the multilevel intakes for downstream temperature management. From spring through the fall, the City continued to use its flow calculator model for determining flow releases on a twice-daily basis using data from previous years to estimate in-stream heating under various conditions.

The bottom gates of the Bull Run Reservoir 2 North Tower were closed on February 28 to ensure that the coldest possible water was captured at the bottom of the reservoir. However, cold water was not isolated until thermal stratification started in mid-April. Prior to stratification, the temperature of the bottom of the reservoir increased or decreased with the temperature of the entire reservoir. A very rapid transition from cool and wet early April conditions to warm and dry late April and early May conditions resulted in cooler bottom water temperatures than had been observed in 2014 through 2018, as the cold bottom water was quickly isolated. Bottom temperatures at the end of June were 6.9 °C, 0.9 °C to 1.8 °C cooler than those in 2014–2018.

The City communicated the water temperature information to ODEQ, NMFS, and ODFW throughout 2019. Those agencies directed the City to continue to monitor water temperatures in the lower Bull Run River and to work with them, starting in May of each year, on operational measures to improve performance of the system for temperature control.

The beginning of the temperature management period was marked by historically dry conditions. This led to an early start of reservoir drawdown on May 7, triggering critical spring conditions in which downstream flow was decreased as early as June 1. Temperature targets for the lower Bull Run River were low (13 °C) at that time and required large rates of release of cold water to meet the target in the period June 1 to June 15.

The lower Bull Run 7-day average of daily maximum (7DADM) temperatures stayed below the moving temperature target through most of the summer management period, early June through the middle of September (Figure 3).

In late September, the Little Sandy temperature decreased rapidly, lowering the target beyond what could be achieved in the lower Bull Run. From September 21 to 26, the lower Bull Run 7DADM exceeded the target and then decreased below the target. Starting October 1, the bottom of Reservoir 2 warmed at an accelerated rate, driven by increased rates of release required in HCP Measure F-1 and marking the depletion of remaining cold water at the bottom of the reservoir.

The Bull Run 7DADM again exceeded the target October 7. Rains in the Bull Run Watershed that began October 15 cooled the Bull Run reservoirs, and the lower Bull Run 7DADM temperature declined to below 13 °C on October 20. Water temperature targets for the lower Bull Run were exceeded for 19 days. During this time, the highest 7DADM temperature during this period was 13.8 °C, and the greatest departure from the target was 0.8 °C.

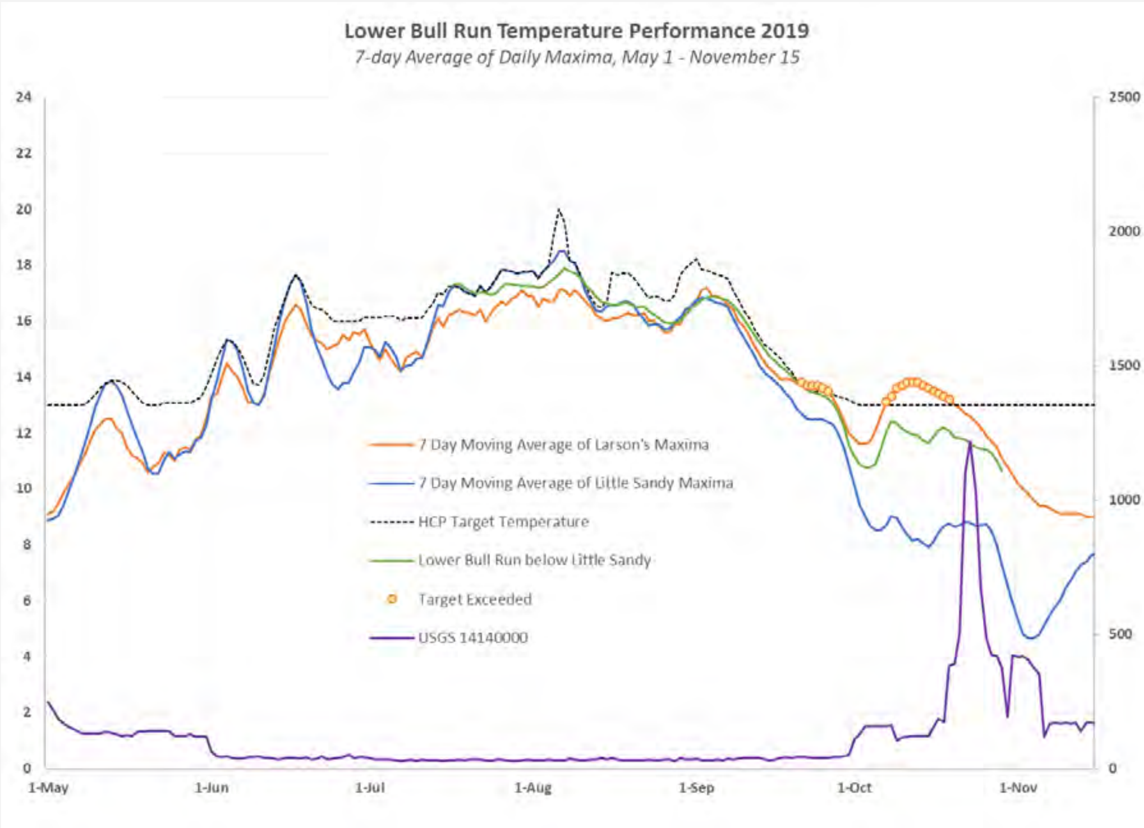

Figure 3. 7-Day Moving Average of Daily Maximum Water Temperature in the Lower Bull Run River at Larson's Bridge (USGS Gage No. 14140020) and at Little Sandy River (USGS Gage No. 14141500) for 2019

Target temperature combines numeric criteria, Little Sandy temperature, and air temperature and calendar exceptions. The modified target temperature represents the joint decision by Portland Water Bureau and regulators to preserve the cold water resource for later critical periods.

Consideration of Air Temperature Exclusions

On four days in 2019 (June 12, August 4 and 27, and September 5), the 90th percentile air temperature was exceeded. For all days that included these dates in its 7-day average (i.e., from six days before to six days after these dates), the temperature target did not have to be met. However, the City met the target in these periods despite this exception.

The Air Temperature Exclusions do not help the City with water supply planning. Since 2014, the City has made twice-a-day decisions about flow releases to meet specific water temperature targets for the lower Bull Run River. This proactive management approach is key for managing water supply. The Air Temperature Exclusions are determined after the

City's decision-making during the summer and fall reservoir drawdown period. So, these exclusions do not help the City plan for water releases or savings.

Consideration of Low Flow Conditions

Low flow conditions, and specifically the 7Q10 low flow, are described in Oregon Administrative Rule 340-041-0028 (12)(b)(D)(d) as an exception to the implementation of temperature criteria.

Stream flow statistics were analyzed for the years 2014–2019 to quantify how severe flow conditions were relative to the historical range. The City calculated 7Q10 low flow statistics on Bull Run stream flows using flow data from the period of 1976 through 2019. Monthly 7Q10 values were determined by calculating the 10th percentiles of the monthly Log-Pearson Type III distribution of total daily stream flows. Then, all days whose total tributary flow was less than the 7Q10 value for that month were flagged, as were the six days following. Temperature exceedances that had occurred on any of these flagged days were not considered exceedances. This logic of applying the exception to the day of occurrence and the six days following is the same logic provided to the City in 2014 regarding the calculation of 90^{th} percentile air temperature exceptions (Karen Williams, personal communication).

Table 7 shows the difference in the number of days that the temperature target was exceeded at Larson's Bridge when days with stream flow below the 7Q10 low flow values are removed.

Table 7. Number of Days Exceeding the Temperature Target by Year, with and without Removal of Days on which Combined Daily Stream Flow Was Below the Monthly 7Q10 Low Flow.

Year	Number of Days Above Target	Number of Days Above Target, 7Q10 Low Flow Applied
2014	36	36
2015	57	34
2016	35	35
2017	34	34
2018	52	46
2019	19	19

The City was not sure whether the Low Flow Exclusion applies to the Bull Run Watershed or if the City's approach was applied correctly. The City requests further guidance from ODEQ on this subject matter.

Planned Accomplishments for Calendar Year 2020

The City will manage flow releases from Headworks to maintain the 7-day average of daily maximum temperatures at Larson's Bridge according to Measure T-2, Post-Infrastructure Temperature Management. The seventh year operating the new multilevel intakes at Bull Run Dam 2 will be 2020. The City will incorporate knowledge from the first six years of operating with the new multilevel intakes to optimize operations in 2020.

Measure R-1—Reservoir Operations

Location: Bull Run Watershed

Benefits: Avoids or minimizes Cutthroat and Rainbow Trout mortality

Contact: Kristin Anderson, Hydrologist, PWB Resource Protection

Primary Objective

The City is continuing to manage the reservoirs to ensure compliance with federal Safe Drinking Water Act standards and to avoid or minimize mortality of Cutthroat and Rainbow Trout.

Measure Commitments

Measure R-1—Reservoir Operations: For HCP Year 1-50, the City will operate the two Bull Run reservoirs to avoid or minimize mortality of Cutthroat and Rainbow Trout. The operating criteria for the reservoirs will be the following:

1. When the City is operating its hydroelectric powerhouses at the two Bull Run dams during the winter, the reservoir surface elevations will not normally vary outside of the upper two feet of the reservoirs' normal full pool range (except as noted in items 2 and 3 below). For Bull Run Reservoir No. 1, the elevation range is 1,034 to 1,036 feet above mean sea level (MSL). For Reservoir 2, the range is 858 to 860 feet above MSL.

2. The City will lower the surface elevation of the two reservoirs beyond the upper two feet of the normal full pool level only for water supply and/or quality reasons, for downstream fish habitat reasons, for dam safety reasons, or for repairs or maintenance to the dam or hydropower project facilities.

3. The City will operate the two reservoirs as needed to maintain required streamflows and water temperatures in the lower Bull Run River for covered species.

4. During the summer drawdown season, Reservoir 1 may be lowered to approximately elevation 970 feet above MSL, and Reservoir 2 may be lowered to approximately 832 feet above MSL as needed for water supply purposes.

5. At the end of each drawdown season, the two Bull Run reservoirs will be filled as rainfall, streamflow, and required downstream releases permit.

6. The spillway gates on Bull Run Dam No. 1 will be lowered onto the spillway crest in the spring to store additional water for use in the summer months. After the risk of major flooding has passed and any habitat maintenance work has been completed in the upper reaches of Bull Run Reservoir No. 1 (see Measure R-3, Reed Canarygrass Removal), the water surface level in that reservoir will be raised to a summer supply full pool level of 1045 feet.

7. The City will use 4-cycle engines on its boats to minimize reservoir water pollution.

Status of Work for Calendar Year 2019

The Bull Run reservoirs were operated to meet the requirements of Measure R-1 in 2019. Graphs of the daily surface elevations of each reservoir are shown in Figures 4 and 5.

Reservoir 1 was operated within two feet of the spillway elevation (1,036 feet above MSL) from January 1 through March 3, with a brief period of drawdown in March caused by low reservoir inflows. The spillway gates were lowered (closed) on March 14, and Reservoir 1 slowly filled to a maximum of 1,044.2 feet on April 28, after which Reservoir 1 started slowly drawing down, with more pronounced drawdown beginning May 13. Reservoir 1 reached a minimum elevation of 997.7 feet on September 14, then refilled to above 1035.1 feet on October 22. Another shorter period of drawdown followed due to high fish flow releases and dry conditions, and Reservoir 1 refilled to 1,034 feet on December 22 (within two feet of spillway elevation 1,036 feet).

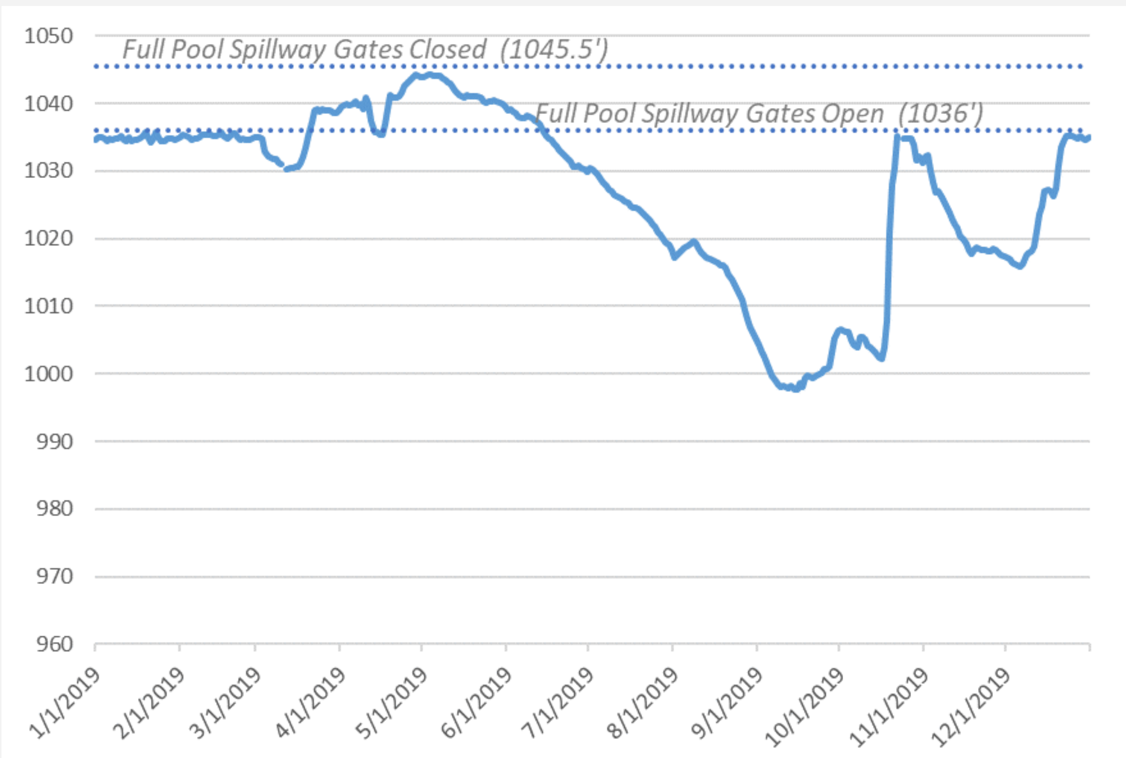

Figure 4. Reservoir 1 Elevations[a] during 2019

[a]Reservoir elevations were recorded at midnight at USGS Gage No. 14139000 in feet above mean sea level (MSL). Reservoir elevations are also tracked via the Portland Water Bureau's SCADA system.

Reservoir 2 was operated within two feet of spillway elevation (860 feet) until August 3, with brief storm-caused increases above 860 feet in the first half of April. Water levels were kept at 855 feet or below for spillway repair work that was carried out August 19 through October 4. Reservoir 2 reached its minimum elevation for 2019 of 852.5 feet on September 16, then refilled to 858 feet (within two feet of spillway elevation 860 feet) on

October 20. Reservoir 2, like Reservoir 1, had another period of drawdown starting November 1 and recovering to within two feet of the spillway on December 14. Reservoir 2 remained above the 858-foot elevation for the remainder of the year.

The City used only 4-cycle engines on all powered boats operated on the Bull Run reservoirs.

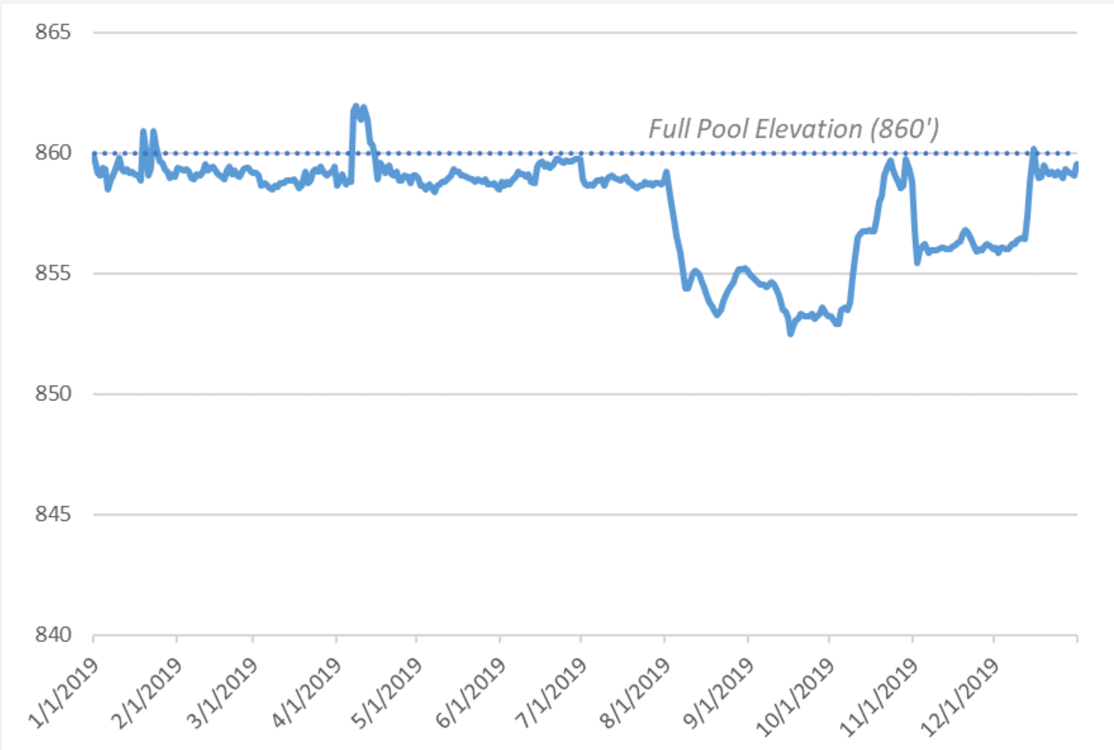

Figure 5. Reservoir 2 Elevations[a] during 2019

[a]Reservoir elevations were recorded at midnight at USGS Gage No. 14139900 in mean feet above sea level (MSL). Reservoir elevations are also tracked via the Portland Water Bureau's SCADA system.

Figure 6. Reservoir 1 and Dam 1 during a Drawdown Period

Planned Accomplishments for Calendar Year 2020

Reservoir elevations will be managed in 2020 according to the commitments of this measure. All boats operated on the Bull Run reservoirs will be powered by 4-cycle engines or human power.

Measure R-3—Reed Canarygrass Removal

Location: Bull Run Watershed

Benefits: Improve terrestrial habitat for wildlife

Contact: John Deshler, Wildlife Biologist, PWB Resource Protection

Primary Objective

To improve breeding and rearing habitat for western toads and red-legged frogs at areas along the upper end of Bull Run Reservoir 1 that the City has identified as important for reproduction and egg incubation.

Measure Commitments

Measure R-3—Reed Canarygrass Removal: For HCP Years 1-50, the City will cut and rake reed canarygrass away from designated areas along the north bank of the upper end of Bull Run Reservoir 1. The City will access the site by boat from the reservoir and by trail. Power tools will be used for cutting the grass. Neither heavy equipment nor additional road access will be needed. The cutting will occur just before the summer season lowering of the spillway gates on Dam 1, which will flood the shallow area of the reservoir.

Status of Work for Calendar Year 2019

The City met the requirements of Measure R-3 by cutting and removing reed canarygrass from the designated areas in April (Figure 7).

Figure 7. Reed Canarygrass Removal, Spring 2019

During the cutting, City staff worked at the north bank of the upper end of Bull Run Reservoir 1 within the western toad and red-legged frog breeding areas. After the areas were cut, the grass was removed with rakes and pitchforks, leaving grass stubble and exposed mineral soil.

In 2019, as in 2018, specific areas along the upper portion of Bull Run Reservoir No. 1 were the primary focus of treatment for this conservation measure. Toad breeding was monitored from May 1 through June 26. During monitoring, data on the location, onset, magnitude, duration, and outcomes of breeding were recorded. Monitoring ended when no toads, eggs, tadpoles, or toadlets were detected at the areas. Appendix I in this report provides more information on the monitoring effort.

Planned Accomplishments for Future Calendar Year

The cutting and removal of reed canarygrass are not having the desired outcome for toads. To date, the removal of reed canarygrass has not been shown to benefit toads because adult toads are mostly avoiding the treated areas.

Information collected during the past four breeding seasons (2016–2019) has shown that adult toads are breeding annually and laying most eggs in areas that have structure. The structure the adults are using is live and dead reed canarygrass attached to the reservoir bottom, and flotsam, especially partially submerged logs, bark, and sticks. Flotsam accumulates at the shoreline of the primary breeding area each winter via back-eddy flows. After eggs hatch, tadpoles aggregate on the structures (Figure 8).

Figure 8. Western Toad Tadpoles Aggregated in Reed Canarygrass and a Partially Submerged Log in 2019

For 2020 and beyond, PWB is asking to change the primary objective of Measure R-3. Instead of cutting and removing grass, PWB would like to continue annual monitoring of toad breeding at Reservoir 1. Through monitoring, PWB seeks either to (1) determine that toad breeding at the site is self-sustaining , or (2) find a way to improve productivity.

The main goal of this conservation measure is to make the primary breeding area more closely resemble habitat at other toad breeding sites on the west slope of the Cascades where reed canarygrass has not invaded. But this approach has not worked and has not benefited toad breeding. The City believes that by focusing on monitoring and seeking to achieve successful recruitment of young toads into the adult population, it will be going beyond the original objective of Measure R-3 (cutting and removing grass).

Measure H-1—Spawning Gravel Placement

Location: Bull Run Watershed

Benefits: Improve instream habitat

Contact: Burke Strobel, Fish Biologist, PWB Resource Protection

Primary Objective

The City is replenishing spawning gravel and mimicking natural supply and accumulation in the lower Bull Run River. The three selected sites provide the best combinations of access for delivery of gravel to the river and proximity to known spawning areas (CH2M HILL 2000).

Measure Commitments

Measure H-1—Spawning Gravel Placement: The City will augment spawning gravel in the lower Bull Run River and monitor the effects of the gravel placements. A total of 1,200 cubic yards of gravel will be placed in the river annually during HCP Years 1–5; 600 cubic yards will be placed annually for the remainder of the HCP term (HCP Years 6–50). The gravel will consist of a spawning matrix composed of medium to very coarse material (0.5 to 4 inches) that has been washed or sorted to remove fine sediment. The City will purchase gravel from companies with current valid permits for the mining or removal of gravel. The City will only purchase gravel that comes from areas outside of river floodplains.

Gravel will be placed in the river downstream of the City's water supply intakes. Equal amounts will be placed at three locations:

- 1,200 feet downstream of the Plunge Pool at RM 5.7
- 450 feet downstream of USGS Gage No. 1414000 at RM 4.7
- 600 feet downstream of Larson's Bridge at RM 4.0

Spawning gravel placement will occur in December after the primary fall Chinook Salmon spawning period and before steelhead spawning starts in the spring.

Gravel placements will continue as described above unless

- the lower Bull Run River does not experience high enough flows to distribute the gravel at the three placement locations

or

- the gravel placement is determined to be ineffective for creating spawning habitat for the covered species.

If either of these two conditions arises, the City will work with the NMFS to modify implementation of the measure as needed.

Appendix C of this report describes how the City assessed the effectiveness of the placed spawning gravel.

Status of Work for Calendar Year 2019

The City met the requirements of the HCP measure. The City successfully placed 600 cubic yards of spawning gravel in the lower Bull Run River in January 2019, at three specified locations. Using trucks with conveyor belts, the City placed a total of 200 cubic yards of gravel into the river at each location in mid-January 2019 (Figure 9). The gravel was obtained from a gravel quarry located near Estacada, Oregon, from an old alluvial terrace above the Clackamas River. The material complies with the specifications described in the measure.

Conveyor trucks were able to throw gravel to the middle of the Bull Run River, where it later was moved downstream by high flows. River flows during implementation of the project ranged from approximately 120 cfs to approximately 602 cfs. No gravel was placed in pools.

Figure 9. Placing Gravel in the Bull Run River in 2019

Gravel placement did not result in accumulations great enough to hinder the movement of fish at any of the three sites. Higher flows of 2,670 cfs on January 19, and 8,600 cfs on April 11, 2019, redistributed most of the placed gravel.

Planned Accomplishments for Calendar Year 2020

Spawning gravel will be placed in the lower Bull Run River in January 2020. The placement methods will be similar to those used in previous years. A total of 600 cubic yards of spawning gravel will be placed, as called for in Measure H-1, in HCP Years 6-50.

Measure H-2—Riparian Land Protection

Location: Bull Run Watershed

Benefits: Improve riparian and instream habitat

Contact: Steve Kucas, Environmental Compliance Manager, PWB Resource Protection

Primary Objective

City-owned lands along the lower Bull Run River are capable of providing riparian habitat at a level comparable to unmanaged late-seral forest. The City will continue managing these lands for the duration of the HCP so that their value to instream habitat will be maintained and, in some cases, improved.

Measure Commitments

Measure H-2—Riparian Land Protection: For HCP Years 1-50, City-owned lands adjacent to the lower Bull Run River will be managed for the conservation of riparian habitat. The City will not cut trees within 200 feet of the river's average high-water level on City-owned lands for the term of the HCP. A tree, as defined here, is any coniferous species with a minimum average diameter at breast height of 12 inches. Exceptions will include selective tree cutting to construct, maintain, and operate water supply and treatment facilities, water monitoring facilities, power lines, roads, and bridges. The City will also remove trees if they threaten City facilities, pose a significant risk to human safety, or when the City and NMFS determine selective cutting is desirable for the purpose of maintaining or improving riparian habitat. If trees are removed, the City will assess the site to determine whether an appropriate riparian species could be planted where the tree (or trees) was removed and will replant trees where feasible. The planted trees will be species that do not grow as tall as the removed trees. See also Measures W-1 and W-2.

Status of Work for Calendar Year 2019

The City met the requirements of Measure H-2. The City did not cut trees within 200 feet of Bull Run River's average high-water level on City-owned lands in 2019. The City also managed invasive species on lower Bull Run River riparian land.

Planned Accomplishments for Calendar Year 2020

The City will continue to monitor activities within 200 feet of the Bull Run River.

Measure O&M-1—Bull Run Infrastructure Operations and Maintenance

Location: Bull Run Watershed

Benefits: Avoid or minimize effects of operations and maintenance activities on covered lands

Contact: Steve Kucas, Environmental Compliance Manager, PWB Resource Protection

Primary Objective

The City will implement the Bull Run Infrastructure Operations and Maintenance (O&M) measure to address the potential impacts of maintaining and operating its water supply facilities in the watershed.

Measure Commitments

Measure O&M-1—Bull Run Infrastructure Operations and Maintenance: For HCP Years 1–50, the City will take the following actions to avoid or minimize effects on species covered or addressed in the HCP in the Bull Run Watershed:

Covered Lands

- The City will prevent paint and debris from falling in the river during bridge and conduit maintenance at all active stream crossings.
- The City will avoid or minimize erosion during repair and maintenance of all water supply infrastructure.
- Water drained from the conduits will be dechlorinated and routed through energy dissipaters prior to releases in the nearest waterway.
- The City will not use insecticides on covered lands. The City will allow BPA to use the herbicide Garlon 3A in a limited manner on the BPA transmission line easement on City land (see Section 8.7 for more information). The City will avoid or minimize use of other herbicides on covered lands except as necessary to control invasive plants. Plans for herbicide use that might affect habitat for covered species will be provided to NMFS for preapproval.
- The City will use fertilizers on lands, if necessary, to encourage plant establishment and growth after projects that cause ground disturbance (e.g., as part of hydroseeding).
- The City will remove trees in riparian areas if they threaten City facilities or pose a significant risk to human safety. The City will plant replacement trees in the same approximate locations if trees of greater than 12 inches diameter at breast height are cut.

Sandy River Station

- Within HCP Years 1–10, the City will evaluate stormwater drainage at Sandy River Station and improve facilities if needed.

Status of Work for Calendar Year 2019

Covered Lands

The City followed all of the commitments stated in Measure O&M-1.

Sandy River Station

The City evaluated the stormwater drainage system for Sandy River Station (SRS) in April 2018 and reported those results in the 2018 HCP Annual Compliance Report.

The stormwater drainage system evaluation has now been completed, and the City will continue with quarterly inspections and maintenance activities to ensure proper operation.

Planned Accomplishments for Calendar Year 2020

The City will continue to monitor the commitments stated in Measure O&M-1.

Measure O&M-2—Bull Run Spill Prevention

Location: Bull Run Watershed

Benefits: Avoid or minimize effects of operations and maintenance activities on covered lands

Contact: Steve Kucas, Environmental Compliance Manager, PWB Resource Protection

Primary Objective

The City will implement the Bull Run Spill Prevention measure to address the potential impacts of maintaining and operating its water supply facilities in the watershed.

Measure Commitments

Measure O&M-2—Bull Run Spill Prevention: For HCP Years 1-50, the City will implement the following actions to avoid or minimize spill effects on the species covered or addressed in the HCP in the Bull Run River and Sandy River:

Headworks

- Fuel and chlorine deliveries will be escorted by a pilot car via paved roads.
- Secondary containment will be provided for the fuel tanks.
- Containment basins will be inspected and pumped out as needed.

Sandy River Station

- Secondary containment systems will be provided for the fuel tanks and pumps to contain any leaks. Containment basins will be inspected and pumped out as needed.
- Within Years 1-5 of the HCP, the City will evaluate the feasibility of moving existing fuel tanks and pumps out of the Sandy River floodplain. This feasibility analysis will be done in conjunction with a City capital improvement project.

Status of Work for Calendar Year 2019

The City complied with all of the commitments in Measure O&M-2 in 2019.

Planned Accomplishments for Calendar Year 2020

The City will continue to monitor adherence to the commitments in Measure O&M-2.

4.1.2 Offsite Measures

The City is implementing conservation measures on land in various locations throughout the Sandy River Basin. The measures are grouped by type: riparian easements and improvements, acquisition of water rights, fish passage, carcass placement, large wood and log jam placement, channel restoration, and terrestrial wildlife habitat conservation.

4.1.2.1 Riparian Easements and Improvements

From the HCP, the City has committed to obtaining easements from willing landowners for a total of 373 acres of riparian lands. The current easement targets are 166, 99, and 108 acres for the lower, middle, and upper Sandy River watershed, respectively (Table 8). For adaptive management reasons, the easement targets have been changed slightly for individual conservation measures. Compliance will be determined by the acres specified, aggregated into the three portions of the basin. The City must obtain the total target acreage by Year 15 of the HCP (2024).

When applicable, the measurable habitat objectives define a number of acres for riparian easements. The intent is for the easements to provide a minimum of a 100-foot-wide buffer from the top of the mean high-water level in the specified reach. The total acres per reach may or may not be contiguous, depending on the opportunities to contact willing sellers.

Table 8. Easement Acre Targets and Acres Obtained for HCP Implementation, Year 10 (2019)

Measure Code	Reaches	HCP Years	Easement Acre Targets	Acres Obtained by Year		Total Acres Obtained
				2010–2018	2018	
Lower Sandy Watershed						
H-11	Sandy 1	2010–2014	0	—	—	—
H-12	Sandy 2	2010–2014	143	145	0	145
H-13	Gordon 1A, 1B	2010–2014	23	23	0	23
		Subtotal	166	168	0	168
Middle Sandy Watershed						
H-14	Sandy 3	2020–2024	7	17	0	17
H-15	Cedar 2 & 3	2015–2019	49	25	—	25
H-16	Alder 1A & 2	2010–2014	43	0	0	0
—[a]	Lower Bull Run River	2012	0	34	0	34
		Subtotal	99	76	0	76
Upper Sandy Watershed						
—[b]	Sandy 7		0	29	20	29
H-18	Sandy 8	2020–2024	25	2	0	2
H-19	Salmon 1	2015–2019	23	0	0	0
H-20	Salmon 2	2020–2024	36	0	0	0
H-21	Salmon 3	2020–2024	12	0	0	0
H-22	Boulder 1	2010–2014	0	0	0	0
H-28	Zigzag 1A & 1B	2020–2024	12	0	0	0
		Subtotal	108	31	0	31
	Grand Total		**373**	**275**	**20**	**295**

[a]No associated HCP measure. The City of Portland acquired land around the lower Bull Run River, as authorized by NMFS, on September 16, 2011 (see summary in Appendix J, Item 3).

[b]No associated HCP measure. The City of Portland acquired an easement in Sandy 7, as authorized by NMFS, on February 13, 2017 (see summary in Appendix J, Item 12.

Measures H-12 and H-13–Riparian Easements and Improvements

Location: Lower Sandy River, middle Sandy River, and upper Sandy River watersheds

Benefits: Improve riparian and instream habitat

Contact: Angie Kimpo, Environmental Program Coordinator

Primary Objective

The City has identified habitat conservation measures that will improve riparian-zone conditions. The land easements will improve a minimum of 100 feet of riparian forest on either side of the active channel width of the river or creeks. The conservation measures include silvicultural practices (e.g., selective thinning and tree planting) to improve the riparian zones. The acreage totals for the land protection easements are calculated by multiplying the lineal distance of the stream by the amount of riparian forest protected by the easement.

A general riparian easement and improvement measure description is provided so that duplicate text is not repeated. The specific HCP measures from the three areas of the Sandy River Basin differ only by the total acreage targets.

Measure Commitments

Within HCP Years 1–5, the City will acquire 100–foot–wide land protection easements from willing private landowners for at least XX acres, which will comprise the total number of lineal feet x 100 feet of riparian width on either side of the Sandy River in the named reaches. At a minimum, the easements will be maintained for the term of the HCP. The City will also consider, on a voluntary and case–by–case basis, obtaining easements with durations longer than the term of the HCP and greater than 100 feet wide. The HCP funding for purchasing and maintaining each easement will be limited to what is defined in Chapter 11 of the HCP for that measure. The easement areas will be managed to support forest of ≥70 percent conifer trees (by canopy cover) where site conditions are conducive to the growth of conifers. Deciduous trees will be selectively thinned, and the easement will be replanted with conifers. If the easement area is not conducive to the growth of conifers, the area will be managed to support the growth of native hardwood species. Management of the easements will also include control of invasive plant species.

Status of Work for Calendar Year 2019

Since the creation of the conservation easement measures in the HCP, land ownership in the Sandy River Basin has changed tremendously. Many private land parcels have been purchased and converted to public lands in the target areas for the HCP easements. The City will continue to assess potential easements and communicate with NMFS about potential habitat benefits and acreage totals for various locations in the Sandy River Basin.

The City has finalized easements for 295 acres (Table 8). The City acquired two easements totaling 20 acres in reach Sandy 7 during 2019. The City is ahead of schedule for acquiring conservation easements in the Sandy River Basin.

For all easements or acquired riparian buffer areas, canopy cover is estimated both prior to work onsite and after planting in five-year increments to determine progress towards canopy cover goals.

Table 9 summarizes the location, acreage total, and condition of the canopy cover for the easements that the City has obtained to date.

The City is obligated to treat all easement areas so that the canopy cover exceeds 70 percent conifer trees, or native hardwood species as the site conditions dictate, over the term of the HCP. The canopy cover for the Mench, TNC Kingfisher, TNC Hyman, and Clackamas easements exceeds the $\geq$70 percent criterion stated in the HCP. The City will continue to track the canopy cover for all easements.

Figure 10. Young Cedar Grove on the Denney Conservation Easement

Table 9. Location, Amount, and Estimate of Canopy Cover for Easements, HCP Year 10 (2019)

Reach/ Property Owner	Year Acquired	Number of Easements	Acres	Initial Canopy Cover Estimate[a]	Five-Year Canopy Cover Estimate
Gordon 1A & 1B		2	**23 Total**		
Maunder	2011		3	45%	45%
Bonner	2012		20	44%	43%
Sandy 2		1	**145 Total**		
TNC Kingfisher	2014		25	71%	
TNC Cornwall	2014		13	64%	61%
TNC Diack	2014		35	53%	50%
TNC Hyman	2014		2	82%	83%
TNC Partridge	2014		16	40%	37%
Camp Collins	2013	1	54	60%	61%
Cedar 2 & 3		2	**25 Total**		
Lowy	2015		9	30%	
Harrison	2015		16	61%	
Lower Bull Run			**34 Total**		
City of Portland	2013		34	52%	
Sandy 3		1	**17 Total**		
Rayne	2011		17	28%	45%
Sandy 7		3	**49 Total**		
Clackamas County	2017		29	79%	
Conlin	2019		9	60%	
Denney	2019		11	69%	
Sandy 8	2011	1	**2 Total**		
Mench	2011		2	92%	96%

Abbreviation: TNC is The Nature Conservancy

[a]Canopy cover data are collected approximately within the first year of easement acquisition and every five years after that.

Planned Accomplishments for Future Years

The City has completed enough easement acquisition. To support that assertion, the City looked at the projected habitat and fish benefits associated with the original HCP conservation easements and compared that to the projections for the actual easements acquired through 2019. The projected fish benefits associated with this easement program meet or greatly exceed the projections from the original HCP. All of this information is summarized in Appendix A of this report.

The City does not plan to pursue addition easements but will continue to monitor canopy cover for existing easements to document HCP compliance.

Figure 11. Looking Across the Sandy River at the Conlin Easement (North Side)

Measures H-23 and H-24–Salmon 2 Miller Quarry Acquisition and Restoration

Location: Salmon River watershed

Benefits: Improve riparian and instream habitat

Contact: Steve Kucas, Environmental Compliance Manager

Primary Objectives

Acquire the Miller Quarry parcel on the Salmon River and implement measures to improve riparian-zone conditions.

Measure Commitments

H-23: Within HCP Years 6-10, the 40-acre Miller Quarry parcel in reach Salmon 2 will be purchased. The restoration commitments are described in Measure H-24.

H-24: Within HCP Years 11-15, the City will remove riprap along 0.25 mile of riverfront of the Miller Quarry parcel to reconnect floodplain and side-channel habitat. Approximately 1,000 feet of new side channel will be opened. 160 pieces of large wood (LW) will be placed in the side channel to create approximately eight log jams. Approximately four acres of riparian zone will be amended with soil and then replanted with suitable riparian species.

Status of Work for Calendar Year 2019

The City has worked on acquisition of the Miller Quarry property since 2011. The steps that the City has taken were described in the 2016 Annual Compliance Report.

The City is unable to complete the purchase and, subsequently, the restoration of the Miller Quarry property on the Salmon River.

For Measures H-23 and H-24, there were projected habitat and fish benefits as described in the HCP. The City will make up for the loss of projected habitat and fish benefits from this measure with the implementation of other conservation measures. This plan is described in detail in Appendix A of this report.

Planned Accomplishments for Future Years

NMFS and ODEQ will review the accomplishments of all HCP conservation measures to date, as described in Appendix A. The City does not anticipate additional efforts to implement Measures H-23 and H-24.

4.1.2.2 Water Rights

Measure F-5—Cedar Creek Purchase Water Right

Location: Cedar Creek in Sandy River Basin

Benefits: Improve instream habitat

Contact: Hassan Basagic, Watershed GIS Specialist, PWB Resource Protection

Primary Objective

Cedar Creek is a populated watershed with numerous privately owned parcels and associated water rights for rural residential and agricultural purposes. The creek has elevated water temperatures in late summer, partially due to water withdrawals. The City will acquire water rights to improve water quality and base flows in Cedar Creek for steelhead, Coho, and Cutthroat Trout.

Measure Commitments

Measure F-5—Cedar Creek Purchase Water Rights: Within the first 10 years of the HCP term, the City will acquire approximately 50 percent of the current certificated surface water rights that affect summer flows on Cedar Creek. These water rights will be acquired from willing sellers and will be converted to instream use for at least the term of the HCP.

Status of Work for Calendar Year 2019

In previous annual compliance reports, the City documented the history of action taken for this conservation measure. The City has found no willing sellers of certified surface water rights in the Cedar Creek drainage. The City will not be able to implement this measure.

For this measure, there were small projected habitat and fish benefits as described in the HCP. The City will make up for the loss of projected habitat and fish benefits from this measure with the implementation of other conservation measures. This plan is described in detail in Appendix A of this report.

Planned Accomplishments for Future Years

NMFS and ODEQ will review the accomplishments of all HCP conservation measures to date, as described in Appendix A. The City does not anticipate additional efforts to implement Measure F-5.

4.1.2.3 Large Wood Placement

Measure H-4—Sandy 2 Log Jams and Measure H—27 Zigzag Channel Design

Location: Sandy River

Benefits: Improve instream habitat

Contact: Burke Strobel, Fish Biologist, PWB Resource Protection

Primary Objective

The City's large wood measures are being implemented to help restore key habitat for fish. The large wood additions for Measure H-4, for example, will increase habitat complexity, providing benefits such as pools and cover for migrating, spawning, and rearing fish in the Sandy River reach 2. Restoring side channel flow for Measure H-4 and removing berms for Measure H-27 will reconnect rivers with their riparian zones.

Section 4.2.1 of this report describes the effectiveness monitoring methods for these measures.

Measure Commitments

The commitments for Measure H-4 have been changed from what was described in the HCP to incorporate benefits from another measure, H-9, which will not be implemented, and to move H-4 benefits planned for Sandy 1 to Sandy 2. Within HCP Years 6-10, the City will work with willing landowners to place a minimum of 530 key logs into the Sandy River in a way that restores flow to at least 2,100 lineal feet of side channel. The City will also increase off-channel habitat in the reach by 8,164 square feet. Large wood will be placed avoiding federal land, land without landowner permission, and land where the preexisting large wood quantity is already adequate. Large wood quantities were chosen to achieve placement densities of approximately 75 pieces per mile on average for the originally planned treatment reach, Sandy 2.

Within HCP Years 11-15, the City will work with willing landowners to modify Zigzag 1A to create more natural channel conditions. Approximately one-half mile of new side channel will be created, and an additional one-half mile of existing side channel will be improved. A minimum of 270 pieces of large wood will be placed in the side channel and mainstem of Zigzag 1A.

Individual LW pieces will be sound conifer logs with a small-end diameter of at least 12 inches and a length of at least 30 feet. The key pieces will be placed to collect other additional woody debris. If available, large root wads will also be selected for placement. Artificial anchoring of the wood will be used only when wood movement cannot be tolerated. Anchoring will be used only if the large wood might move downstream and damage road culverts, bridges, private property, or other streamside improvements. It is desirable for the stream to redistribute the placed large wood to some extent as long as damage is avoided. Methods and timing for LW placement will be determined in consultation with NMFS and the ODFW.

The LW placements will be maintained for 15 years. Year 1 of the maintenance will be the calendar year following the wood placement.

Effectiveness monitoring is described in Section 4.2.1 of this report.

Status of Work for Calendar Year 2019

Under the terms of HCP measure H-4, Sandy 2 Log Jams, the City is obligated to place 530 key logs in the Sandy River in a way that activates at least 2,100 feet of side channel at bankfull flows and to create 8,164 square feet of off-channel habitat. HCP Measure H-9 will not be implemented, and habitat goals were added to Measure H-4 (see Appendix H, Item 10 in the 2015 Annual Compliance Report), including the addition of off-channel habitat and the placement of additional large wood.

Under the terms of HCP measure H-27, the City is obligated to place 270 key logs and rootwads in the Zigzag River and to remove berms in a way that reconnects or improves up to one mile of side channels and provides habitat complexity.

H-4 Sandy 1 and 2 Log Jams

Construction relating to Measure H-4 was completed in 2018, and revegetation efforts continued in 2019. Revegetation work focused on maintaining plantings and the creation of wetlands as compensatory mitigation for wetlands disturbed by the reintroduction of water to the historic side channel.

Figure 12. Zigzag Large 1A Channel Design; Apex Log Jam at the Downstream-most Berm Breach

H-27 Zigzag 1A Channel Design

Measure H-27 was constructed and completed in 2019. The City provided 281 logs, project performance criteria, and funding to the U.S. Forest Service, who led design and construction tasks. Berms were removed at six locations to reconnect the Zigzag River to approximately 18 acres of floodplain. Six apex engineered log jams were built, and in-channel large wood pieces were placed at various locations.

Planned Accomplishments for Calendar Year 2020

H-4 Sandy 1 and 2 Log Jams

The City plans to continue revegetation for this measure, focusing on completing compensatory wetland mitigation requirements. All plantings will be maintained for an additional two years after the completion of revegetation.

4.1.2.4 Terrestrial Wildlife Habitat Conservation

Measures W-1, W-2, and W-3—Minimum Impacts to Spotted Owls, Bald Eagles, and Fishers

Location: Sandy River Basin

Benefits: Avoid disturbance of species' habitat

Contact: Steve Kucas, Environmental Compliance Manager, PWB Resource Protection

Primary Objectives

The objective for Measures W-1 and W-2 is to avoid or minimize the periodic, temporary disturbance of habitat that might result from the routine operation, maintenance, and repair of water supply facility from implementation of HCP measures.

Although fishers have not been found in the Sandy River Basin, the City developed Measure W-3 as a contingency habitat measure to avoid or minimize impacts to fishers during the performance of covered activities in the basin.

Measure W-1 Commitments

Measure W-1—Minimize Impacts to Nesting Spotted Owls: For the term of the HCP, the City will take steps to avoid or minimize impacts to nesting spotted owls on all covered lands. The terms of the measure are described on page 7-66 to 7-69 of the HCP.

Measure W-2 Commitments

Measure W-2—Minimize Impacts to Bald Eagles: For the term of the HCP, the City will take steps to avoid or minimize impacts to bald eagles on all covered lands. The terms of the measure are described on page 7-69 to 7-74 of the HCP.

Measure W-3 Commitment

Measure W-3—Minimize Impacts to Fishers: If the fisher is found to occur within 30 miles of the Bull Run Watershed or the locations of any unfinished HCP measures, the City will meet with U.S. Fish and Wildlife Service (USFWS) to discuss whether any steps need to be taken to avoid or minimize impacts to fishers during the performance of the covered activities.

Status of Work for Calendar Year 2019

For Measures W-1, W-2, and W-3, the City avoided or minimized impacts to spotted owls and bald eagles for all City projects in 2019.

Fishers have not been found to occur anywhere near the Bull Run Watershed, and therefore, no avoidance or minimization actions were necessary.

Planned Accomplishments for Calendar Year 2020

The City will continue to evaluate potential impacts to spotted owls and eagles when considering City projects. The City will continue to be vigilant about any information related to fishers and will consider such information during the performance of covered activities.

4.1.3 Monitoring for Clean Water Act 401 Certification Conditions

As part of HCP Measure T-2—Post-infrastructure Temperature Management—PWB completed a project to modify a water intake tower at Bull Run Dam 2 to allow withdrawal of water from the reservoir at different levels. PWB has a non-capacity license amendment with the Federal Energy Regulatory Commission (FERC) for the tower modifications. According to Section 401 of the Clean Water Act (CWA) and as part of the condition of the amended hydroelectric project license from FERC, the Oregon Department of Environmental Quality (ODEQ) reviewed the impacts of the proposed Bull Run Dam 2 Tower project on water-quality parameters that have the potential to be affected by construction on the intake tower. The five water-quality standards that had the potential to be affected by work in Bull Run Reservoir 2 are listed in Table 10 with the language from the Oregon Administrative Rule that describes the standard.

Table 10. Water Quality Parameters to Monitor for CWA Section 401 Certification

Water Quality Parameter	Potential Impact Description in Oregon Administrative Rule
Nuisance Phytoplankton Growth	Changes in reservoir circulation may lead to changes in nutrient concentrations, which in turn may lead to algal blooms.
Creation of Taste, Odors, Toxic Conditions	Taste and odor or toxic conditions can occur from nuisance algal blooms.
Dissolved Oxygen (DO)	Changes in water circulation in reservoir may alter dissolved oxygen concentration, especially at depth with change in residence time deep in reservoir; algal bloom respiration and decay may also consume DO.
pH	Algal blooms may cause spikes in pH values.
Temperature	Changes in withdrawal depth may result in temperature changes downstream.

The City monitored water quality parameters for five consecutive years (2014–2018), as directed in the 401 Certification. The monitored water quality parameters showed either no differences from the baseline conditions, slight changes, or still require future monitoring beyond the time frame conditions of the 401 certification. All of the previous monitoring results are summarized in the 2018 HCP Compliance Report. The City will continue to monitor and report on downstream water temperature for the lower Bull Run River and report back to ODEQ and NMFS via direct conversations, biweekly reports during the summer and early fall, and the annual compliance reports for Habitat Conservation Plan activities.

4.2 Effectiveness Monitoring

The City is conducting effectiveness monitoring for some of the HCP conservation measures. Those measures include large wood placement/log jam creation, side-channel development, river mouth reestablishment, and floodplain reconnection. For these measures, there is some degree of uncertainty about the biological effectiveness.[1] All effectiveness monitoring is conducted to test the hypothesis that at least 80 percent of the projected changes in the key habitat variables will occur in each stream reach. The City is using the habitat variable ratings from the Ecosystem Diagnosis and Treatment (EDT) model and has provided estimated improvements from HCP measures in Appendix E of the HCP. For a detailed description of effectiveness monitoring for offsite in-channel conservation measures, including sampling methods and assessment procedures, see Appendix A of the HCP.

4.2.1 Large Wood and Log Jam Placement

Measures H-4, H-5, H-6, and H-27—Large Wood Placement

Location: Sandy River, Gordon Creek, Trout Creek, and Zigzag River in the Sandy River Basin

Benefits: In-stream habitat

Contact: Burke Strobel, Fish Biologist, PWB Resource Protection

Primary Objective

The City's large wood measures are being implemented to help restore key habitat for fish. The large wood additions will increase habitat complexity, providing benefits such as pools and cover for migrating, spawning, and rearing fish in the Sandy River reach 2, Gordon Creek reaches 1A and 1B, Trout Creek reach 1A, and Zigzag River reach 1A.

Measure Commitments

The measure commitments for HCP Measures H-4, H-5, H-6, and H-27 are described in Section 4.1.2.3, which starts on page 43 of this report.

Measurable Habitat Objectives

The measurable habitat objectives for the large wood measures share the common objective of achieving 80 percent of the predicted increase in pieces of large wood within 15 years of implementation. Additional habitat objectives include the following: come within 80 percent of the predicted increase in off-channel habitat in Sandy reach 2, achieve 80 percent of the predicted increase in pool and pool tail habitat in Gordon

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[1] In some cases, the City does not plan to conduct effectiveness monitoring because the outcomes are already known and are well-supported by the available scientific literature.

Creek reaches 1A and 1B, and attain 80 percent of the predicted decrease in artificial confinement and increase in pools in the Zigzag River reach 1A within 15 years of implementation. Reach 1A of Trout Creek has no additional habitat objectives associated with instream conservation measures.

Effectiveness Monitoring Method

To test whether the habitat variable ratings in the current EDT database are representative of pre-project conditions, and to determine whether the projected increases in habitat ratings are an accurate representation of post-project conditions, the City is implementing the following monitoring methodology:

- Conduct baseline habitat surveys in both the project reaches and in upstream control reaches, where no habitat enhancement projects are planned.
- Conduct post-project habitat surveys in both the project reaches and in upstream control reaches.
- Compare the baseline and post-project survey results for project and control reaches. Effectiveness will be evaluated by comparing observed changes with the measurable habitat objectives after adjusting for background changes observed in control reaches.

Status of Work for Calendar Year 2019

The City fully complied with the effectiveness monitoring as required by the HCP for Measures H-4, H-5, H,6, and H-27 in 2019. Baseline monitoring continued for Measure H-27, and post-treatment began for Measure H-4 and continued for Measure H-5 and H-6. The specific monitoring accomplishments are referenced by measure name (e.g., Gordon 1A and 1B LW Placement) in Appendix B of this report.

Planned Accomplishments for Calendar Year 2020

The collection of post-treatment data for effectiveness monitoring will begin in 2020 in the Zigzag River for Measure H-27. Post-treatment data collection for effectiveness monitoring will continue in 2020 in Cedar Creek for Measure H-17. Post-treatment habitat surveys will follow protocols identical to those used in 2019.

4.3 Research Program

4.3.1 Bull Run Research

4.3.1.1 Spawning Gravel Placement

Under the HCP, the City places spawning gravel in the lower Bull Run River to increase spawning habitat, primarily for Chinook Salmon and steelhead. Each year, the City evaluates the gravel placement to determine the amount of resulting surface area covered by gravel suitable for spawning salmon and steelhead (see Figure 13).

The City conducted this evaluation of spawning gravel placement as planned in 2019. The combined surface area of adequately sized spawning gravel patches was significantly higher than the baseline average for steelhead and for Chinook at all flows. The surface area of spawning gravel in 2019 was within the range of previous years (2010–2018) at all locations and flows and was the largest observed since 2015. A detailed account of the gravel placement protocol is available in Appendix F of the HCP. The current status of spawning gravel placement is detailed in Appendix C of this report.

4.3.1.2 Gravel Scour

The City measures the depth to which high flows in the lower Bull Run River scour gravel patches that Chinook Salmon have used for spawning. Scour depth is compared to the depth range at which Chinook Salmon tend to bury their eggs in order to evaluate the likely success of Chinook Salmon egg incubation in the lower river.

The City monitored gravel scour during the winter of 2018–2019. This was the third of five planned years of gravel scour monitoring. Only 11 of 20 scour monitoring devices could be relocated, resulting in data for 7 out of 10 monitored Chinook redds. Three of 7 redds (43 percent) were scoured to a depth where eggs in a typical Chinook redd would be impacted. Three of the relocated devices, however, had been scoured to their maximum depth, and the majority of the 9 devices that could not be relocated were probably fully scoured and washed downstream. Significant effort was expended trying to find them at the locations where they had been installed. All monitored Chinook Salmon redds were made in gravel patches that were shallower than Chinook prefer. It is likely that most of them were disturbed to some extent by scouring flows.

A detailed description of the Gravel Scour monitoring protocol is available in Appendix F of the HCP. The results of this year's Gravel Scour Monitoring are in Appendix D of this report.

Figure 13. PWB Staff Installing a Gravel Scour Monitoring Device in the Lower Bull Run River Adjacent to a Chinook Salmon Redd

4.3.1.3 Total Dissolved Gas

The City has evaluated the structures, valves, and turbines in the Bull Run water supply system since 2005 to determine whether any facilities would exceed the state standard for total dissolved gas (TDG). For the state standard, the concentration of total dissolved gas relative to atmospheric pressure at a sample collection point may not exceed 110 percent of saturation except when stream flow exceeds the 10-year, 7-day average flood. Additional TDG data were collected on two occasions in 2019, and those measurements were below the 110% threshold.

The City has measured TDG levels in excess of 110 percent at river flows below the 10-year, 7-day average flood (7Q10) flow on three occasions in the past. On all three occasions, the water with high TDG levels had not yet had a chance to mix with the low-TDG water from Powerhouse 2. The average saturation level for TDG in the river was calculated to be less than 110 percent.

The detailed account of the TDG evaluation protocol is available in Appendix F of the HCP. The results of the TDG evaluation are in Appendix F of this report.

4.3.1.4 Bull Run Adult Chinook Population

In conjunction with other agencies in the Sandy River Basin, the City has partially funded research of the status of fish listed under the Endangered Species Act. The results of the research will be evaluated along with the results of the City's effectiveness monitoring to determine the City's adaptive management response over time.

The City collects adult Chinook Salmon information for the lower Bull Run River. The City conducts annual surveys of the lower river from RM 0 to RM 6.0 to count adult spring and fall Chinook Salmon from August through mid-December. Surveys will be conducted on a weekly basis provided instream flows allow for safe navigation of the river channel. Overall, the City anticipates funding 20 years of surveys over the 50-year term of the HCP.

The City conducted this annual survey of the Bull Run Chinook population as planned in 2019, but personnel issues and high flows in mid-October prevented scheduled surveys from being conducted on two occasions. The peak adult Chinook count and minimum escapement[2] estimate in 2019 were the lowest recorded since 2005. The cumulative redd counts for both spring and fall Chinook, however, were within the range of past years' estimates.

A detailed description of the Bull Run Adult Chinook Population Research protocol is available in Appendix H of the HCP. The results of the current year's survey are available in Appendix G of this report.

Additional surveys were conducted on three occasions — in June, July, and August — following different protocols from those described in HCP Appendix H. The additional surveys were snorkel counts to evaluate the effectiveness of a weir near the mouth of the Bull Run River operated by ODFW to collect returning adult hatchery Chinook Salmon. A maximum of 10 hatchery adult Chinook were observed while snorkeling the Bull Run River during the summer. These Chinook probably entered before installation of the ODFW weir. No effort was made to remove them because of the small number.

4.3.2 Sandy River Basin Research

4.3.2.1 Sandy River Basin Juvenile Outmigrants

Although the HCP is habitat-based and not focused on the specific population responses of the species, information about juvenile outmigrants (JOMs) is needed to obtain a complete picture of the condition and change in freshwater productivity through time. The results of the JOM research will be evaluated with other monitoring results to determine the City's adaptive management response over time.

The City will provide funds for collecting JOM information in the Sandy River Basin. This money will be leveraged with other funds to create a coordinated monitoring program. Twelve sites in the basin will be monitored and will serve as an index for the entire basin.

The City and its partners monitored JOM production in seven streams in 2019, one less than planned: Clear Fork Sandy, Still Creek, Zigzag River, Bull Run River, Little Sandy

[2] Escapement is the number of fish that avoid or escape all harvest and return to spawn in their home streams.

River, Gordon Creek, and Beaver Creek. Cedar Creek was not monitored as planned because of a landowner dispute. Population estimates were calculated for steelhead and Coho smolts in seven streams, and fork length distributions, condition factors, and emigration patterns were analyzed. The ages of smolts from Lost Creek, Still Creek, Clear Creek, Salmon River, Cedar Creek, Little Sandy River, Bull Run River, Gordon Creek, and Beaver Creek from 2018 were calculated by aging fish using fish scale samples, and those ages were added to age distribution information for all trap sites derived from fish scales collected between 2009 and 2016.

Steelhead and Coho smolts from different streams in the Sandy River Basin showed significant differences in weighted mean fork length of smolts. Low-elevation streams had longer smolts than high-elevation streams.

Steelhead and Coho smolts from different streams in the Sandy River Basin also showed significant differences in mean condition factors. Condition factors negatively correlated weakly with fork length.

Steelhead smolts emigrated earlier, on average, than Coho smolts in most streams. Steelhead emigrated earlier from low-elevation than from higher-elevation streams, while Coho showed no geographic pattern.

High-elevation streams had a larger proportion of older-age steelhead and Coho smolts. Length-at-age calculations revealed that steelhead smolt fork lengths are shorter on average for a given age in higher-elevation streams than in low-elevation streams, as is seen in Coho, but this fact is masked by their older average age.

The City's specific commitments and the approach to JOM research are outlined in Appendix H of the HCP. The results of this research are presented in Appendix H of this report.

4.4 Adaptive Management Program

The Bull Run HCP defined adaptive management along two concurrent tracks: adaptive responses for individual measures and decision milestones for addressing the effectiveness of the HCP as a whole. Through monitoring, the City will evaluate its progress on implementation as well as effectiveness of the measures. Should monitoring results indicate, the City will use its adaptive management program to change its approach.

If monitoring results indicate that a measure cannot be implemented, that an instream measure has not met its measurable objective, or that factors outside the City's control have reduced the habitat benefits of a measure by more than 20 percent, then the City will implement adaptive management. The adaptive management response includes several factors: consultation with NMFS, site surveys, and rerunning the EDT model to characterize baseline watershed conditions.

If, after taking these steps, the City and NMFS reach the conclusion that an additional or substitute measure is necessary, the City will follow the guidelines outlined in Chapter 9 (Section 9.4.3) of the HCP in its approach. Costs for implementing additional measures after the original measure has been implemented will be paid from the adaptive management section of the Habitat Fund. See the description of the Habitat Fund measure, below.

Measure H-30—Habitat Fund

Location: Covered lands

Benefits: Assists in meeting HCP objectives

Contact: Steve Kucas, Environmental Compliance Manager, PWB Resource Protection

The adaptive management portion of the Habitat Fund will be used to implement additional projects if one or more of the offsite measures does not meet its objectives. The Sandy River Basin Partners' portion of the fund will be used to implement additional habitat projects that help compensate for water system impacts not fully addressed by other projects. The details of the Habitat Fund measure are presented in Chapters 7 and 11 of the HCP.

Primary Objective

The Habitat Fund enables adaptive management and allows the City to address water system impacts that may not otherwise be addressed, respond to unknown future opportunities, and contribute to partnership projects.

Measure Commitments

The City will provide money to create a Habitat Fund of $9 million. A $5-million portion of the Habitat Fund is available in four increments prior to HCP Year 20 and is dedicated to partnership projects. The increments are described in Chapters 9 and 11 of the HCP (see also Figure 11-1). The remaining $4 million is dedicated to adaptive management needs but will be used for additional partnership projects if not needed for adaptive management (see Chapters 9 and 11). Projects will be selected in consultation with the HCP Implementation Committee (see Chapter 9) and will be guided by the Sandy River Basin Restoration Strategy. The City and NMFS will make the final project selection decisions.

Of the $5 million, the City will specifically dedicate $1.7 million toward habitat enhancement projects on the Salmon River to be implemented jointly by the Sandy River Basin Partners and with additional funds from the Partners and/or from grants. If partnership funds cannot be obtained to implement these projects, the City funds will be used for other projects in the Sandy River Basin.

Based on an informal agreement in October 2004, the City will also work with the Partners to provide resources from the $5-million portion of the Habitat Fund to (1) participate in basin-wide efforts to control invasive plants that threaten riparian habitat, and (2) build the organizational capacity of the Partners to implement the basin-wide Restoration Strategy, including outreach.

Status of Work through June 2020

The City was in full compliance with Measure H-30—Habitat Fund.

Through June 2020, the City committed to fund one project for building funding capacity for the Sandy River Basin Partners, three projects to do scale analysis, one culvert replacement project in the Salmon River Basin, and nine restoration projects for the upper Sandy River, the Salmon River, Lost Creek, or Still Creek, which are priority restoration areas for the partners. The City committed a total of $1,221,594 through June 2020. See Table 11 for a summary of past projects.

The City has committed a total of $162,000 of Habitat Fund dollars through June 2021 to projects implemented by Sandy River Basin Partners. See Table 12 for projects from July 2020 through June 2021.

Table 11. Past Projects Funded through the HCP Habitat Fund

Number	Project Partner	Amount	Duration	Purpose
Grant Agreement 32000035	Oregon Trout	$25,000	2009	Build the capacity of the Sandy River Basin Partners in obtaining additional funding to help implement the Partners' restoration strategy
Grant Agreement 182484	Freshwater Trust	$50,000	July 2009 through June 2010	Partially fund implementation of the Sandy River Basin Short-term Restoration Strategy, partially fund stream restoration measures in the Salmon River and the Salmon River subbasin.
Grant Agreement 30001899	Freshwater Trust	$50,000	July 2010 through June 2011	Partially fund design and construction of habitat restoration projects to reconnect isolated habitat, restore habitat complexity, and monitor project impacts in the Salmon River subbasin.
Grant Agreement 32000592	Freshwater Trust	$50,000	July 2011 through June 2012	Fund design and construction of habitat restoration projects to reconnect isolated habitat and restore habitat complexity in the Salmon River subbasin.
Grant Agreement 30002765	Freshwater Trust	$70,780	Summer of 2012	Fund the purchase and installation of a culvert on side-channel 18 of the Salmon River.
Grant Agreement 32001021	Freshwater Trust	$127,500	July 2014 through June 2015	Fund the design and construction of habitat restoration projects on the Salmon River and Still Creek.

Table 11. Past Projects Funded through the HCP Habitat Fund				
Number	**Project Partner**	**Amount**	**Duration**	**Purpose**
Intergovernmental Agreement 30004381	Oregon Department of Fish and Wildlife	$12,105	July 2014 through June 2015	Complete a scale analysis of juvenile Coho Salmon and steelhead smolts to determine age structure and freshwater productivity.
Grant Agreement 32001148	Freshwater Trust	$100,000	July 2015 through June 2016	Fund the design and construction of habitat restoration projects in Still Creek.
30005230	Freshwater Trust	$96,458	July 2016 through June 2017	Fund the design and construction of habitat restoration projects on the Salmon River and Still Creek.
32001339	Sandy River Basin Watershed Council	$145,000	July 2016 through June 2017	Restoration work on the upper Sandy River.
Intergovernmental Agreement 30004381	Oregon Department of Fish and Wildlife	$6,385	July 2016 through June 2017	Complete a scale analysis of juvenile Coho Salmon and steelhead smolts to determine age structure and freshwater productivity.
32001489	Freshwater Trust	$148,398	July 2017 through June 2018	Restoration work on the Salmon River and Still Creek.
32001768	Freshwater Trust	$150,000	July 2018 through June 2019	Restoration work in the Salmon River and Lost Creek.
	Oregon Department of Fish and Wildlife	$7,485	July 2018 through June 2019	Scale analysis of juvenile Coho Salmon and steelhead smolts to determine age structure and freshwater productivity.
32001884	Freshwater Trust	$125,000	July 2019 through June 2020	Restoration work in the Salmon River and the Zigzag River.
32001963	Sandy River Watershed Council	$125,000	July 2019 through June 2020	Restoration work on Sandy–Salmon confluence.
30006124	Oregon Department of Fish and Wildlife	$7,483	July 2019 through June 2020	Scale analysis.
Subtotal for Past Projects		$1,221,594		

Planned Accomplishments through June 2021

The City has approved two projects from Sandy River Basin Partners to be implemented between July 2020 and June 30, 2021. The City will provide funding to The Freshwater Trust to support construction of habitat restoration projects on the Salmon River, Lost Creek, and the main Sandy River. The City will also continue to fund ODFW for scale analysis associated with Sandy Basin smolt trapping. Table 12 shows the projects planned to be funded through the HCP Habitat Fund.

Table 12. Planned Projects to be Funded through the HCP Habitat Fund

Number	Project Partner	Amount	Duration	Purpose
Not yet assigned	Freshwater Trust	$150,000	July 2020 through June 2021	Restoration work on the Salmon River and the Clear Fork.
Not yet assigned	Oregon Department of Fish and Wildlife Service	$ 12,000	July 2020 through June 30, 2021	Scale analysis.
Subtotal for Planned Projects		$162,000		

Table 13. Summary of All Measures

This table includes all of the HCP measures. Measures that are not relevant to this reporting year are shaded with a gray background. The Status column shows the activity for the measure in 2019 (HCP Year 10), whether the measure has been completed or removed from the HCP, and other relevant information. If the Status column is blank, the measure is yet to be implemented. In some cases, the status description includes a reference to an appendix where more detailed measure information is available.

Bull Run Measures–Compliance

#	Measure	Measurable Habitat Objective	Compliance Monitoring	Years	Status
F-1	**Minimum Instream Flow, Normal Water Years**	Provide instream flows	Record hourly flows at USGS Gage No. 1414000	2010–59	Ongoing measure. Measure was in full compliance for 2019.
F-2	**Minimum Instream Flows, Water Years with Critical Seasons**	Provide instream flows	Record hourly flows at USGS Gage No. 1414000	2010–59	Ongoing measure. Measure was in full compliance for 2019.
F-3	**Flow Downramping**	Maintain downramping rate at or below 2 inches/hour	Record hourly flows at USGS Gage No. 14140000	2010–59	Ongoing measure. Measure was in full compliance in 2019.
F-4	**Little Sandy Flow Agreement**	Avoid conflicts with natural instream flows	Document completion of flow agreement	2010–14	Measure was completed in 2014. Confirmed by NMFS December 4, 2014 (see Appendix J, Item 9).
T-1	**Pre-infrastructure Temperature Management**	Pre-infrastructure objective: Maintain water temperatures at or below 21 °C at Larson's Bridge	Record water temperatures hourly for the lower Bull Run River and Little Sandy River	2010–13	Measure was in full compliance for 2010–2013. Measure was completed in 2013.

Bull Run Measures–Compliance

#	Measure	Measurable Habitat Objective	Compliance Monitoring	Years	Status
T-2	**Post-infrastructure Temperature Management**	Post-infrastructure objective: Maintain water temperatures at their natural thermal potential	Record water temperatures hourly for the lower Bull Run River and Little Sandy River	2014–59	Ongoing measure. All infrastructure changes for the measure were completed by 2014. The City did not meet some water temperature targets in 2019.
P-1	**Walker Creek Fish Passage**	Provide year-round upstream and downstream passage for steelhead and Coho	Document passage conditions compared with NMFS design criteria	2010–14	Measure was completed in 2010.
R-1	**Reservoir Operations**	Avoid or minimize mortality of Cutthroat and Rainbow Trout	Document reservoir surface elevations	2010–59	Ongoing measure. Measure was in full compliance for 2019.
R-2	**Cutthroat Trout Rescue**	Prevent mortality of Cutthroat Trout in spillway canal	Document any fish mortality that occurs in the canal and/or during handling (prior to release)	2010–59	Measure was implemented from 2010–2012. Benefits to Cutthroat Trout were very low. The measure was cancelled in 2013. Change authorized by NMFS, April 26, 2013 (see Appendix H, Item 7 in the 2013 report).
R-3	**Reed Canarygrass Removal**	Improve one-third acre of habitat for Western toad, red-legged frog, and northwestern salamander through annual removal of reed canarygrass	Provide photo documentation of sites after reed canarygrass removal	2010–59	Ongoing measure. Measure was in full compliance for 2019. Appendix I summarizes 2019 monitoring conducted to determine whether the measure is having the desired outcomes.

Bull Run Measures–Compliance

#	Measure	Measurable Habitat Objective	Compliance Monitoring	Years	Status
H-1	**Spawning Gravel Placement**	Supply spawning gravel in amounts equivalent to natural accumulation	Survey the lower Bull Run River (RM 0.0–RM 6.0) annually in Years 1–10 and every five years thereafter Document the amount of gravel placed, the placement locations, and amount of gravel usable for spawning by fish in annual report as described in Appendix C of the HCP	2010–59	Ongoing measure. Measure was in full compliance for 2019.
H-2	**Riparian Land Protection**	Preserve the riparian forest on City land along the lower Bull Run River	Survey riparian forest condition during annual spawning and gravel surveys; document results in annual report	2010–59	Ongoing measure. Measure was in full compliance for 2018.
O&M-1	**Bull Run Infrastructure Operations and Maintenance**	Avoid or minimize the effects of operations and maintenance activities on covered lands in the Bull Run Watershed	Document any releases of sediment or debris to the reservoirs, the lower Bull Run River, or any tributary streams Document changes in stormwater facilities at Sandy River Station, if needed Document tree planting and success of revegetation efforts	2010–59	Ongoing measure. Measure was in full compliance for 2018.
O&M-2	**Bull Run Spill Prevention**	Avoid or minimize effects of spills from water supply operations on covered species in the Bull Run River and the Sandy River below the confluence with the Bull Run	Document any spills to the reservoirs, the lower Bull Run River, or to any tributary streams	2010–59	Ongoing measure. Measure was in full compliance for 2018.

Offsite Measures–Compliance

#	Measure	Measurable Habitat Objective	Compliance Monitoring	Years	Status
Riparian Easements and Improvements					
H-11	**Sandy 1 Riparian Easement and Improvement**	Establish riparian forest of ≥70% site potential trees (by canopy cover) for approximately 11 acres (with 100-foot buffer widths) within 15 years	Complete an aerial photograph analysis or site survey to determine whether planting is needed Repeat the analysis every five years for the term of the HCP to verify that initial planting has succeeded and/or if replanting is warranted Document date riparian easement is completed and when site potential forest is established	2010–14	Measure will not be implemented. Acreage target was moved to Measure H-12 Sandy 2 Riparian Easement and Improvement. Change authorized by NMFS on January 5, 2012 (see Appendix G, Item 5 in the 2012 report).
H-12	**Sandy 2 Riparian Easement and Improvement**	Establish riparian forest of ≥70% site potential trees (by canopy cover) for approximately 62 acres (with 100-foot buffer widths) within 15 years	Same as above	2010–14	Measure was completed in 2014. All easement acreage targets have been met for the lower Sandy River Basin. Canopy cover monitoring is ongoing.

Offsite Measures–Compliance

#	Measure	Measurable Habitat Objective	Compliance Monitoring	Years	Status
H-13	**Gordon 1A and 1B Riparian Easement and Improvement**	Establish riparian forest of ≥70% site potential trees (by canopy cover) for approximately 78 acres within 15 years of establishment of easement Fifteen (15) acres are added to this measure to compensate for the acreage anticipated from Boulder 1 Riparian Easement and Improvement (H-22).	Complete an aerial photograph analysis or site survey to determine whether planting is needed Repeat the analysis every five years for the term of the HCP to verify that initial planting has succeeded and/or if replanting is warranted Document date riparian easement is completed and when site potential forest is established	2010–14	23 acres of easement area obtained in Gordon Creek (20 acres in 2012; 3 acres in 2011). 70 acres moved to Sandy 2 Riparian Easement and Improvement. Change authorized by NMFS on September 25, 2012 (see Appendix G, Item 6 in the 2012 report). Measure was completed in 2014. All easement acreage targets have been met for the lower Sandy River Basin. Canopy cover monitoring is ongoing.
H-14	**Sandy 3 Riparian Easement and Improvement**	Establish riparian forest of ≥70% site potential trees (by canopy cover) for approximately 7 acres (with 100-foot buffer widths) within 15 years of establishment of easement	Same as above	2020–24	Measure was completed in 2012. Canopy cover monitoring is ongoing.
H-15	**Cedar 2 and 3 Riparian Easement and Improvement**	Establish riparian forest of >70% site potential trees (by canopy cover) for approximately 49 acres (with 100-foot buffer widths) within 15 years of establishment of easement	Same as above	2015–19	25 acres of easement area obtained in Cedar Creek in 2015. Measure is in process. Canopy cover monitoring is ongoing.

Offsite Measures–Compliance

#	Measure	Measurable Habitat Objective	Compliance Monitoring	Years	Status
H-16	**Alder 1A and 2 Riparian Easement and Improvement**	Establish riparian forest of >70% site potential trees (by canopy cover) for approximately 43 acres (with 100-foot buffer widths) within 15 years of establishment of easement	Same as above	2010–14	PWB is not pursuing easement acreage in Alder Creek due to unwillingness of private landowners to participate in program. The City is obtaining easements in reaches Sandy 7 and 8 to compensate for the acreage that could not be obtained in Alder Creek. Change authorized by NMFS, July 12, 2013, and February 13, 2017 (see Appendix J, Items 11 and 12).
	Sandy 7 Riparian Easement and Improvement	Establish riparian forest of ≥70% site potential trees (by canopy cover, with 100-foot buffer widths) within 15 years of establishment of easement	Same as above		29 acres of easement acquired in 2017. Change authorized by NMFS on February 13, 2017. Permission given to acquire easements on Sandy 7, 8 in lieu of Salmon 1, 2, 3 (see Appendix J, Item 12 in the 2017 report).
H-18	**Sandy 8 Riparian Easement and Improvement**	Establish riparian forest of ≥70% site potential trees (by canopy cover) for approximately 25 acres (with 100-foot buffer widths) within 15 years of establishment of easement	Same as above	2020–24	19 acres of easement from two landowners acquired in 2019. Easement acres in lieu of Measure H-16. Canopy cover monitoring is ongoing.

Offsite Measures–Compliance

#	Measure	Measurable Habitat Objective	Compliance Monitoring	Years	Status
H-19	**Salmon 1 Riparian Easement and Improvement**	Establish riparian forest of $\geq$70% site potential trees (by canopy cover) for approximately 23 acres (with 100-foot buffer widths) within 15 years of establishment of easement	Same as above	2015–19	This measure will not be implemented. The City is pursuing easements in Sandy 7, 8 to compensate for the acreage that could not be obtained in Salmon 1, 2, or 3. Change authorized by NMFS, February 13, 2017 (see Appendix I, Item 12, in the 2017 report).
H-20	**Salmon 2 Riparian Easement and Improvement**	Establish riparian forest of $\geq$70% site potential trees (by canopy cover) for approximately 36 acres (with 100-foot buffer widths) within 15 years. of establishment of easement	Same as above	2020–24	
H-21	**Salmon 3 Riparian Easement and Improvement**	Establish riparian forest of $\geq$70% site potential trees (by canopy cover) for approximately 12 acres (with 100-foot buffer widths) within 15 years of establishment of easement	Same as above	2020–24	
H-22	**Boulder 1 Riparian Easement and Improvement**	Establish riparian forest of >70% site potential trees (by canopy cover) for approximately 15 acres (with 100-foot buffer widths) within 15 years of establishment of easement	Same as above	2010–14	This measure will not be implemented. The City has obtained easements in Gordon Creek and the lower Sandy River to compensate for the acreage that could not be obtained in Boulder Creek. Change authorized by NMFS, May 11, 2011 (see Appendix F, Item 1, in the 2011 report).

Offsite Measures–Compliance

#	Measure	Measurable Habitat Objective	Compliance Monitoring	Years	Status
H-28	**Zigzag 1A/1B Riparian Easement and Improvement**	Establish riparian forest of >70% site potential trees (by canopy cover) for approximately 12 acres (with 100-foot buffer widths) within 15 years of establishment of easement	Same as above	2020–24	
H-23	**Salmon 2 Miller Quarry Acquisition**	Negotiate a sales agreement for the Miller Quarry property	Document purchase of the site in annual report Complete an aerial photograph analysis or site survey to determine whether planting is needed Repeat the analysis every five years for the term of the HCP to verify that initial planting has succeeded and/or if replanting is warranted Document date riparian easement is completed and when site potential forest is established	2015–19	PWB has worked since 2011 to purchase the Miller Quarry property. The property has lead contamination, which the sellers are unwilling to address. PWB is unable to purchase the property and will discuss the impacts to the measure's projected benefits with NMFS.

Offsite Measures–Compliance

#	Measure	Measurable Habitat Objective	Compliance Monitoring	Years	Status
H-24	**Salmon 2 Miller Quarry Restoration**	Establish riparian forest of >70% site potential trees (by canopy cover) for approximately 40 acres (with 100-foot buffer widths) within 15 years of acquisition	Document purchase of the site in annual report Complete an aerial photograph analysis or site survey to determine whether planting is needed Repeat the analysis every five years for the term of the HCP to verify that initial planting has succeeded and/or if replanting is warranted Document date riparian easement is completed and when site potential forest is established	2015–19	See Measure H-23. PWB cannot acquire, or restore, the Miller Quarry property. PWB will discuss measure with NMFS.
Water Rights					
F-5	**Cedar Creek Purchase Water Rights**	During HCP Years 1–10, purchase approximately 50% of the current surface water rights that affect summer flows	Document the rights purchased and the estimated amount of additional flow for fish	2010–19	Measure cannot be completed due to unwilling seller. PWB will discuss with NMFS.
Fish Passage					
P-2	**Alder 1 Fish Passage**	Provide year-round upstream and downstream passage for steelhead	Document passage conditions compared with NMFS design criteria once every three years after project implementation	2010–14	Measure was completed in 2013.
P-3	**Alder 1A Fish Passage**	Provide upstream and downstream passage for native fish during the months of water diversion operation	Same as above	2010–14	Measure was completed in 2014.

Offsite Measures–Compliance

#	Measure	Measurable Habitat Objective	Compliance Monitoring	Years	Status
P-4	**Cedar Creek 1 Fish Passage**	Provide up to $3.7 million dollars to fund fish passage improvements on Cedar Creek	Same as above	2010–14	Measure was completed in 2014.
Carcass Placement					
H-25	**Salmon 2 Carcass Placement**	Place 1,800 salmon carcasses in one season	Document number of carcasses, release sites, and year of implementation	2015–19	Measure was completed in the Zigzag and upper Sandy Rivers in 2013. Change authorized by NMFS, December 3, 2013 (see Appendix H, Item 8 in the 2013 report). Measure was completed early.
H-29	**Zigzag 1A, 1B, and 1C Carcass Placement**	Place 1,800 salmon carcasses in one season	Same as above	2020–24	Measure was completed in the Zigzag and upper Sandy Rivers in 2014. Change authorized by NMFS, December 3, 2013 (see Appendix H, Item 8 in the 2013 report). Measure was completed early.
Large Wood					
H-3	**Little Sandy 1 and 2 LW Placement**	Place 50 key pieces of LW and achieve 80% of predicted woody debris levels within 15 years of placement	Monitor number of pieces of wood in the stream as described in HCP Appendix F	2015–19	Measure was completed in 2014, earlier than specified in the HCP.

Offsite Measures–Compliance

#	Measure	Measurable Habitat Objective	Compliance Monitoring	Years	Status
H-4	**Sandy 2 Log Jams**	Place 2 engineered log jams and other large wood in reach Sandy 2, totaling 530 pieces. Increase off-channel habitat by 8,164 square feet. 80% of predicted woody debris levels will be attained within 15 years of placement.	Same as above	2015–19	Measure was completed in 2018. Measure incorporates benefit increases to offset those of canceled Measure H-9. Change authorized by NMFS, April 14, 2015 (see Appendix H, Item 10 in the 2015 report).
H-5	**Gordon 1A and 1B LW Placement**	Place 300 key pieces of LW in reaches Gordon 1A and 1B and achieve 80% of predicted woody debris levels within 15 years of placement An additional 65 key pieces of LW will be placed in reaches Gordon 1A and 1B to compensate for the wood that was not placed in Boulder 0 and 1.	Same as above	2010–14	Measure was completed in 2013.
H-6	**Trout 1A LW Placement**	Place 25 key pieces of LW and achieve 80% of predicted woody debris levels within 15 years of placement	Same as above	2010–14	Measure was completed in 2013.
H-7	**Trout 2A LW Placement**	Place 20 key pieces of LW in reach Trout 2A and achieve 80% of predicted woody debris levels within 15 years of placement	Same as above	2010–14	Measure will not be implemented. Large wood placements planned for this measure have been added to Trout 1A LW Placement project instead. Change authorized by NMFS, March 15, 2012 (see Appendix G, Item 4 in the 2012 report).

Offsite Measures–Compliance

#	Measure	Measurable Habitat Objective	Compliance Monitoring	Years	Status
H-17	**Cedar 2 and 3 LW Placement**	Place 600 key pieces of LW in reaches Cedar 2 and 3 and achieve 80% of predicted woody debris levels within 15 years of placement	Same as above	2015–19	Measure was completed in 2016. Only 470 pieces of LW were placed because of limited landowner permissions.
H-26	**Boulder 0 and 1 LW Placement**	Place 65 key pieces of LW in reaches Boulder 0 and 1 and achieve 80% of predicted woody debris levels within 15 years of placement	Same as above	2010–14	Measure will not be implemented. Large wood placements planned for this measure have been added to Gordon 1A and 1B LW Placement instead. Change authorized by NMFS, August 16, 2011 (see Appendix F, Item 2 in the 2011 report).
Channel Restoration					
H-8	**Sandy 1 Reestablishment of River Mouth**	Create one additional mile of stream by reconnecting with original river mouth	Document reestablishment of the historical Sandy River mouth	2015–19	The measure was completed in 2013, approximately five years ahead of schedule.
H-9	**Sandy 1 Channel Reconstruction**	Open one-third river miles of side-channel habitat Place 25 logs in side channel	Tag all side-channel logs at the time of placement for later identification Once every three years, resurvey the stream to document seasonal flooding of the side-channel habitat and determine how many pieces of LW are still within the side channel	2015–19	Measure will not be implemented. Large wood placements planned for this measure have been added to Measure H-4 Sandy 2 Log Jams instead. Change authorized by NMFS, April 14, 2015 (see Appendix H, Item 10 in the 2015 compliance report).

Offsite Measures–Compliance

#	Measure	Measurable Habitat Objective	Compliance Monitoring	Years	Status
H-10	**Sandy 1 Turtle Survey and Relocation**	Avoid direct impacts to western painted turtles and northwestern pond turtles	Document surveys of potential turtle habitat. Document all turtle relocations (species, number, locations, and dates) Note: Measure H-10 is only necessary for projects conducted in the Sandy River delta.	2015–19	Measure was completed in 2013 in conjunction with Measure H-8.
H-27	**Zigzag 1A Channel Design**	Open or improve one mile of side channel habitat for steelhead, Coho, and spring Chinook Place 270 pieces of LW in reach Zigzag 1A	Tag all pieces of LW at the time of placement for later identification Once every three years, resurvey the stream to determine how many pieces of LW are still within the side channel	2020–24	Measure implemented in 2019. Planning was initiated in 2018.
Terrestrial Wildlife Habitat Conservation					
W-1	**Minimize Impacts to Spotted Owls**	Avoid disturbance of active nesting habitat	Survey protocols for owls, eagles, and fishers have not yet been determined Protocols will be available within six months of the start of the HCP term	2010–59	Ongoing measure. Measure was in full compliance in 2019.
W-2	**Minimize Impacts to Bald Eagles**	Avoid disturbance of active winter night roosts or nests	Survey protocols for owls, eagles, and fishers have not yet been determined Protocols will be available within six months of the start of the HCP term	2010–59	Ongoing measure. Measure was in full compliance in 2019.
W-3	**Minimize Impacts to Fishers**	Avoid disturbance of fisher habitat	Survey protocols for owls, eagles, and fishers have not yet been determined Protocols will be available within six months of the start of the HCP term	2010–59	Ongoing measure. Measure was in full compliance in 2019.

Monitoring for Clean Water Act Section 401 Certification

Topic	Monitoring Protocol & Analysis	Results Reporting	Duration	Status and Report Location
Monitoring for CWA Section 401 Certification	Monitor for five required water-quality parameters	Include with annual compliance report	For the first 5 years of operation of the modified Bull Run Dam 2 Tower	Baseline data collection period was August 2012–December 2013. Monitoring occurred through 2018, as directed by ODEQ. Monitoring for lower Bull Run River water temperatures continues as described by Measure T-2.

Offsite Measures—Effectiveness

#	Measure	Measurable Habitat Objective	Effectiveness Monitoring	Years	Status
Large Wood					
H-5	**Gordon 1A and 1B LW Placement**	Achieve 80% of predicted increase in pieces of LW within 15 years of implementation	Conduct habitat surveys per monitoring protocol	2010–14	Measure was completed in 2013. Effectiveness monitoring will continue through 2025. See Appendix B.
H-6	**Trout 1A LW Placement**	Achieve 80% of predicted increase in pieces of LW within 15 years of implementation	Conduct habitat surveys per monitoring protocol	2010–14	Measure was completed in 2013. Effectiveness monitoring will continue through 2025. See Appendix **B**.
H-7	**Trout 2A LW Placement**	Achieve 80% of predicted increase in pieces of LW within 15 years of implementation	Conduct habitat surveys per monitoring protocol	2010–14	Measure will not be implemented and associated effectiveness monitoring has been cancelled. Change approved by NMFS March 15, 2012 (see Appendix G, Item 4 in the 2012 report.)
H-3	**Little Sandy 1 and 2 LW Placement**	Achieve 80% of predicted increase in pieces of LW within 15 years of implementation Achieve 80% of predicted increase in backwater pools, pools, and pool-tail habitat within 15 years of implementation Achieve 80% of predicted increase in percentage of total habitat that is large-cobble riffles, within 15 years of implementation	Conduct habitat surveys per monitoring protocol	2015–19	Measure was completed in 2014. Effectiveness monitoring will continue through 2027.

Offsite Measures—Effectiveness

#	Measure	Measurable Habitat Objective	Effectiveness Monitoring	Years	Status
H-26	**Boulder 0 and 1 LW Placement**	Achieve 80% of predicted increase in pieces of LW within 15 years of implementation	Conduct habitat surveys per monitoring protocol	2010–15	Measure will not be implemented and associated effectiveness monitoring has been cancelled. Change authorized by NMFS, August 16, 2011 (see Appendix F, Item 2 in the 2011 report).
H-4	**Sandy 2 Log Jam Placements**	Achieve 80% of predicted increase in pieces of LW within 15 years of implementation Achieve 80% of predicted increase in off-channel habitat within 15 years of implementation	Conduct habitat surveys per monitoring protocol	2015–19	Measure was completed in 2018. Effectiveness monitoring was initiated in 2015 and will continue through 2031.

Offsite Measures—Effectiveness

#	Measure	Measurable Habitat Objective	Effectiveness Monitoring	Years	Status
H-17	**Cedar 2 and 3 LW Placement**	Achieve 80% of predicted increase in pieces of LW within 15 years of implementation Achieve 80% of predicted increase in percentage of off-channel, beaver pond and pool habitat within 15 years of implementation	Conduct habitat surveys per monitoring protocol	2015–19	Measure completed in 2016. Effectiveness monitoring was initiated in 2014 and will continue through 2029.
Channel Restoration					
H-9	**Sandy 1 Channel Reconstruction**	Achieve 80% of predicted increase in percentage of off-channel habitat within 15 years of implementation	Every three years, resurvey the site to determine whether the gradient control structure is maintaining flow in the side channel and the river	2015–19	Measure will not be implemented, and associated effective monitoring has been cancelled. Fish production anticipated from this measure will be offset by enhanced habitat restoration efforts in Sandy 2. Change authorized by NMFS, April 14, 2015 (see Appendix H, Item 10, in the 2015 compliance report).

Offsite Measures—Effectiveness

#	Measure	Measurable Habitat Objective	Effectiveness Monitoring	Years	Status
H-24	**Salmon 2 Miller Quarry Restoration**	Achieve 80% of predicted improvements in off-channel habitat within 15 years of implementation	Once every three years after measure implementation, survey opened floodplain area and side channels	2020–24	
H-27	**Zigzag 1A Channel Design**	Achieve 80% of predicted habitat improvements within 15 years of implementation	Conduct habitat surveys per monitoring protocol	2020–24	Measure was completed in 2019. Effectiveness monitoring was initiated in 2018 and will continue through 2032.
H-30	**Habitat Fund**	The City will provide money to create a Habitat Fund of $9 million to contribute to large-scale partnership projects and to implement additional projects for adaptive management, if necessary	Determined through measure effectiveness monitoring	2010–59	Ongoing measure. Measure was in full compliance in 2019.

Research

Topic	Research Protocol & Analysis	Results Reporting	Years	Status and Report Location
Spawning Gravel Placement	Change in gravel from baseline each year, trends over time, using t-tests and linear regression	Include with annual compliance report, Years 2010–2019 and then every fifth year until 2049.	2010–59	Measure was in full compliance in 2019. See Appendix C.
Spawning Gravel Scour	Change in bed elevation, depth of scour, percentage of redds with significant scour	Monitoring starts HCP Year 5; reporting in Year 2016	2015–19	Measure was in full compliance in 2019. See previous compliance reports.

Research

Topic	Research Protocol & Analysis	Results Reporting	Years	Status and Report Location
Total Dissolved Gas	Exceedence of 110% TDG saturation, rate of TDG dissipation downstream of monitoring. Regression analysis, possibly modeling.	Include with annual compliance report	2010–59	Measure was in full compliance in 2019. See Appendix F.
BR Adult Chinook Population	Survey, sampling, linear regression	Include with annual compliance report	2010–59	Measure was in full compliance in 2019. See Appendix G.
Sandy River Basin Smolt Monitoring	Mark recapture study, various analyses methods	Include with annual compliance report	2010–59	Measure was in full compliance in 2019. See Appendix H.

Appendixes

A. Effect of the HCP on the Four Primary Covered Fish Species: 10-Year Summary

B. Effectiveness Monitoring for Offsite In-Channel Conservation Measures

C. Lower Bull Run River Spawning Gravel Research

D. Lower Bull Run River Spawning Gravel Scour Research

E. Lower Bull Run River Shading Monitoring 2019

F. Total Dissolved Gases in the Bull Run River

G. Lower Bull Run River Adult Chinook Population

H. Sandy River Basin Smolt Monitoring

I. Western Toad Monitoring for Reservoir Operations Measure R-3

J. Correspondence on Measures

Appendix A

Effect of the HCP on the Four Primary Covered Fish Species: 10-Year Summary

June 2020

Steve Kucas, Burke Strobel,
and Kristin Anderson
City of Portland Water Bureau

PORTLAND WATER BUREAU
FROM FOREST TO FAUCET

Contents

Tables

Figures

1. Summary

- The City is proud of what it has accomplished in the Sandy River Basin in the first 10 years of HCP implementation. All major HCP measures have been implemented ahead of schedule, and there are no large habitat projects left to complete.
- The habitat goals of only one conservation measure (HCP Measure T-2—Post-infrastructure Temperature Management) have not been fully met. The City provides an analysis indicating that even with the water temperature performance to date and considering the extreme water temperatures from 2014-2019, fish production has not been negatively impacted, and the beneficial uses have been protected.
- Three conservation measures (Measure F-5—Cedar Creek Purchase Water Rights, Measure H-23—Salmon 2 Miller Quarry Acquisition, and Measure H-24—Salmon 2 Miller Quarry Restoration) could not be implemented because of unwilling landowners. The projected benefits of those original HCP measures have been compensated for by the implementation of other measures.
- The HCP conservation easement program has been very successful. The projected fish benefits associated with the easement program meet or greatly exceed the projections from the original HCP. The City does not intend to pursue additional conservation easements.
- All in-stream habitat measures have been implemented. The projected fish habitat benefits from those measures either approximate or exceed those benefits projected by the similar HCP measures.
- The City also provides an analysis of the projected effects on Sandy River fish populations of the measures implemented in the first 10 years of HCP implementation using EDT (Ecosystem Diagnosis and Treatment) modeling and a comparison of Viable Salmonid Parameters in the same way it was analyzed in the original HCP. EDT model predictions indicate that for the four primary HCP fish species considered there will be significant habitat benefits from the conservation measures already implemented in the first 10 years.

2. Introduction

The 10-year point of HCP implementation is an appropriate milestone to examine what the City proposed with the original HCP commitments and contrast that with achievements to date. The HCP described 49 conservation measures that the City is implementing over the plan's 50-year schedule. The HCP commitments are intended to be front-loaded. That is, the major measures were designed to be implemented in the first 15 years of the 50-year HCP term to quickly benefit ESA-listed fish species and assist in their recovery.

All of the major HCP measures have been implemented as planned or are ahead of schedule. Some measures have been moved, replaced, or consolidated with others with approval from the National Marine Fisheries Service (NMFS). For the first 10 years (2010–2019) of HCP implementation, the City met the terms and conditions of all but four conservation measures. Three of those measures could not be implemented due to unwilling landowners and were not replaced or consolidated with others.

The four HCP conservation measures that were not fully implemented were downstream water temperature targets described by HCP Measure T-2—Post-infrastructure Temperature Management, Measure F-5—Cedar Creek Purchase Water Rights, Measure H-23—Salmon 2 Miller Quarry Acquisition, and Measure H-24—Salmon 2 Miller Quarry Restoration.

The City has successfully completed its acquisitions of conservation easements in the Sandy River Basin ahead of schedule. Despite many land ownership changes in the basin, the City was able to identify and secure easements that will produce productive habitat for fish species covered by the HCP.

Effectiveness monitoring is also continuing for some offsite measures to document the achievement of specific habitat goals.

The HCP achievements are discussed according to habitat effects in the Bull Run Watershed and offsite for the Sandy River Basin in the same manner it was organized in the HCP. Sandy River Basin fish population projections from the HCP measures implemented through 2019 are also discussed.

3. Habitat Effects of Lower Bull Run River Conservation Measures

All HCP lower Bull Run River conservation measures have been implemented successfully and the initial habitat goals achieved except for meeting lower Bull Run River water temperature targets (see Table 7, 2019 HCP Annual Compliance Report).

There are several reasons why the City has not been able to meet those temperature targets. This section outlines multiple components of water temperature management for the lower Bull Run River. First, an explanation of what the City promised in terms of water temperature targets in the HCP is presented. Next, a discussion about what was learned since creating those water temperature predictions over 10 years ago is provided. Lastly, a presentation is given of what is now known about water temperature targets during extreme weather years and the predicted habitat effects on fish populations in the Sandy River Basin.

3.1 HCP Projected Water Temperature Effects

The City used the CE-QUAL-W2 water quality model, relying primarily on 2001 and 2005 weather and stream flow conditions, to inform the development of the Habitat Conservation Plan and the associated Water Temperature Management Plan (Appendix G of the HCP). Early modeling efforts conducted to inform the Sandy River Basin total maximum daily load (TMDL) (ODEQ, 2005) used 2001 as the primary model year. Data from 2001 were the basis for the model calibration for three primary reasons: (1) the data coincided with the Oregon Department of Environmental Quality's (ODEQ) FLIR and Heat Source analyses in 2001; (2) the City's model development occurred about this time, so these [then] recent data were the most readily available; and (3) a subsequent comparison of five years of preceding data (1996–2001) indicated that 2001 was the driest of those years and thus challenging for water temperature management. The model was well calibrated, and its validity was ensured through a peer-review process (Jain, 2000). ODEQ drew from the City's model simulations estimating "natural" (pre-dam) water temperatures to determine the appropriate temperature criteria for the Bull Run River in the Sandy River Basin TMDL. The Temperature Management Plan (TMP) for the lower Bull Run River likewise drew from the same modeling work by the City of Portland (2004).

Over the years of planning for the HCP, field data were still being collected, creating more years with complete data sets available for modeling. The TMP mentions that by the time the TMP was finished, the City had run the model using 2005 conditions. The reason for using 2005 as a second modeling exercise was that summer conditions were warmer in 2005 than in 2001, suggesting that temperature management in 2005 would be more challenging. The City's 2005 model simulations estimating water temperature for the lower Bull Run River when operating multilevel intakes (see Figure 8-4 from the HCP) were used as the basis for determining fish effects in the HCP (Chapter 8).

At that time, natural condition criteria were acceptable for setting water temperature targets, and they were part of the Sandy River Basin TMDL (ODEQ 2005). Even though natural condition criteria have since been removed by ODEQ appropriate water temperature targets, the City continues to follow the requirements as outlined in the HCP. Temperature targets are set based on a combination of natural condition criteria and numeric criteria, and those results have been reported in HCP annual compliance reports.

[from 2008 Bull Run Water Supply Habitat Conservation Plan] Figure 8-4. Comparison of Actual 7-Day Maximum Water Temperatures for the Little Sandy Rivers with Predicted 7-Day Maximum Average Temperatures for the Lower Bull Run River, June 16–October 24, 2005.

Source: USGS Gauge No. 14141500 on the Little Sandy River (RM 3.8) and CE-QUAL-W2 Modeled Temperatures (February 2006)

Figure 1. Figure 8-4 from the 2008 Habitat Conservation Plan

With the HCP-projected temperature effects, as expressed in Figure 1 (which is Figure 8-4 of the 2008 Habitat Conservation Plan), the City asserted that water temperature impacts on spring and fall Chinook, Coho Salmon, and steelhead, and a variety of other aquatic species, would be minimized (see Chapter 8 of the HCP).

3.2 Water Temperatures since 2014

The City committed to modifying the Dam 2 water intake towers to allow selective withdrawal from different elevations in Bull Run Reservoir 2, which had emerged as the most viable option for meeting water temperature targets in the lower Bull Run River. The Dam 2 north water intake tower modifications were completed in 2014. Since the installation of multilevel intakes, water temperature management has changed considerably. While significant improvements for water temperature have been realized, the City has not been able to meet all HCP water temperature targets.

Since 2014, water temperatures have exceeded the HCP targets for approximately 20 to 50 days each year, mostly in the fall months. During these periods, targets have been exceeded by an average 1.0 °C. Figure 2 shows 7-day averages of daily maximum (7DADM) temperatures as modeled for years 2001 and 2005 and as observed in implementation years 2014 through 2019. See HCP Annual Compliance Reports 2014–2019 for details.[1] There are several reasons that the City has not been able to meet the temperature targets for the lower Bull Run River.

The reasons it has been difficult to meet the HCP water temperature targets include:

1. Imperfect model simulations.

   Models used for planning purposes were calibrated to reservoir conditions different from those present with multilevel intakes, leading to some limitations in how they simulated future operations.

   Most significantly, the CE-QUAL-W2 model had a cold bias at the bottom of Reservoir 2, which was not evident when calibrated to reservoir operations with bottom-only intakes but affected estimates of future temperature performance.

2. Sensitive Bull Run system temperature dynamics.

   The Bull Run supply is sensitive to ambient conditions. Bull Run reservoirs and streams respond quickly to changes in precipitation and temperature. These quick hydrologic responses affect spring and fall transition periods, which play a large role in the ability to meet temperature targets.

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[1] As part of this 10-year review, the City audited all temperature performance calculations under HCP Measure T-2 for years 2014 through 2019. Some small adjustments were made to calculations to ensure consistency across years. Where approved USGS data showed there to be no exceedance on days that provisional data had shown there to be an exceedance, exceedances were removed. In addition, a 7Q10 low-flow exception for years 2014 through 2019 was considered, whereas it had not been taken into account in previous years. See Section 4.1 Compliance Monitoring, Consideration of 7Q10 Low Flow Exception (page 20) of this annual report for a discussion on the 7Q10 exception.

Data from years that would have highlighted challenging spring and fall transitions were not available during HCP planning. Therefore, these dynamics were not well anticipated.

3. Challenging weather conditions.

   Meteorological conditions of 2014–2019 were considerably warmer and drier than the 2001 and 2005 modeled years, and air temperature exceptions written into the HCP could not be effectively utilized.

   The original modeling considered a normal reservoir drawdown window based on historical records, which was approximately early July to early October. It did not consider the water supply and temperature demands associated with longer reservoir drawdown periods, which happened frequently from 2014–2019.

These factors are described in more detail below.

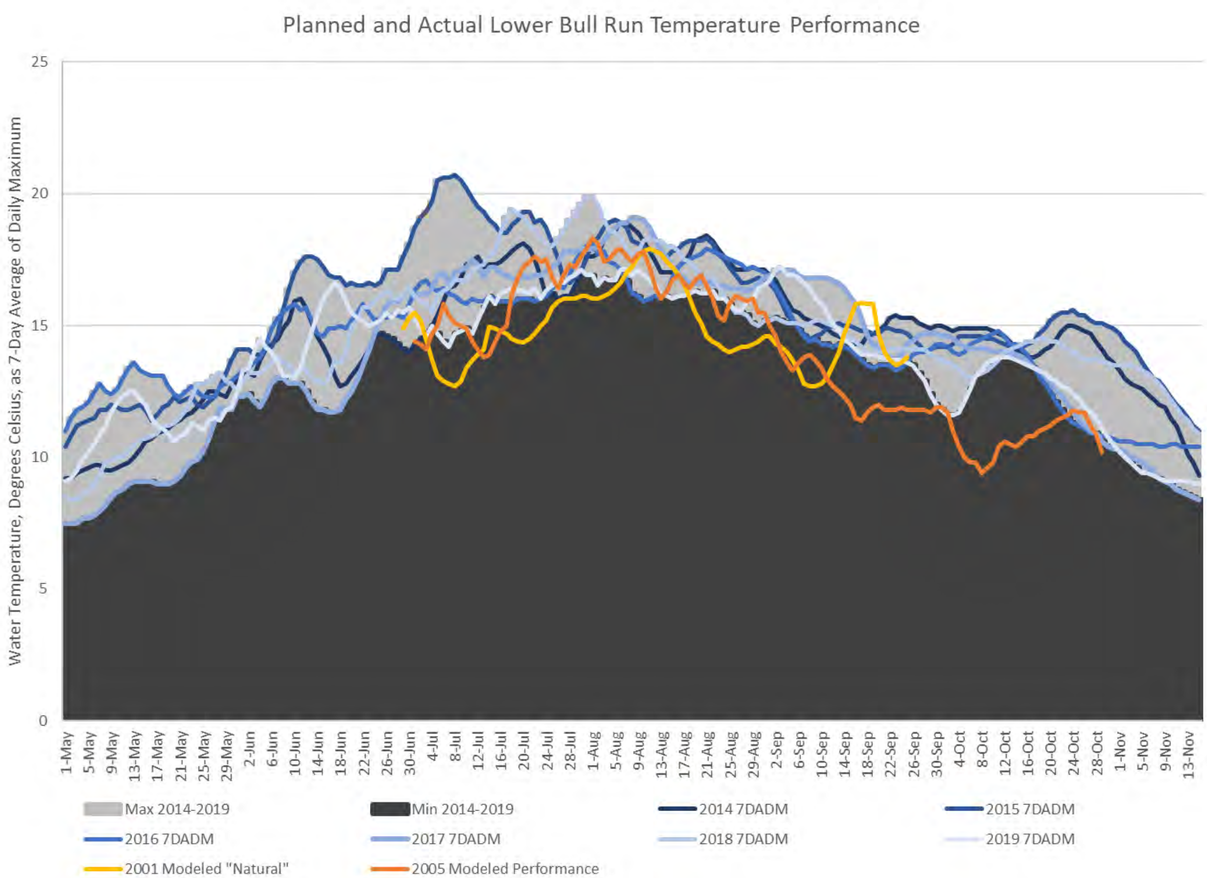

Figure 2. Water Temperature on the Lower Bull Run River at Larson's Bridge

3.2.1 Model Limitations

A CE-QUAL-W2 model of Bull Run Reservoirs was used in the HCP planning phases of to test the feasibility of meeting temperature targets with the operation of multilevel intakes. Although very well calibrated to the data available under pre-2014 operational and infrastructural constraints and supported with extensive field observations, the model did not represent reservoir bottom dynamics under selective withdrawal conditions precisely enough to highlight performance limitations.

The City updated the CE-QUAL-W2 model in 2013 and has continually improved the model, calibrating it to the empirical data of years since 2014 when selective withdrawal operations began. These modeling efforts showed that the model had a cold-water bias, simulating bottom temperatures that were colder than observed and that colder temperatures were maintained at the bottom of the reservoir for longer periods than experienced in reality. A combination of multiple calibration parameters and the model's ability to set up reservoir stratification precisely contributed to this bias. Computer models are not expected to simulate reality perfectly, and for a system with larger reservoirs and less responsive hydrology, this type of model imprecision would be less critical. Empirical experience with multilevel intake operations has shown the Bull Run temperature dynamics to be quite sensitive (see section 3.2.2). For the Bull Run system, this hidden model bias played a substantial role in limiting the City's ability to foresee temperature performance challenges.

In addition, multilevel gates originally were simulated as simple structures prior to the engineering design work needed to determine required dimensions and specifications. In practice, gates had to be designed with fairly large vertical openings to handle hydrodynamics within the wet wells. This design led to wider cones of influence. Besides the bottom gates withdrawing from a zone that includes higher elevations, the middle gates also withdraw water from a zone that includes lower elevations. This consideration changed the conceptual understanding of the need to have 2 billion gallons of cold water reserved for downstream temperature management to having 0.8 billion gallons. The change in gate specifications does not materially change the ability to meet temperature targets. The City has to manage both downstream and distribution system temperatures, and the governing limitation is the size of the reservoirs and the ability to bank water for the season. However, this understanding of the system may have influenced the level of confidence in meeting targets during the planning phases.

Finally, the heating regression for the lower Bull Run River also had limitations. Data from downstream releases made in the late 1990s and early 2000s were used to develop a multivariate regression. The regression fit the data well, but like the CE-QUAL-W2 model, the only data available to develop the model were collected under different operational and weather conditions. This scenario presented limitations on understanding in-stream heating, particularly in the spring and fall, the two most difficult management periods. Data collected from 2014 through 2019 under selective withdrawal operations showed that the regression underpredicts heating of cold release water and of release rates above 60–70 cfs. The modeled scenarios of 2001 and 2005 showed successful temperature management with lower release rates than have been required from 2014 to 2019. The potential impact on the City's ability to conserve the banked cold water is mitigated in practice by shorter release periods in the summer.

3.2.2 Sensitive Bull Run System Dynamics

The Bull Run water supply is sensitive to ambient conditions, and multiple factors play a role in this. The hydrology of the watershed is responsive, with stream flows reacting quickly to transitions from wet to dry and dry to wet. Baseflow recession curves in the Bull Run are steep. This quick responsiveness typically means that the difference between a difficult spring and an average spring lies in a few shower events.

Stream and reservoir temperatures also react quickly to changes in air temperature and solar radiation. Because the Bull Run Watershed is located in the lower elevations of the Cascades, snowpack that accumulates in the winter typically is melted prior to the active temperature management period. Therefore, there is no moderating effect of snowmelt on stream temperatures during that period.

Bull Run reservoirs are relatively small compared to the size of the watershed and its water production. This factor means they are more impacted by the temperature of tributary inflows than reservoirs that are larger relative to watershed area. Smaller reservoir size also presents a limit on how much cold water can be banked for a season and how vulnerable the bottom cold water layer, the hypolimnion, is to overall reservoir dynamics such as destratification.

The impact of reservoir destratification in the fall was not foreseen in planning. Bottom-only intakes at Reservoir 2 prevented that reservoir from stratifying substantially. Destratification in Reservoir 1 in years 2001 and 2005 was quite gradual compared to what is now typically experienced at Reservoir 2, so there were not strong indicators in those years of how dominant that dynamic would be in temperature management.

Regardless of what type of weather occurs in the summer, each year lakes and reservoirs naturally lose their thermal stratification in a process called "lake turnover," in which surface water cools, becomes dense, and sinks, causing the entire water column to mix. This mixing causes cold water remaining at the bottom to be lost and for all remaining heat from the summer to be mixed homogenously in the reservoir. For a period of time every year after turnover, the reservoir will be too warm to meet temperature targets until enough incoming cool stream flow cools it down.

The impact on temperature objectives of increased minimum downstream flows in October is substantial. If destratification has not already occurred, the rapid release of water from the bottom of the reservoir drives the reservoir to destratify. Planning documents from 2002 to 2007 mention in various places that October temperature management was anticipated to be challenging, but data to understand this more completely were not available as planning years did not have prolonged dry seasons.

3.2.3 Meteorological Conditions and Reservoir Drawdown

Table 1 below summarizes weather and water temperature information for planning years 2001 and 2005 and implementation years 2014 through 2019. Weather metrics include average air temperature and reservoir drawdown duration. Reservoir drawdown occurs when there are sustained warm and dry conditions. Therefore, the duration of reservoir drawdown is an excellent indicator of the persistence of these conditions in a given year.

Table 1. Weather and Temperature Metrics for 2001, 2005, 2014–2019. Where Percentiles of the Historical Range are Given, They are Color-Coded on a Color Gradient of Blue (0) to Red (1)

	Warm Season Weather Metrics					Water Temperature Performance Metrics		
Year	Average Air Temperature May-September *Indicative of Heat Loading in Critical Period*			Reservoir Drawdown Duration *Indicative of Persistence of Warm, Dry Conditions*		Frequency of Target Exceedance	Maximum Departure above Target: Bull Run at Larson's Bridge	Maximum Departure above Target: Bull Run below Little Sandy
	°F	°C	Percentile of Historical	Days	Percentile of Historical	Days	°C	°C
2001	61.4	16.3	0.56	99	0.63	NA	NA	NA
2005	61.6	16.5	0.63	80	0.39	NA	NA	NA
2014	62.9	17.1	0.88	111	0.73	36	2.0	NA
2015	63.7	17.6	0.95	160	0.97	45	2.6	1.1
2016	61.6	16.5	0.62	96	0.56	35	1.8	0.3
2017	63.0	17.2	0.90	87	0.47	34	1.5	1.0
2018	62.5	17.0	0.84	160	0.97	49	1.5	0.8
2019	60.9	16.0	0.35	133	0.90	19	0.8	0.3

Note: Changes in the air temperature gage observations occurred in 2008 that created a shift in the data, making temperatures post-2008 appear cooler relative to the pre-2008 data. While there is no accepted way to correct for this shift, maximum temperatures are affected more than minimum temperatures. Average temperatures are given in this table. These same percentile calculations using minimum temperatures show May to September temperatures in all years from 2014 to 2019 in the 88th percentile or higher of the historical range.

Temperatures in the Bull Run were high in the summers 2014–2019, and notably higher than in planning years 2001 and 2005 (see note at the end of Table 1). HCP Measure T-2 includes multiple exceptions based on high air temperatures. The lower Bull Run River 7DADM water temperature can exceed the 7DADM target temperature by 1 °C or 1.5 °C when the 7DADM air temperature exceeds 27 °C or 28 °C, respectively. These two exceptions are specific to the HCP. They are based upon the modeling work that showed the lower Bull Run naturally exceeded the Little Sandy temperature in hot weather conditions (City of Portland, 2004).

A third air temperature exception written into the Oregon Administrative Rules exempts the City from the requirement to adhere to the 7DADM water temperature target when any single day's air temperature exceeds the 90th percentile of the 7DADM air temperature calculated in a yearly series over the historical record.

These three air temperature exceptions were often exceeded in years 2014 to 2019. But these exceptions do not functionally allow the City to operate differently than if the exceptions were not in place because they are not predictable enough to manage to. When they occur, the 27 °C and 28 °C exceptions bump the 7DADM water temperature target up immediately, and they drop off just as quickly. Operating to a 7-day average target, the City cannot reliably predict and then manage to a quick 1 °C or 1.5 °C reduction in the target. The 90th percentile exclusion is also highly unpredictable, as weather forecasts can differ from actual maximum air temperatures by several degrees.

In addition to ambient temperatures, reservoir drawdown was quite prolonged in many of the years, starting as early as May, in three of the years (average drawdown start time is early July). For two of the three years with closer to average drawdown periods, there had been early false starts to drawdown in which drawdown began much earlier than average; then later showers refilled reservoirs before drawdown commenced again. These early drawdown starts highlighted challenges in downstream temperature management under conditions that were not foreseen.

Under Measure F-2 of the HCP, the required minimum downstream flow release in a critical spring (when drawdown starts early) is 30 cfs, whereas under normal conditions it is 120 cfs. The temperature target the first half of June is typically 13 °C, or sometimes slightly above, based on Little Sandy temperatures. Meeting a target that low at flows below 120 cfs can be challenging. Though reservoir temperatures are relatively cool at that time, high flows up to and above 120 cfs have been required to meet the target. Conditions in the planning years of 2001 and 2005 did not indicate that this would be a challenge.

Late ends to drawdown lengthen the period of time that temperature targets are difficult to meet. If tributary inflows do not replace the warmer, destratified reservoir water, it can take a long time for the reservoir to cool down without being flushed out with colder water. This effect was particularly noticeable in 2014, 2015, and 2018.

The City's secondary drinking water source, the Columbia South Shore Well Field, was used extensively in the last six years to mitigate Bull Run reservoir drawdown. In 2015, the City pumped 5.8 billion gallons (BG) of groundwater to augment supply—its largest supply augmentation to date and greater than anticipated in the HCP—in order to maintain Bull Run reservoir levels above the limits set forth in HCP Measure R-1. These limits protect the bank of cold water in the reservoirs, and they are also in place for drinking water-quality purposes. In addition to 2015, groundwater was also used for summer augmentation in 2018 (4.6 BG) and 2019 (1.8 BG).

The City monitored water temperatures at the Larson's Bridge USGS station on the Bull Run River (River Mile 3.8, compliance point for Measure T-2) and the Bull Run River below the confluence with the Little Sandy River (RM 3.0 on the Bull Run River) via a temperature logger. The City came close to but did not always meet the water temperature targets for the lower Bull Run River in the fall because the supply of cold water in the reservoirs was depleted. The 7DADM temperature exceeded the target at Larson's Bridge by a maximum of 2.6 °C and at the Bull Run River below the Little Sandy by a maximum of 1.1 °C.

The depletion of cold water in Bull Run reservoirs occurred each year despite significant and continuous efforts through the active management season to judiciously release only the amount of water needed each day to meet temperature targets.

The year 2015 was a historical extreme, being exceedingly warm and having a very long dry period. The experience of operating the system toward temperature management in the lower Bull Run River under these conditions is a valuable planning asset for the future. The City has used this experience along with improved modeling to assess performance under different conditions and targets.

The City is anticipating meetings with ODEQ in the near future to discuss numeric criteria and natural conditions for the Bull Run Watershed. Those discussions may result in setting different water temperature targets for the HCP.

3.3 Sandy River Basin Fish Population Water Temperature Effects

The City determined the potential environmental effects associated with the HCP and other alternatives, which were summarized in an environmental impact statement (EIS-citation). The City also determined the effects of each EIS alternative on Viable Salmonid Parameters of Sandy River Basin fish populations and compared the HCP results to the EIS No Action Alternative. That analysis approach was duplicated for this appendix to analyze the potential impacts of water temperatures in the Bull Run River that were warmer than those described in the HCP.

Because HCP water temperature targets have been exceeded on some days in each year since 2014, the City evaluated the potential impacts on Sandy River fish populations of the warmer-than-expected temperatures in the Bull Run River. The warmest year since 2014 was selected for this purpose.

The last six years (2014–2019) of empirical temperature data were examined to determine which year had the warmest meteorological conditions (Table 1). 2015 had the hottest average air temperature for the months of May through September of the last six years and was in the warmest 95th percentile of the entire historical record (1900–2019). It also had the single largest exceedance of the water temperature target of the last six years. Conditions in 2015 were significantly warmer than in 2005, the HCP modeled year, which was in the warmest 63rd percentile. Four of the last six years have been much warmer than 2005, which explains in part why the City has struggled to hit some of the HCP temperature targets. The City, in its HCP, did not anticipate the magnitude of the observed warming trend in regional streams.

The City used 2015 water temperature data to model fish population projections under difficult environmental conditions. The intent was to estimate the fish population sizes conservatively under some of the warmest meteorological conditions ever recorded for the Bull Run River Basin and compare those to the HCP fish population projections to see if the estimates would be lower.

The City used the water temperature information for the lower Bull Run River in 2015 to re-rate the EDT attribute for maximum daily temperature. The City ran the EDT model using the revised temperature ratings to determine new VSP (viable salmonid population) parameters for the HCP target fish populations under the most extreme observed conditions. Table 2 summarizes the results and compares them with HCP fish population projections.

Table 2. EDT Model Predictions of VSP Parameters and Increases above EIS No Action Alternative[1]

VSP Parameters	Productivity	Diversity	Abundance	Abundance (NEQ)
Spring Chinook				
Original HCP Commitments	12%	6%	13%	785
2015 Observed Conditions	13%	6%	13%	771
Fall Chinook				
Original HCP Commitments	12%	10%	10%	622
2015 Observed Conditions	13%	10%	10%	620
Coho				
Original HCP Commitments	5%	22%	23%	568
2015 Observed Conditions	4%	20%	20%	484
Winter Steelhead				
Original HCP Commitments	7%	13%	13%	431
2015 Observed Conditions	7%	11%	13%	428

[1]Values shown for the original HCP commitments are slightly different than those in the EIS because VSP parameter estimates for both the EIS No Action Alternative and the HCP commitments were recalculated using EDT3, the replacement software for EDT2 (used in the creation of the EIS). A comparison of EDT2 and EDT3 results can be found in correspondence with NMFS about replacing the use of one with the other.

Warmer water temperatures in the Bull Run River, such as those experienced in 2015, were estimated to have only minor impacts on the VSP parameters for Sandy River fish populations modeled under the Original HCP Commitments scenario. Productivity and diversity under the 2015 Observed Conditions scenario were very similar to those under the Original HCP Commitments scenario, and abundance varied to a significant degree only for Coho. All four Sandy River fish species' abundance estimates were slightly lower under the warmer 2015 conditions, with Coho decreasing by 84 fish. The City does not believe that warmer water temperatures in the lower Bull Run River, such as those observed from 2014 to 2019, will significantly decrease the HCP measures' anticipated benefits to Sandy River salmon and steelhead populations.

4. Habitat Effects of Offsite Sandy River Basin Conservation Measures

Almost all offsite Sandy River Basin conservation measures have been implemented successfully and ahead of schedule within the first 10 years of the HCP. HCP conservation easements have been modified and acquired. Only three offsite measures were not implemented or replaced during the first 10 years of HCP implementation because of unwilling landowners. The three measures that were not implemented or replaced are Measure F-5—Cedar Creek Purchase Water Rights, Measure H-23—Miller Quarry Acquisition, and Measure H-24—Miller Quarry Restoration. These measures have been discussed in previous HCP annual compliance plans. Effectiveness monitoring of offsite measures is also continuing.

4.1 Conservation Easements

Since the creation of the conservation easement measures in the HCP, land ownership in the Sandy River Basin has changed considerably. Many private land parcels have been purchased and converted to public lands in the target areas for HCP easements. The City continually assessed potential easements and communicated with NMFS about potential habitat benefits and acreage totals for various Sandy River Basin locations.

In the HCP, the City identified conservation easements that will improve riparian conditions in the lower, middle, and upper Sandy River Basin. The easements were designed to protect and improve riparian forest within a minimum of 100 feet of the active channel on one or both sides of the river or creek. The City has completed its acquisitions of conservation easements in the Sandy River Basin. The City has finalized easements for 295 acres (see Compliance Monitoring, Measures H-12 and H-13–Riparian Easements and Improvements in this report, pp. 36–39).

For all easements or acquired riparian buffer areas, canopy cover was estimated prior to work onsite and will be reassessed repeatedly after planting to determine progress towards canopy cover targets given in the HCP. The City is obligated to treat all easement areas so that the canopy cover exceeds 70 percent conifer trees or native hardwood trees, as the site conditions dictate.

Even with continuing land ownership changes, the City has been able to successfully acquire enough quality easements to fully meet the fish benefit goals of its conservation easement program, including several easements with perpetual terms. The City has used EDT to estimate the projected fish population benefits associated with the original HCP conservation easements and compared those to the projections for the actual easements acquired through 2019 (Figure 3). The benefits of Measure H-23—Miller Quarry Acquisition were added to those of the original HCP conservation easements for this analysis. All species are expected to benefit more from the actual easements acquired as of 2019 than from the easements originally envisioned in the HCP, with the exception of winter steelhead, which are expected to benefit to approximately the same degree.

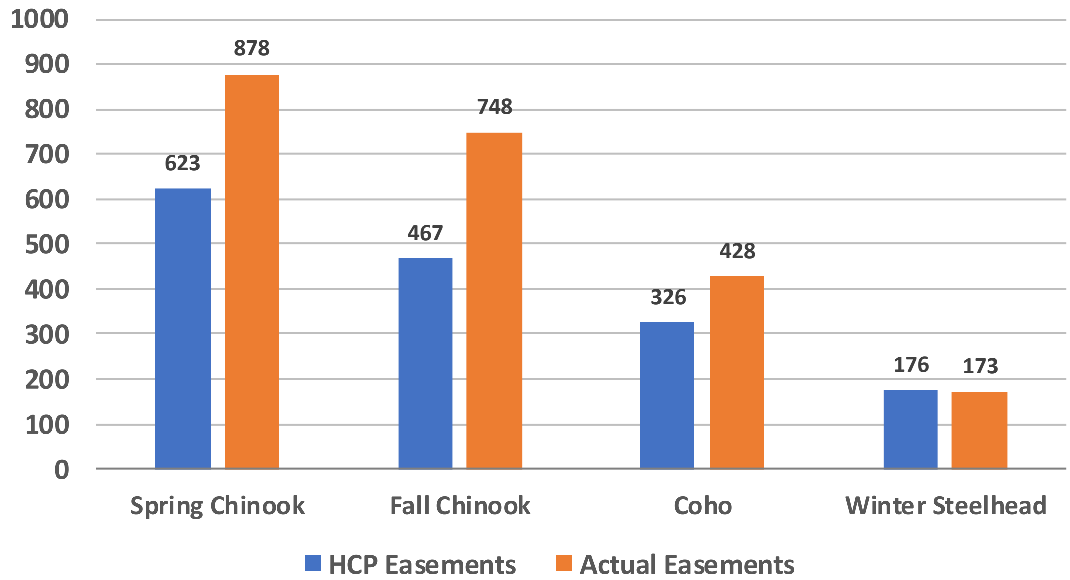

Figure 3. Comparison of Estimated Adult Fish Resulting from the Conservation Easements Anticipated in the HCP and the Actual Easements Acquired by the City as of 2019

4.2 In-stream Habitat Measures

The measures described in the HCP can be divided into two categories: measures that incorporate compliance monitoring only and measures that also include effectiveness monitoring (see Appendix B). Although all measures are described for the purpose of EDT analysis in terms of the same 46 EDT attributes (City of Portland 2008, Appendix D), only certain projects are monitored to ensure that they produce the anticipated habitat attribute benefits. These include in-stream habitat measures such as large wood placements or side-channel reconstructions/berm removals. The benefits of other types of measures involve little uncertainty about their biological effectiveness. For some of those measures (for example, conservation easements), the habitat benefits will be realized only over time as natural processes reassert themselves.

The benefits specifically of in-stream measures implemented in the period 2010 to 2019, which include effectiveness monitoring, were estimated using EDT and compared to the anticipated benefits of in-stream measures originally described in the HCP. Included with the in-stream measures originally described in the HCP were Measure F-5—Cedar Creek Purchase Water Rights and Measure H-24—Miller Quarry Restoration. The results of the comparison are summarized in Figure 4.

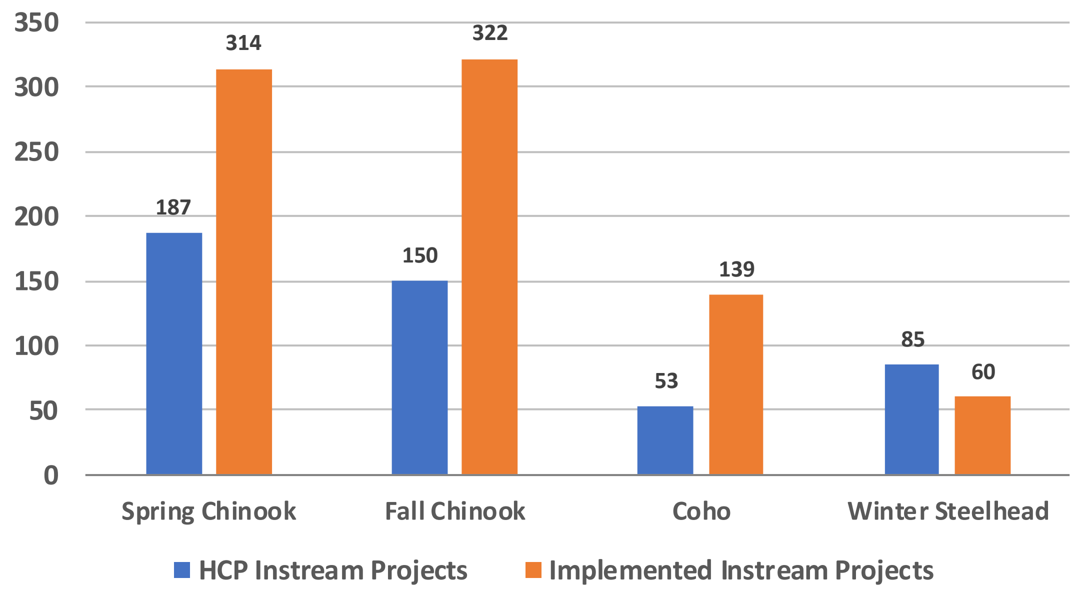

Figure 4. Comparison of Estimated Adult Fish Resulting from In-stream Measures Anticipated in the Original HCP and the Actual HCP Measures Implemented in 2010–2019

For spring Chinook, fall Chinook, and Coho Salmon, the benefits of monitored in-stream measures implemented since 2010 fully replace and exceed the benefits of in-stream measures anticipated in the HCP. The benefits to those species deriving from the two measures that were not implemented or replaced (Measure F-5—Cedar Creek Purchase Water Rights and Measure H-24—Miller Quarry Restoration) were also fully offset by the implemented and monitored instream measures. Benefits to winter steelhead were not fully offset. This is probably because less habitat was improved in higher-gradient, swifter streams that steelhead prefer, such as the Salmon River, in favor of habitat improvements in the main stem of the Sandy River preferred by salmon, especially Chinook Salmon.

4.3 Measure F-5 – Cedar Creek Purchase Water Rights

Efforts to complete this measure were previously described in the 2015 and 2016 HCP annual compliance reports. The City found no willing sellers of certified surface water rights within the Cedar Creek drainage.

The City reviewed all certificated surface water rights with the Cedar Creek drainage to identify potential rights it could purchase to identify willing sellers, as per the HCP measure commitment. A total of 37 water rights were identified with a total point of diversion (POD) rate of 89.2 cfs (see 2015 HCP Annual Compliance Report). Oregon Department of Fish and Wildlife holds senior rights dated from the 1920s to the 1950s for operation of the fish hatchery on Cedar Creek. The Oregon Water Resources Department holds junior rights filed in the 1990s. Together, those two agencies hold

97% of the water rights for Cedar Creek. Of the remaining rights, only three were for parcels large enough for the City to consider for acquisition/leasing to meet the habitat goals of Measure F-5. The City examined water right 35, a 1-cfs POD rate for fish propagation, with a priority date of 1926. The City's examination of historical records indicated the water right was not used after the original owner claimed it, and there was no evidence the water right was conveyed with the sale of the property. Because the right is not being used by the current property owner, there would be no water quality benefit from acquiring the water right. The City is no longer considering water right number 35. The other water rights of interest, held by the City of Sandy, have two priority dates and a combined POD rate of 0.9 cfs.

The City of Sandy water rights are located at Brownell Springs on Cedar Creek. The City had the rights appraised by a consultant (see 2016 HCP Annual Compliance Report). In 2016, the City met with the City of Sandy to discuss the possibility of leasing its Brownell Springs water rights to return water to upper Cedar Creek from June to September. The City of Sandy discussed this at their City Council meeting in November 2016. The City of Sandy declined to enter into any agreement with the City of Portland regarding water rights on Cedar Creek.

For Measure F-5, there were small projected habitat and fish benefits as described in the HCP. The City will make up for the loss of projected habitat and fish benefits from this measure with the implementation of other conservation measures. That plan is described in detail in section 4.2 of this appendix.

4.4 Land Acquisition and Restoration

There is only one property acquisition in the HCP (Measure H-23—Miller Quarry Acquisition), and the City also committed to restoring that land (Measure H-24—Miller Quarry Restoration). Efforts to complete these two conservation measures were described previously in the 2016 HCP Annual Compliance Report.

The City has worked on acquisition of the Miller Quarry property since 2011. The following steps have been taken:

- The City paid for a property appraisal in 2011.
- The City then negotiated a purchase price with the owners for $150,000, pending environmental review of the property.
- The environmental site assessment indicated lead contamination from more than 30 years of illegal shooting activity on the parcel.
- City staff developed a very rough estimate of $300,000 to remove and transport the contaminated soil.
- The City would not acquire the property unless the parcel was cleaned up and declared free of contamination.

- The owners were not willing to accept responsibility for the contamination, and the potential property sale was stalled.
- Other Sandy River Basin Partners, specifically The Nature Conservancy and The Freshwater Trust, volunteered staff resources and outside funding to address the lead contamination to complete a property sale.
- The owners still would not proceed with a sale based on the additional resources brought by the Sandy River Basin Partners.

The City was not able to complete the purchase and, consequently, the restoration of the Miller Quarry property on the Salmon River.

For Measures H-23 and H-24, there were projected habitat and fish benefits as described in the HCP. The City will make up for the loss of projected habitat and fish benefits from these measures with the implementation of other conservation measures. That plan is described in detail in sections 4.1 and 4.2 of this appendix.

5. Effects on Sandy River Fish Populations

<u>EDT Results</u>

The City analyzed the projected benefits to fish from the conservation measures completed within the first 10 years of HCP implementation while considering the warmer water temperature experienced since 2014 and the three measures that could not be completed due to unwilling landowners. The City again relied on the EDT model for comparison purposes.

The EDT model was used to estimate the benefits for spring Chinook Salmon, fall Chinook Salmon, Coho Salmon, and steelhead that are likely to result from the implementation of HCP measures that have been completed in the last 10 years. Those results are compared to the original EDT model results that were summarized in the HCP and to the Modified Historical Bull Run Condition. The Modified Historical Bull Run Condition is an estimate of what the Bull Run habitat might be capable of producing if it were restored to modified historical conditions. The Modified Historical Bull Run Condition was described and utilized in the HCP and assumes historic Bull Run flows and fish access to all streams. It also assumes fish passage at 100% efficiency (upstream and downstream) of Bull Run dams, and that the reservoirs would be in place.

The Modified Historical Bull Run Condition is the most liberal possible estimate of the state of fish habitat if all effects of the City's Bull Run municipal water supply operations were removed other than the presence of reservoirs. This estimate provides a target number of fish to contrast with the HCP projections, and now the 10-year accomplishments of implementation. Figure 5 summarizes the EDT model projections of population increases for four fish species under the original HCP measures, the HCP measures implemented from 2010 to 2019, and the Modified Historical Bull Run

Condition. The results are expressed as increases above the relevant habitat baseline. The baseline data used for the original HCP measures and the Modified Historical Bull Run Condition were based on the best information available at the time, being gleaned from a number of habitat surveys conducted by various agencies or estimated from other similar streams. The baseline used for the actual HCP measures implemented since 2010 included data collected over multiple years in the reaches corresponding to each HCP in-stream restoration project prior to its implementation.

Model predictions indicate that for the four primary HCP fish species considered, there will be significant habitat benefits from the conservation measures already implemented in the first 10 years. In fact, the model indicates that the fish numbers generally meet or exceed the HCP predictions but also meet or exceed the Modified Historical Bull Run Conditions.

EDT predicts that the Sandy River Basin populations of two species of fish will benefit significantly more from the HCP measures implemented from 2010 to 2019 than from the original measures described in the HCP, while two species will stay the same or decrease slightly. Both spring and fall Chinook populations are predicted to increase more under the implemented measures (by 25% and 42%, respectively). This result stems from a larger proportion of acquired conservation easements being located in reaches especially productive for these two populations than easements anticipated in the original HCP.

Fewer Coho are expected to be produced under the implemented measures because of a combination of factors. Coho decreased more under the conservative 2015 water temperature regime than the other species. Habitat conditions were also thought to be better for Coho in Cedar Creek than subsequent baseline surveys showed them to be. Therefore, provision of fish passage resulted in a lesser benefit. Benefits to winter steelhead were essentially unchanged. The populations of all species but winter steelhead are predicted to increase more than what would directly offset the impacts of the City's municipal water supply operations in the Bull Run River (the Modified Historical Bull Run Condition). This was also the case under the original HCP measures.

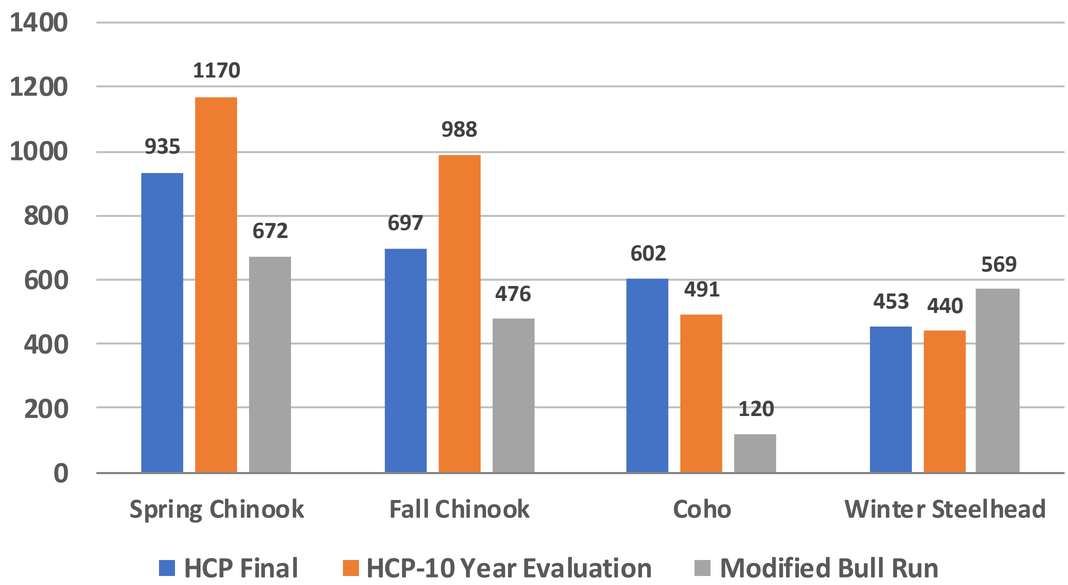

Figure 5. Comparison of Estimated Adult Fish Resulting from the Original HCP, the Actual HCP Measures Implemented in 2010–2019, and the "Modified Historical Bull Run Condition"

Even though the scenario "HCP 10-Year Evaluation" predicts large gains in adult fish, it is a very conservative prediction (low for fish projections). The evaluation includes all conservation measures implemented through 2019 and assumes the unusually warm water temperatures observed during the difficult year of 2015. Meteorological conditions in the future are not expected to be consistently as warm as those observed in 2015.

In-stream projects are also expected to continue to improve fish habitat over time. In-stream wood placements, for example, invariably involve primarily large logs and rootwads. EDT, however, considers the presence and value of smaller wood pieces (as small as 7 feet long and 4 inches diameter), which can make up half to two-thirds of large wood pieces in a stream (unpublished baseline survey data, PWB). These smaller pieces are expected to accumulate over time, captured by the larger pieces during high flow events. Over time and with more moderate stream temperatures, fish numbers would even be greater than Figure 5 indicates.

VSP Parameters

The City also looked at the effects of the scenario "HCP 10-Year Evaluation" on Sandy River salmon and steelhead populations relative to the HCP EIS No Action Alternative to compare the effects of the "original HCP commitments," as expressed in VSP parameters (see Table 3). To provide for a legitimate comparison, the EIS No Action Alternative was duplicated using the same assumptions as the original analysis but starting with the same revised baseline condition as the "HCP 10-Year Evaluation." Each species' VSP parameters were calculated as percent increases above the respective version of the EIS No Action Alternative.

Table 3. EDT Model Predictions of VSP Parameters and Increases above Corresponding EIS No Action Alternatives[1,2]

VSP Parameters	Productivity	Diversity	Abundance	Abundance (NEQ)
Spring Chinook				
Original HCP Commitments	12%	6%	13%	785
HCP 10-Year Evaluation	8%	9%	16%	1,002
Fall Chinook				
Original HCP Commitments	12%	10%	10%	622
HCP 10-Year Evaluation	17%	7%	13%	895
Coho				
Original HCP Commitments	5%	22%	23%	568
HCP 10-Year Evaluation	-2%	15%	20%	484
Winter Steelhead				
Original HCP Commitments	7%	13%	13%	431
HCP 10-Year Evaluation	4%	11%	12%	419

[1]Values shown for the Original HCP Commitments are slightly different than those in the EIS because VSP parameter estimates for both the EIS No Action Alternative and the HCP Commitments were recalculated using EDT3, the replacement software for EDT2 (used in the creation of the EIS). A comparison of EDT2 and EDT3 results can be found in correspondence with NMFS about replacing the use of one with the other.
[2]The EIS No Action Alternative for comparison with the Original HCP Commitments was modeled from the same baseline data as the Original HCP Commitments. The EIS No Action Alternative for comparison with the HCP 10-Year Evaluation was modeled from the same revised baseline data as the HCP 10-Year Evaluation.

All VSP parameters for all species but one showed increases above the EIS No Action Alternative; however, the relative increase differed from that of the "Original HCP Commitments" in varying ways—sometimes higher and sometimes lower. Coho productivity decreased slightly under the "HCP 10-Year Evaluation" from the EIS No Action Alternative. This occurrence is because many of the additional Coho generated under the actual HCP measures implemented from 2010 to 2019 came from reaches with lower average productivity (offspring per adult) than the average productivity under the EIS No Action Alternative. As a consequence, while diversity increased and more Coho were produced, the average number of offspring per adult decreased slightly. Even assuming that the lower Bull Run River would continue to be as warm as it was in 2015, almost all VSP parameters still indicate a sizeable increase under the HCP measures that have been implemented.

The estimation of benefits to the VSP parameters of Sandy River Basin salmon and steelhead populations also does not include benefits from several measures described in the HCP and implemented in the period 2010–2019. Measures that were not included, but nonetheless provide benefits to fish populations include Measure P-1—Walker Creek Fish Passage, Measure H-3—Little Sandy 1 LW Placement, Measure P-2—Alder 1

Fish Passage, and Measure P-3—Alder 1A Fish Passage. It was difficult to assess these additional benefits, so they were left out of the VSP analysis.

6. Works Cited

City of Portland. 2004. *Bull Run River Water Temperature Evaluation*. Portland, Oregon.

City of Portland. 2008. *Bull Run Water Supply Habitat Conservation Plan*. Portland Oregon. 805 pages.

Jain, R., E.M. Buchak, G.A. Krallis. 2000. Review of the CE-QUAL-W2, Version 3 Model Applications to the Bull Run System. Prepared for the Bureau of Water Works, City of Portland, Oregon. J.E. Edinger Associates, Inc., Wayne, Pennsylvania.

Oregon Department of Environmental Quality (ODEQ). 2005. *Sandy River Basin Total Maximum Daily Load (TMDL)*. Portland, Oregon.

Appendix B

Bull Run HCP Effectiveness Monitoring Report

Effectiveness Monitoring for Offsite In-Channel Conservation Measures

June 2020

Burke Strobel
City of Portland Water Bureau

Contents

Tables

1. Summary

The City of Portland Water Bureau (PWB) has committed to implementing seven offsite in-channel conservation measures that require effectiveness monitoring.

PWB was in full compliance with its Habitat Conservation Plan obligations in 2019 with regard to effectiveness monitoring for offsite in-channel conservation measures. Fish habitat surveys were conducted for four offsite measures: H-4 Sandy 1/2 Log Jams, H-5 Gordon 1A/1B LW Placement, H-6 Trout 1A LW Placement, and H-27 Zigzag 1A Channel Design.

This appendix summarizes the results of the 2019 surveys. The data collected in 2019 for H-27 Zigzag 1A Channel Design contribute to information about baseline conditions with which the post-treatment conditions of this stream will be compared. 2019 was the first year of post-treatment monitoring on the main stem of the Sandy River and the third year of post-treatment monitoring in Gordon Creek and Trout Creek.

2. Introduction

PWB committed through its Bull Run Water Supply Habitat Conservation Plan (HCP; Portland Water Bureau 2008) to implement in-channel fish habitat enhancement measures at offsite locations. Offsite locations are those not in the Bull Run Watershed but located in other Sandy River Basin streams. These include various tributaries in the basin, portions of the main stem of the Sandy River, and the Little Sandy River. In-channel measures are being completed within the normal high-flow channel of a stream. In-channel measures do not include efforts to improve the riparian zone.

One or more measurable habitat objective is associated with each offsite in-channel measure. The effectiveness of PWB's efforts to improve fish habitat at these offsite locations is being evaluated by measuring the habitat attributes associated with these objectives and determining how closely the habitat attributes approach or surpass the value of the respective objective. A total of seven offsite, in-channel measures have been implemented that have associated effectiveness monitoring. These measures, their year of implementation, and the year effectiveness monitoring will be completed, are summarized in Table 1.

Table 1. HCP Offsite Instream Habitat Measures with Associated Effectiveness Monitoring[a]

Measure	Year of Construction	Last Year of Monitoring
H-4 Sandy 2 Engineered Log Jams	2017/18	2031
H-5 Gordon 1A/1B LW Placement	2012	2025
H-6 Trout 1A LW Placement	2012	2025
H-3 Little Sandy 1/2 LW Placement	2014	2027
H-17 Cedar 2/3 LW Placement	2016	2029
H-4 Sandy 1/2 Log Jams	2017–18	2031
H-27 Zigzag 1A Channel Design	2019	2032

[a]Some offsite habitat measures (H-7 Trout 2A LW Placement, H-9 Sandy 1 Channel Reconstruction, and H-26 Boulder 0/1 LW Placement) will not be implemented. Other measures will be completed to compensate for the habitat benefits of the original measures. These changes have been authorized by NMFS and are explained in Table 12 of the 2018 Annual Compliance Plan.

In 2019, baseline data and post-treatment data were collected in streams. Baseline data were collected in the Zigzag River. Post-treatment data were collected for the Sandy River, Gordon Creek, and Trout Creek.

This appendix describes the effectiveness monitoring protocols and results to date for the in-channel measures completed or to be conducted in the Sandy River, Gordon Creek, Trout Creek, and Zigzag River. These measures involve placing large wood and creating log jams to influence stream morphological features such as pools and riffles and to accumulate spawning gravel.

3. Measurable Objectives

The offsite in-channel measures discussed in Chapter 7 of the HCP and their predicted effects on habitat attributes have been evaluated using the Ecosystem Diagnostic and Treatment (EDT) model (City of Portland and Mobrand Biometrics 2004). The anticipated benefits of these measures are summarized by reach and by the predicted net change in the attributes' respective metrics listed in Table 2. The net attribute changes in Table 2 include only those benefits expected to be derived from the proposed in-channel restoration projects. Other measures, such as riparian easements, may occur in and have benefits for the same reaches, but these benefits are expected to occur over timescales that are longer than the timescales for the offsite in-channel measures. The benefits of other measures are not part of the scope of this research.

The net changes predicted in Table 2 represent measurable habitat objectives created for each individual reach. The monitoring objective is to document how effectively the offsite in-channel measures accomplish measurable habitat objectives. PWB's working hypothesis for effectiveness monitoring of these measures is that at least 80 percent of the projected changes in the key habitat attributes (pre-project versus post-project conditions) will occur in each affected stream reach.

PWB has committed to a performance level of 80 percent of projected changes (instead of 100 percent) because there will be a high degree of natural variation year to year and site to site. The natural variation will be further compounded by the error associated with measuring habitat variables in the field. Given this high level of variation, it would not be possible statistically to detect a difference between a 100 percent change in a habitat variable and a much smaller change. PWB chose 80 percent as a minimum performance standard. If that level of habitat response is not met, additional actions may be required, and PWB will follow the adaptive management program described in Chapter 9 of the HCP.

Table 2. Attributes and Measurable Habitat Objectives in Reaches Affected by In-Channel Measures and Surveyed in 2019

	Measurable Habitat Objective (80% of Net Change in Metric)		
Attribute	**Metric**	**Net Change**	**Reach**
Large Woody Debris	Number of pieces per channel width	39%	Sandy 2
Off-Channel Habitat	Percentage of reach (by surface area) that comprises off-channel habitat	1%	
Large Woody Debris	Number of pieces per channel width	567%	Gordon 1A
Backwater Pools	Percentage of reach (by surface area) that comprises backwater pools	Increase from 0% to 5%	
Pool Habitat	Percentage of reach (by surface area) that comprises pool habitat	115%	
Pool Tail Habitat	Percentage of reach (by surface area) that comprises pool tails	46%	
Small-Cobble Riffles	Percentage of reach (by surface area) that comprises small-cobble riffles	–33%	
Large-Cobble Riffles	Percentage of reach (by surface area) that comprises large-cobble riffles	–17%	
Fine Sediment	Percentage of gravel patches (by surface area) that is fine sediment	–25%	
Large Woody Debris	Number of pieces per channel width	567%	Gordon 1B
Backwater Pools	Percentage of reach (by surface area) that comprises backwater pools	Increase from 0% to 5%	
Pool Habitat	Percentage of reach (by surface area) that comprises pool habitat	212%	
Pool Tail Habitat	Percentage of reach (by surface area) that comprises pool tails	326%	

Table 2. Attributes and Measurable Habitat Objectives in Reaches Affected by In-Channel Measures and Surveyed in 2019

	Measurable Habitat Objective (80% of Net Change in Metric)		
Attribute	**Metric**	**Net Change**	**Reach**
Small-Cobble Riffles	Percentage of reach (by surface area) that comprises small-cobble riffles	–40%	
Large Woody Debris	Number of pieces per channel width	7%	Trout 1A
Large Woody Debris	Number of pieces per channel width	13%	Trout 2A
Large Woody Debris	Number of pieces per channel width	291%	Zigzag 1A
Artificial Confinement	% length artificially confined	–38%	
Small-Cobble Riffle	Percentage of reach (by surface area) that comprises small-cobble riffles	4%	
Pool Habitat	Percentage of reach (by surface area) that comprises pool habitat	27%	
Pool Tails	Percentage of reach (by surface area) that comprises pool tails	15%	

4. Key Questions and Hypothesis

One key question and its related null hypothesis (H_o) will be answered by the offsite monitoring protocol:

<u>Question</u>: Did the implementation of the restoration projects result in the changes to the monitored habitat attributes that were predicted by the EDT assessment?

> H_o: The difference between the mean of baseline values and the mean of post-treatment values in treatment reaches will not be significantly less than the difference predicted by the EDT assessment.

In order to make this comparison, the baseline values in the EDT model will be updated by collecting at least two years of pre-treatment data on all the habitat attributes that are predicted to change significantly (summarized in Table 2). The differences in habitat conditions between the actual pre-treatment and post-treatment data will be used to determine whether the projected EDT fish benefits, as expressed in the HCP, are realized.

The comparison of the observed changes in monitored habitat attributes to measurable habitat objectives will be analyzed both numerically and statistically (using a 95 percent level of confidence). The numeric test will simply determine whether the mean of post-treatment values is at least 80 percent of the target values. The measurable habitat objective for each offsite, in-channel measure response variable was set at 80 percent of the projected change to account for the fact that each variable is expected to show a large degree of variation. The statistical test will assign a level of confidence to each of the pre-treatment and post-treatment values and determine the power of the statistical test to detect significant shortfalls. Having a level of confidence associated with each value will be helpful during the adaptive management process should any post-treatment value fall short of the measurable habitat objective.

5. Monitoring Design

5.1 Study Design

PWB uses a Before-After with Control-Impact (BACI) study design to monitor the effects of the HCP offsite, in-stream mitigation projects (Roni et al., 2005). Control reaches upstream of the treated reaches will be surveyed in addition to the treated reaches, as indicated in Table 3. Control reaches will be entire upstream reaches delineated for EDT or one mile in length, whichever is less, to minimize survey effort and yet provide a representative length of stream. In cases in which a treated reach is very long (more than five miles), and the treatment is restricted to the lower portion of the reach, the upstream portion of the same reach will serve as a control. This approach is used because the further upstream a control reach is, the less representative it probably is of the habitat in which treatment occurred. PWB will use attribute values for the entire EDT reach (including the control reach segment) as the treatment reach values and just use attribute values from the control reach segment as the respective control reach values.

Table 3. Paired Treatment and Control Reaches in Streams Surveyed in 2019

Watershed	Treated Reaches	Control Reaches
Lower Sandy River	Sandy 2	Sandy 2 (upper 4 miles)
Lower Sandy River	Gordon 1A	Gordon 2A
Lower Sandy River	Gordon 1B	Gordon 2A
Lower Sandy River	Trout 1A	Trout 3A
Lower Sandy River	Trout 2A	Trout 3A
Zigzag River	Zigzag 1A	Zigzag 1B (lower 1.6 miles)

5.2 Spatial Scale

The measurable habitat objectives (in Table 2) are reach-scale objectives. The survey protocol is to collect data at both the habitat-unit and reach scales, but all the data are used to derive reach-scale assessments of habitat condition. Reaches vary in length, so all attribute values are normalized by either channel length or surface area.

5.3 Replication/Duration

Most habitat attributes are naturally variable from year to year. For example, if wood is added to a reach but high flows do not occur the following winter, there may be no resultant formation of pools. In other years, winter high flows may fill in some pools and create new ones elsewhere. For this reason, before (baseline) and after (post-treatment) data will be replicated over time.

Surveys are conducted in the summer or early fall when flows are low, and the stream channels are most navigable. Two to four pre-treatment surveys and five post-treatment surveys are conducted. Pre-treatment surveys were conducted annually prior to treatment. Post-treatment surveys are conducted at three-year intervals beginning the year after treatment and continuing for 12 additional years, for a total of five post-treatment surveys.

5.4 Variables

The habitat attributes used by EDT to evaluate restoration alternatives are derived from the data types summarized below. All data types are information collected during stream surveys. However, not all attributes are used to evaluate the effectiveness of the offsite in-channel measures.

- Reach-scale data
  - Active channel (bankfull)[1] width (feet)
  - Gradient (percent)
  - Total surface area of off-channel habitat (estimated visually, in square feet)
- Habitat unit-scale data
  - Habitat type (pool, backwater pool, beaver pond, glide, small-cobble riffle, large-cobble riffle)
  - Average length (feet)
  - Average width (feet)
  - Amount of pool tail-out habitat (data collected in pools only; percentage of total surface area that is at the downstream end of the pool and flowing with velocities comparable to those of neighboring glides and riffles)
  - In-channel wood (number of pieces greater than 4 inches in diameter and greater than 7 feet long in the active channel of the habitat unit)
  - Fine sediment in spawning habitat types (percentage surface area of gravel patches in small-cobble riffles, pool tail-outs, glides)

[1]The active channel, or bankfull channel, is the portion of the channel where flows occur often enough to prevent the establishment of vegetation, generally corresponding to a break in the slope of the bank.

- Embeddedness in spawning habitat types (percent of the vertical dimension of surface cobbles and large gravel that is buried in fine sediment in gravel patches in small-cobble riffles, pool tail-outs, glides)

These data enable PWB to evaluate how well it has met most of the measurable habitat objectives summarized in Table 1. The percentage of fine sediment in spawning gravels may show too much in-reach variability to allow the detection of the anticipated change.

5.5 Sampling Scheme

Habitat attributes in both treatment and control reaches are monitored using a modified Hankin and Reeves-type stratified systematic inventory of stream channel characteristics (Hankin and Reeves 1988).

Hankin and Reeves-type protocols involve two main sources of error. PWB adjusts its protocols to reduce these sources of error. The first source of error stems from the strategy of estimating habitat dimensions throughout a reach and then using a subset of measurements to correct the estimates. These corrections are associated with a range of variability, which decreases confidence in the final result. To maximize the statistical power of the monitoring data analysis, given the small sample size of pre-treatment data, all habitat unit dimensions are measured. The second source of error is measurement error, which can accumulate over the length of a reach. PWB reduces this form of error by using normalized data (percentages) for habitat quantities and standardized reach lengths and widths between years for the calculation of pieces of wood per channel width.

6. Analysis

6.1 Data Storage

Monitoring data collected during the HCP are maintained by PWB in Microsoft® Excel spreadsheets. Summary data will be added to the Sandy River EDT database. The data will be made available to the National Marine Fisheries Service, U.S. Fish and Wildlife Service, Oregon Department of Fish and Wildlife, and other regulatory agencies ("Services") for review at any time and will be extensively discussed during the HCP Year 20 check-in meeting of PWB with the services. Following quality assurance/quality control procedures and review and approval by PWB and the Services, the data will be made available to the StreamNet Library (through the Columbia River Inter-Tribal Fish Commission [CRITFC] technical reports), Oregon Department of Fish and Wildlife AIP (http://oregonstate.edu/Dept/ODFW/freshwater/inventory/index.htm), and the U.S. Forest Service Natural Resource Information System (NRIS) Water Module databases. Each of these databases was consulted extensively in the Sandy River Basin EDT analysis. Appropriate treatment and control-reach data that are already in these databases will be used to bolster the sample size of the pre-treatment habitat attributes. Pre-existing data will not be used if the habitat in the respective streams has since been modified by restoration activities other than the planned HCP offsite in-channel measures.

6.2 Hypothesis Testing

Both the numeric and statistical evaluation of the hypothesis for the monitoring plan key question suggest a fundamental comparison between baseline and post-treatment data on a reach-by-reach, attribute-by-attribute basis. Control reaches will be employed to subtract out variation due to large-scale effects outside of PWB's control. An example of how this will occur is given below (T=Treatment reach value, C=Control reach value):

$$\left.\begin{matrix} T_{before1}-C_{before1} \\ T_{before2}-C_{before2} \end{matrix}\right\} \textbf{ mean } \text{ vs. } \textbf{ mean } \left\{\begin{matrix} T_{after1}-C_{after1} \\ T_{after2}-C_{after2} \\ T_{after3}-C_{after3} \\ T_{after4}-C_{after4} \\ T_{after5}-C_{after5} \end{matrix}\right.$$

The numeric comparison of the means of pre-treatment and post-treatment data will determine whether or not the post-treatment mean is equal to or greater than 80 percent of the measurable habitat objective. For statistical comparisons, t-tests will be performed on the differences between treatment reach and control reach habitat attribute values, with a 95 percent level of confidence.

7. Adaptive Management

If data indicate that the effectiveness monitoring protocol null hypotheses should not be rejected and if the new EDT results indicate that the predicted changes to freshwater productivity are less than originally described for PWB's offsite in-channel conservation measures, PWB will follow the adaptive management process described in Chapter 9 of the HCP.

8. 2019 Results

Tables 4, 5, 6, and 7 summarize the results for offsite in-stream measure effectiveness monitoring surveys conducted in 2019 in the Sandy River, Gordon Creek, Trout Creek, and Zigzag River, respectively. The tables also compare survey results with the values for the current condition of the same habitat attributes in the EDT database. The control reach for Sandy 2 is the upstream 4 miles of Sandy 2, upstream of where City HCP measures have been implemented. The control reach for Zigzag 1A is the lower 1.6 miles of the reach immediately upstream.

Table 4. Comparison of Values for Various Habitat Attributes[a] in the Sandy River Derived from the EDT Database and 2019 Survey Results

	Treatment Reach		Control Reach	
	Sandy 2		Sandy 2 (control)	
Attribute[a]	EDT Current	2019 Survey	EDT Current	2019 Survey
Large Wood (pieces/CW)[b,c]	6.5	10.4	6.5	4.4
Backwater Pools	2.4%	0.44%	2.4%	0.51%
Beaver Ponds	0.0%	0.72%	0.0%	0.00%
Pools	13.9%	29.96%	13.9%	20.97%
Pool Tails	2.8%	2.38%	2.8%	1.00%
Small-Cobble Riffles	34.8%	17.69%	34.8%	4.47%
Large-Cobble Riffles	34.8%	20.78%	34.8%	41.47%
Glides	11.1%	28.03%	11.1%	31.58%
Off-Channel Habitat	3.0%	0.18%	3.0%	0.00%
Percent Fines	14.5%	19.65%	14.5%	13.72%
Embeddedness	37.5%	36.50%	37.5%	28.39%

[a]The selected attributes are expected to respond to HCP in-stream conservation measures.

[b]Large wood is given as a standardized metric (pieces of wood per average high-flow channel width [CW].)

[c]Sandy 2 Large Wood value does not include wood placed by the Metro Regional Government in 2017.

Table 5. Comparison of Values for Various Habitat Attributes[a] in Gordon Creek Derived from the EDT Database and 2019 Survey Results

	Treatment Reaches				Control Reach	
	Gordon 1A		Gordon 1B		Gordon 2A	
Attribute[a]	EDT Current	2019 Survey	EDT Current	2019 Survey	EDT Current	2019 Survey
Large Wood (pieces/CW)[b]	1.5	1.8	1.5	2.7	1.5	1.9
Backwater Pools	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Beaver Ponds	0.0%	10.4%	0.0%	7.1%	0.0%	0.0%
Pools	3.2%	19.7%	6.5%	14.4%	3.2%	14.0%
Pool Tails	3.2%	1.2%	1.3%	0.2%	3.2%	0.4%
Small-Cobble Riffles	40.6%	15.3%	58.4%	4.3%	40.6%	1.2%
Large-Cobble Riffles	52.9%	44.3%	33.8%	73.0%	52.9%	83.3%
Glides	0.0%	9.2%	0.0%	1.0%	0.0%	1.1%

Table 5. Comparison of Values for Various Habitat Attributes[a] in Gordon Creek Derived from the EDT Database and 2019 Survey Results

	Treatment Reaches				Control Reach	
	Gordon 1A		Gordon 1B		Gordon 2A	
Attribute[a]	EDT Current	2019 Survey	EDT Current	2019 Survey	EDT Current	2019 Survey
Off-Channel Habitat	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Percent Fines	8.5%	12.1%	8.5%	10.5%	8.5%	6.0%
Embeddedness	0.0%	30.3%	0.0%	29.3%	0.0%	23.8%

[a]The selected attributes are expected to respond to HCP in-stream conservation measures.

[b]Large wood is given as a standardized metric (pieces of wood per average high-flow channel width [CW].)

Table 6. Comparison of Values for Various Habitat Attributes[a] in Trout Creek Derived from the EDT Database and 2019 Survey Results

	Treatment Reaches				Control Reach	
	Trout 1A		Trout 2A		Trout 3A	
Attribute[a]	EDT Current	2019 Survey	EDT Current	2019 Survey	EDT Current	2019 Survey
Large Wood (pieces/CW)[b]	1.5	2.9	1.5	2.0	1.5	1.5
Backwater Pools	10.3%	0.0%	0.0%	0.0%	0.0%	0.0%
Beaver Ponds	0.0%	14.0%	0.0%	0.0%	0.0%	0.0%
Pools	4.1%	45.6%	0.0%	6.4%	3.9%	13.1%
Pool Tails	1.0%	0.1%	0.0%	0.0%	0.0%	0.2%
Small-Cobble Riffles	41.2%	4.5%	58.0%	93.5%	54.9%	86.8%
Large-Cobble Riffles	43.3%	9.3%	42.0%	0.0%	41.2%	0.0%
Glides	0.0%	26.6%	0.0%	0.0%	0.0%	0.0%
Off-Channel Habitat	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Percent Fines	14.5%	24.5%	8.5%	10.0%	8.5%	5.0%
Embeddedness	0.0%	54.0%	0.0%	60.0%	0.0%	0.0%

[a]The selected attributes are expected to respond to HCP in-stream conservation measures.

[b]Large wood is given as a standardized metric (pieces of wood per average high-flow channel width [CW].)

Table 7. Comparison of Values for Various Habitat Attributes[a] in the Zigzag River Derived from the EDT Database and 2019 Survey Results

	Treatment Reach		Control Reach	
	Zigzag 1A Reach		Zigzag 1B Reach	
Attribute	EDT Current	2019 Survey	EDT Current	2019 Survey
Large Wood (pieces/CW)[b]	0.7	3.4	0.7	0.9
Backwater Pools	0.0%	0.0%	0.0%	0.0%
Beaver Ponds	0.0%	0.9%	0.0%	0.0%
Pools	15.0%	14.3%	15.0%	5.9%
Pool Tails	3.0%	0.4%	3.0%	0.0%
Small-Cobble Riffles	57.7%	5.2%	57.7%	0.0%
Large-Cobble Riffles	20.0%	78.8%	20.0%	94.0%
Glides	7.0%	0.5%	7.0%	0.0%
Off-Channel Habitat	5.0%	0.0%	5.9%	0.0%
Percent Fines	NR[c]	47.3%	NR[c]	30.0%
Embeddedness	14.5%	11.8%	14.5%	27.9%

[a]The selected attributes are expected to respond to HCP in-stream conservation measures.

[b]Large wood is given as a standardized metric (pieces of wood per average high-flow channel width [CW]).

[c]NR = Not Rated. The EDT database does not include a Current rating for this attribute.

Table 8 summarizes the averages of baseline values, standard deviations, and post-treatment targets for the habitat attributes that have measurable habitat objectives in each treatment reach. Control reaches are not included because they do not have measurable habitat objectives. The number of baseline survey years that are incorporated into each baseline average and the number of post-treatment survey years incorporated into each post-treatment average are given in respective order in parentheses in the Reach column, separated by a comma.

Table 8. Baseline Averages, Post-Treatment Targets, and Post-Treatment Averages for Habitat Attributes with Measurable Habitat Objectives in Streams Surveyed in 2019[a,b]

Attribute	Baseline Average	Standard Deviation	Post-Treatment Target	Post-Treatment Average[c]	Reach
Large Woody Debris (pieces/CW)	7.3	0.5	9.0	11.3	Sandy 2 (n=2,1)
Off-Channel Habitat	0.03%	0.0%	3.0%	0.2%	

Table 8. Baseline Averages, Post-Treatment Targets, and Post-Treatment Averages for Habitat Attributes with Measurable Habitat Objectives in Streams Surveyed in 2019[a,b]

Attribute	Baseline Average	Standard Deviation	Post-Treatment Target	Post-Treatment Average[c]	Reach
Large Woody Debris	2.3	0.4	10.0	2.5	Gordon 1A (n=4, 3)
Backwater Pools	0.5%	0.8%	5.1%	0.1%	
Pool Habitat	36.3%	7.4%	30.0%	30.5%	
Pool Tail Habitat	1.0%	0.6%	5.1%	1.7%	
Small-Cobble Riffles	8.2%	5.0%	34.8%	15.7%	
Large-Cobble Riffles	43.6%	7.7%	25.0%	38.8%	
Fine Sediment	12.6%	9.7%	18.0%	14.2%	
Large Woody Debris	3.7	0.5	10.0	4.0	Gordon 1B (n=4,3)
Backwater Pools	0.1%	0.1%	4.7%	0.0%	
Pool Habitat	26.1%	8.5%	20.2%	20.3%	
Pool Tail Habitat	0.4%	0.3%	5.5%	0.5%	
Small-Cobble Riffles	2.3%	1.8%	35.0%	4.0%	
Large Woody Debris	1.1	1.0	1.6	2.3	Trout 1A (n=4, 3)
Large Woody Debris	5.5	1.2	1.7	3.6	Trout 2A (n=4, 3)
Large Woody Debris (pieces/CW)	2.7	0.9%	2.6	NA	Zigzag 1A (n=2,0)
Artificial Confinement	40%	NA	25%	NA	
Small-Cobble Riffle	3.9%	1.8%	57.0%	NA	
Pool Habitat	14.4%	0.2%	17.2%	NA	
Pool Tails	0.4%	0.1%	3.8%	NA	

[a]Source: EDT model run (10/20/2005) for current and historical status of attributes and expected values after implementation of individual measures.

[b]Appendix E of the HCP, Offsite Habitat Effects Tables, provides the list of all attributes, habitat objectives, and reaches that may be affected by the HCP measures.

[c]NA indicates that data have not yet been collected, or a statistic cannot yet be calculated.

9. Discussion

The results presented in Tables 4, 5, 6, and 7 of this report contribute to the baseline average of values and begin a record of post-treatment values for the respective monitored habitat attributes. Measure H-4 (Sandy 2 Large Wood Placement) was implemented in 2017 and 2018, so the habitat attribute data collected in this stream in 2019 are post-treatment measurements. Further post-treatment data will be collected in the Sandy River in 2022, 2025, 2028, and 2031. Measures H-5 (Gordon 1A and 1B Large Wood Placement) and H-6 (Trout 1A Large Wood Placement) were implemented in 2012, so the habitat attribute data collected in these streams in 2019 are also post-treatment measurements. Further post-treatment data will be collected in Gordon Creek and Trout Creek in 2022 and 2025. Measure H-27 Zigzag 1A Channel Design was implemented in 2019, so the habitat attribute data collected in this stream in 2019 was the final addition of baseline data. PWB will collect post-treatment data in 2020, 2023, 2026, 2029, and 2032.

The comparison of baseline values to the current condition values in the EDT database will help determine whether more restoration is needed than was assumed during the development of the HCP. The comparison of the averages of post-treatment values for habitat attributes to the averages of baseline values in each treatment reach and with the respective averages in control reaches will determine whether PWB has met its restoration targets in those streams and whether additional efforts are necessary.

10. Works Cited

City of Portland. 2004. Development and Application of the EDT Database and Model for the Sandy River Basin. Prepared with assistance from Mobrand Biometrics, Inc. Portland, Oregon.

Hankin, David G., and Gordon H. Reeves. 1988. Estimating Total Fish Abundance and Total Habitat Area in Small Streams Based on Visual Estimation Methods. *Can. J. Fish. Aquat. Sci.* 45:834-844.

Portland Water Bureau. 2008. Bull Run Water Supply Habitat Conservation Plan for the Issuance of a Permit to Allow Incidental Take of Threatened and Endangered Species. Portland, Oregon.

Roni, Philip, Andrew H. Fayram, and Michael A. Miller. 2006. Monitoring and evaluating instream habitat enhancement. Pages 209–236 in *Monitoring Stream and Watershed Restoration* (P. Roni, ed.). American Fisheries Society. Bethesda, Maryland.

Appendix C

Bull Run HCP Research Report

Lower Bull Run River Spawning Gravel Research

June 2020
Burke Strobel
City of Portland Water Bureau

Contents

Tables

Figures

1. Summary

The City of Portland Water Bureau (PWB) was in full compliance with its Habitat Conservation Plan obligations in 2019 with regard to lower Bull Run River spawning gravel research. A survey of gravel patches of sufficient area and with adequately sized substrate for Chinook Salmon and steelhead spawning was conducted from the mouth of the Bull Run River (RM 0) to the former site of the Dam 2 spillway plunge pool rock weir (river mile [RM] 5.8).

The combined surface area of adequately sized spawning gravel patches was significantly higher than the baseline average for steelhead and for Chinook at all flows. The surface area of spawning gravel in 2019 was near the top of the range of what had been observed in all previous years (2010–2018) at all locations and flows and slightly larger than it was in 2018. The largest accumulations of gravel were in the river channel immediately downstream of Larson's Bridge. In the first five years of the HCP, elevated gravel additions significantly increased the surface area of spawning gravel for Chinook and steelhead in the lower Bull Run River. The increased surface area of spawning gravels was maintained over the following five years with reduced gravel additions. This appendix summarizes the results of this study.

2. Introduction

The availability of appropriate gravel patches can limit the productivity of salmonid populations within a given stream. The dams on the Bull Run River block the downstream movement of streambed substrates. These obstructions have contributed over time to a net loss of spawning gravel patches in the lower Bull Run River, as gravel is washed away and then not replaced.[1]

Under the conditions of the Bull Run Water Supply Habitat Conservation Plan (HCP; Portland Water Bureau 2008), PWB adds gravel annually to the lower Bull Run River to supplement naturally occurring spawning gravel. A total of 600 cubic yards of adequately sized gravel was added to the lower Bull Run River in 2019 to benefit spawning salmonids. This was the tenth treatment year. In years 2010–2014, 1,200 cubic yards of gravel was added annually to the Bull Run River. This amount was decreased to 600 cubic yards in 2015. In future years, for the duration of the HCP term, the amount of spawning gravel added to the Bull Run River will be 600 cubic yards. This appendix describes the methods and protocols for monitoring the effectiveness of this effort to increase the surface area of spawning gravel in the lower Bull Run River and provides a summary of the findings for 2019.

[1] More information on the role of gravel in spawning is available in Chapter 8 and Appendix E of the HCP.

3. Research Objective

PWB identified a measurable habitat objective for the spawning gravel placement conservation measure (H-1) detailed in HCP Chapters 7 and 9. PWB is supplying spawning gravel in amounts equivalent to or exceeding natural supply rates. PWB augmented spawning gravel in the lower Bull Run River with a total of 1,200 cubic yards of gravel annually for the first five years of HCP implementation. This amount roughly doubled the estimated natural recruitment rate of gravel in the absence of reservoirs (calculations and estimates summarized in CH2M HILL 2003) and was intended to accelerate the accumulation of gravel in the lower Bull Run River.

After five years (in 2015), the rate of gravel supplementation was decreased to 600 cubic yards annually for the remainder of the HCP, the estimated natural recruitment rate in the absence of upstream reservoirs. PWB, however, cannot predict how the gravel will be distributed or how quickly it will be moved downstream. There is no information on how much gravel was in the lower Bull Run channel and how it varied from year to year before construction of the first Bull Run dam blocked its recruitment from the upper river in 1923.

The objective of the Bull Run River spawning gravel research is to measure the surface area of patches of gravel suitable for spawning steelhead and Chinook in the lower Bull Run River. Gravel that is suitable for steelhead spawning is defined as particle sizes between 0.01 feet (0.12 inches) and 0.4 feet (4.8 inches) in diameter. Gravel that is suitable for Chinook spawning is defined as particle sizes between 0.01 feet (0.12 inches) and 0.5 feet (6 inches) diameter. Effective spawning gravel patches are patches that experience adequate depth and flow throughout the egg and alevin incubation period. Separate estimates will be generated for steelhead and Chinook. PWB will quantify the surface area of all patches that have substrate in suitable size ranges. (The surface area of the subset of the patches that would be effective for spawning may also be analyzed in the future.)

4. Key Questions and Hypotheses

The key questions and related null hypotheses (H_o) to be answered by the Bull Run River spawning gravel research are described below.

4.1 Area of Spawning Gravel

<u>Question 1:</u> What is the summed surface area of gravel patches suitable for steelhead and Chinook spawning in the lower Bull Run River and has it significantly increased from pre-supplementation values?

H_o: The summed surface area of spawning gravel patches in each post-supplementation year will not be significantly greater than the mean of pre-supplementation years (one-sample t-test, α=0.05).

The pre-supplementation years that will be used for the analysis are 2007, 2008, and 2009. Gravel data were also collected by PWB in 1997, 1999, and 2001. The data from these surveys were not included in the baseline averages because they were collected using different protocols, with conclusions based on different flow assumptions. The comparison will use only gravel patches between the Dam 2 spillway plunge pool at RM 5.8 and the Portland General Electric (PGE) Bull Run Powerhouse at RM 1.5 because the 2007 survey data do not cover the river downstream of this point.

4.2 Trend over Time

Question 2: What is the trend in the summed surface area of spawning gravel patches and the effective spawning area for each reach?

H_o: The summed surface area of spawning gravel patches in post-supplementation years will not show a significant increase over time (α=0.05).

H_o: The summed surface area of effective spawning gravel patches at various flow combinations in post-supplementation years will not show a significant increase over time (α=0.05).

4.3 Reach-Level Effective Spawning Gravel

Although the HCP calls for determining the quantity of effective spawning gravel, this objective has proven to be impractical. Determining the effective spawning area for each reach requires information on water surface elevation and water velocity for each gravel patch through time.

The following HCP key question and hypothesis were not addressed:

Question 3: What is the effective spawning area of each reach at various combinations of flows and at the flows actually observed during steelhead incubation in the lower Bull Run River?

H_o: The summed effective spawning area at various flow combinations in each post-supplementation year will not be significantly greater than the mean of pre-supplementation years (one-sample t-test, α=0.05).

The total of the areas of gravel that meet the depth and water velocity criteria for both spawning and incubation of steelhead and Chinook (summarized in Appendix F, Table F-5, of the HCP) during the respective time periods are used to determine the "effective spawning area" of each reach (R2 Resource Consultants 1998). These variables, however, will change continuously through time as they are the sum of current and future conditions for each point in space and time.

If a method for accurately estimating depth and water velocity through time for each gravel patch is devised, an analysis of effective spawning gravel may be attempted in the future.

4.4 Distribution of Spawning Gravel

Although there were no key questions or hypotheses identified in the HCP regarding how gravel will be moved naturally by flows over time in the Bull Run channel, understanding how the longitudinal and lateral distribution of gravel patches changes over time will be useful to evaluate the effectiveness of this measure. The following questions will be investigated. There are no associated null hypotheses:

Question 4: What is the longitudinal distribution of the surface area of gravel patches, and how does it change from year to year?

Question 5: Where in the channel laterally (as described in terms of being wetted at specific flows[2]) does gravel accumulate, and how does the lateral distribution change from year to year?

5. Methods

5.1 Gravel Estimates per Seasonal Flow

The design of the lower Bull Run River spawning gravel research involved the use of surveys of spawning gravel surface areas to create a snapshot of the distribution of spawning gravel at a particular point in time. Predicted relationships between stage and flow were developed for multiple points along the lower Bull Run River using Hydrologic Engineering Center's River Analysis System (HEC-RAS).[3] These relationships were then used to estimate the amount of spawning gravel that would be wetted at each flow. All gravel that was available to spring Chinook for spawning would be a subset of what was available to fall Chinook. All gravel that was available to fall Chinook would have been accessible to steelhead, but some of those patches would not be usable by steelhead because the substrate size would have been too large. Although not all wetted gravel patches would have the proper depth, velocity, or degree of turbulence for spawning, it was assumed throughout the subsequent analyses that the change in overall surface area of gravel can serve as a predictor of the surface area of the subset of that gravel that can be used for spawning.

[2] Gravel patches that are located laterally further to the edge of the active channel require a higher flow to become wetted.

[3] HEC-RAS is a software package developed by the U.S. Army Corps of Engineers for predicting the behavior of flowing channels using one-dimensional hydraulic modeling.

5.1.1 Steelhead Spawning Gravel

The amount of **steelhead spawning gravel** was estimated for the following peak steelhead spawning time (March, April, and May) flows:

- **1,405 cfs:** 10 percent average exceedance flow
- **614 cfs:** 50 percent average exceedance flow
- **120 cfs:** The lowest allowed flow under the HCP measure for minimum flows (actual flows may be higher)

5.1.2 Spring Chinook Spawning Gravel

The amount of **spring Chinook spawning gravel** was estimated for the following peak spring Chinook spawning time (September and October) flows:

- **358 cfs:** 10 percent average exceedance flow
- **77 cfs:** 50 percent average exceedance flow
- **30 cfs**: The lowest allowed flow under the HCP measure for minimum flows (actual flows may be higher)

5.1.3 Fall Chinook Spawning Gravel

The amount of **fall Chinook spawning gravel** was estimated for the following peak fall Chinook spawning time (October and November) flows:

- **1,480 cfs:** 10 percent average exceedance flow
- **77 cfs:** 50 percent average exceedance flow
- **30 cfs**: The lowest allowed flow under the HCP measure for minimum flows (actual flows may be higher)

Calculating the amount of spawning gravel at the 10 percent and 50 percent exceedance flows, as well as at the minimum allowable flow for each species' peak spawning period, allows for comparisons in the amount of spawning gravel across flows and across years. The amount of gravel wetted at the minimum allowable flow represents the minimum amount of gravel that would be available to each species. The amount of gravel wetted at the 10 percent and 50 percent exceedance flows indicates how far up the margins of the channel gravel accumulates and how much gravel remains available for spawning. This combined information can be used to evaluate the effectiveness of the HCP gravel placement effort at increasing the amount of spawning gravel for steelhead and spring and fall Chinook.

5.2 Spatial Scale

Surveys were used to determine the amount and quality of spawning gravel at various flows within the lower Bull Run River from the mouth (RM 0.0) to the Reservoir 2 spillway plunge pool (RM 5.8). Results are applicable only to the lower Bull Run River and have a reach-scale resolution.

5.3 Replication/Duration

Surveys are conducted once each year in the late spring/early summer or early fall in conjunction with adult Chinook surveys. The surveys occur after high flows associated with winter and spring storms have ceased and spawning gravel patches have stabilized, representing the amount of gravel available to steelhead and later to Chinook spawners for that year. There is no spatial replication; the entire channel is surveyed.

Three pre-treatment surveys were conducted in 2007, 2008, and 2009. These surveys form the baseline against which individual post-treatment years will be compared. One post-treatment survey was conducted each year during HCP Years 1–5, while the maximum amount of gravel supplementation (1,200 cubic yards) occurred. This represents the period of time when gravel was expected to accumulate most rapidly in the lower Bull Run River. The final year of maximum gravel supplementation was 2014.

After gravel supplementation was reduced in Year 6 (2015) of the HCP (to the maintenance level of 600 cubic yards), gravel surveys were conducted once per year and will be continued for a total of five years at the lower treatment level, HCP Years 6–10. During this phase, gravel supplementation is primarily intended to maintain gravel deposits in the lower Bull Run River, and surveys are designed to allow for an analysis powerful enough to detect negative trends in the surface area of spawning gravel. 2019 was the final year of annual surveys.

Provided that gravel supplementation at maintenance levels does not result in a rapid negative trend during HCP Years 6–10, the frequency of gravel surveys will be reduced to once every five years for the duration of the HCP. The next gravel survey in the lower Bull Run River will be in 2024.

5.4 Variables

The following variables were measured for each gravel patch:

Longitudinal Location. Location relative to the beginning of the reach, measured with a hand-held global positioning system (GPS) device

Lateral Location. Location within the channel—in the center of the channel, in the channel margin, or above the channel margin (outside the wetted area but within the active channel)

Retention Feature. Feature that acts on the current to allow gravel deposition: pool-tail, boulder, bedrock, large wood, and/or slow margins

Patch Size. Surface area of patch (square feet), calculated as total length multiplied by average width

Depth or Elevation. For submerged patches, depth of the center of the patch below the water surface; for gravel patches above the water surface, elevation of the center of the patch above the water surface

Embeddedness. The visually estimated percentage of the vertical dimension of surface substrates between 1.8 inches and 4 inches intermediate axis (roughly golf-ball size to softball size) that is surrounded by silt and sand. Average of 10 particles per patch of varying sizes. The percentage of total embeddedness is calculated as

%Total Embedded=([(%Embedded large particles/100)*(100–% fines)]+[% fines])/100

(Embeddedness procedures are reviewed in Sylte and Fischenich 2002).

Percentage of Fines. Estimated surface area of patch covered by silt and sand (not a thin film over other obvious surface substrates)

Upper and Lower 10th Percentile of Substrate Size. The sizes of particles corresponding to the upper and lower 10th percentile for each gravel patch were visually estimated. Particle size reflects the intermediate axis of the particle, or the axis that controls the particle's passage through a sieve

5.5 Sampling Scheme

Sampling protocols were slightly altered from those described in Appendix F of the HCP.

The lower Bull Run River was divided into a total of 16 segments, each one 2,000 feet in length. These smaller divisions will provide for greater resolution when tracking the dispersal of gravel through time than the original six reaches proposed in the HCP.

Segments were surveyed from upstream to downstream.

The 2019 survey was conducted at a discharge flow that varied between 24 cfs and 61 cfs as measured at U.S. Geological Survey (USGS) Gage No. 14140000.

Patches of gravel suitable for spawning steelhead and/or Chinook were identified along the length of the channel. Patches of spawning gravel were defined as being equal to or greater than 9 square feet, lying within the active channel and composed of substrates between 0.01 and 0.5 feet in diameter along their intermediate axis for Chinook and between 0.01 and 0.4 feet in diameter for steelhead.

A HEC-RAS model was developed for the lower Bull Run River using cross-sections taken from Light Detection and Ranging (LiDAR)[4] data. The model was calibrated using actual stage-discharge relationships from USGS Gage No. 14140000, as shown in Figure 1. The depth at each gravel patch at various flow levels was determined using stage-discharge relationships developed for each 2,000-foot river segment.

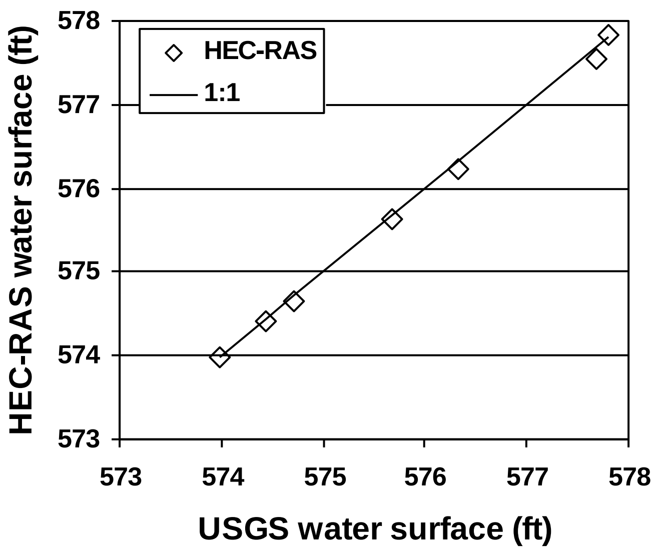

Figure 1. Comparison of HEC-RAS Model River Stage Results with USGS Stage/Discharge Curve Values

6. Analysis

Data Storage. Data are stored in Microsoft® Excel spreadsheets managed by the City of Portland Water Bureau.

Hypothesis Testing. The hypotheses relating each year's measured surface area of gravel to the mean of pre-gravel supplementation years were evaluated using one-tailed, one-sample t-tests (α=0.05).

7. Results

A total of 503 gravel patches with substrate sizes suitable for spawning Chinook were identified within the active channel in 2019, with a total of 55,430 square feet of

[4] LiDAR is a method of determining surface topography using reflected returns from a downward-pointed laser mounted on an aircraft. LiDAR has a resolution of 3 feet squared.

combined surface area. Of these, 473 patches also had substrate sizes suitable for spawning steelhead, with a total of 52,643 square feet of combined surface area.

7.1 Area of Spawning Gravel

7.1.1 Steelhead

There was more combined surface area of gravel patches with substrate sizes suitable for spawning steelhead in 2019 than the baseline average at all flows. This difference was statistically significant at all flows evaluated (one-sample, one-tailed t-test, α=0.05, df=2). The combined surface area, baseline average, standard deviation, and significance for each flow are summarized in Table 1.

Table 1. Combined Surface Area of Steelhead Spawning Gravel Patches in the Lower Bull Run River, 2019

	120 cfs	614 cfs	1,405 cfs
2019 Survey Results	36,195 ft^2	46,350 ft^2	49,803 ft^2
Baseline Average	5,159 ft^2	8,373 ft^2	12,532 ft^2
Baseline Standard Deviation	2,396 ft^2	4,723 ft^2	5,708 ft^2
Significantly Greater than Baseline?	Yes	Yes	Yes

7.1.2 Spring Chinook

In 2019, there was significantly more combined surface area of gravel patches with substrate sizes suitable for spawning spring Chinook than the baseline average at all flows (one-sample, one-tailed t-test, α=0.05, df=2). The combined surface area, baseline average, standard deviation, and significance for each flow are summarized in Table 2.

Table 2. Combined Surface Area of Spring Chinook Spawning Gravel Patches in the Lower Bull Run River, 2019

	30 cfs	77 cfs	358 cfs
2019 Survey Results	27,630 ft^2	35,434 ft^2	42,910 ft^2
Baseline Average	4,621 ft^2	4,994 ft^2	7,941 ft^2
Baseline Standard Deviation	1,578 ft^2	1,506 ft^2	3,294 ft^2
Significantly Greater than Baseline?	Yes	Yes	Yes

7.1.3 Fall Chinook

In 2018, there was significantly more combined surface area of gravel patches with substrate sizes suitable for spawning fall Chinook than the baseline average at all flows (one-sample, one-tailed t-test, α=0.95, df=2). The combined surface area, baseline average, standard deviation, and significance for each flow are summarized in Table 3.

Table 3. Combined Surface Area of Fall Chinook Spawning Gravel Patches in the Lower Bull Run River, 2019

	30 cfs	77 cfs	1,480 cfs
2019 Survey Results	27,630 ft^2	35,434 ft^2	51,931 ft^2
Baseline Average	4,621 ft^2	4,994 ft^2	13,912 ft^2
Baseline Standard Deviation	1,578 ft^2	1,506 ft^2	5,134 ft^2
Significantly Greater than Baseline?	Yes	Yes	Yes

7.2 Trend over Time

The increase in gravel surface area over time in post-supplementation years has been statistically significant. Ten years of post-supplementation data on gravel surface area have been collected, which is adequate to evaluate whether gravel surface area shows an increasing or decreasing trend over time. Despite the high degree of variability that can be attributed to varying river flows from year to year, the increase in the surface area of spawning gravel patches above baseline levels has continued to a point where it is extremely unlikely to be due to chance (Figures 2 and 3). The statistical significance of each trend in Figures 2 and 3 is indicated by the *p* value. Decreasing *p* values indicate increasing statistical significance, where 95 percent confidence equates with p=0.05.

The trend in gravel surface area over time is expected to become less significant as the years progress. Spawning gravel accumulated over the first five years of the HCP when it was added at twice the estimated historical rate of recruitment from the upper basin. After the rate of addition was decreased to the estimated historical rate of recruitment, gravel surface area declined and appears to have approximately stabilized. Provided the surface area of gravel continues to fluctuate within a range representing an approximate equilibrium between additions and gravel being washed out of the river, the linear trend should asymptotically approach a slope of zero.

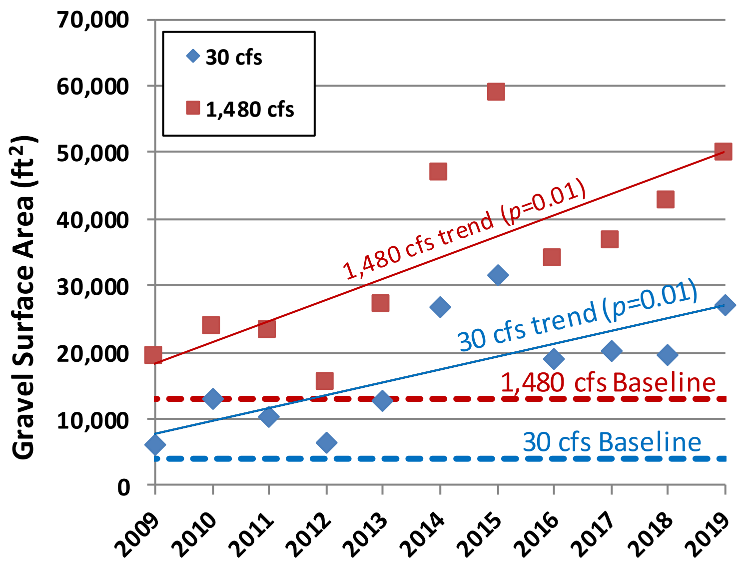

Figure 2. Trends in the Surface Area of Steelhead Spawning Gravel Wetted at 30 cfs and 1,480 cfs in Post-Treatment Years. Baseline Surface Areas Are Indicated

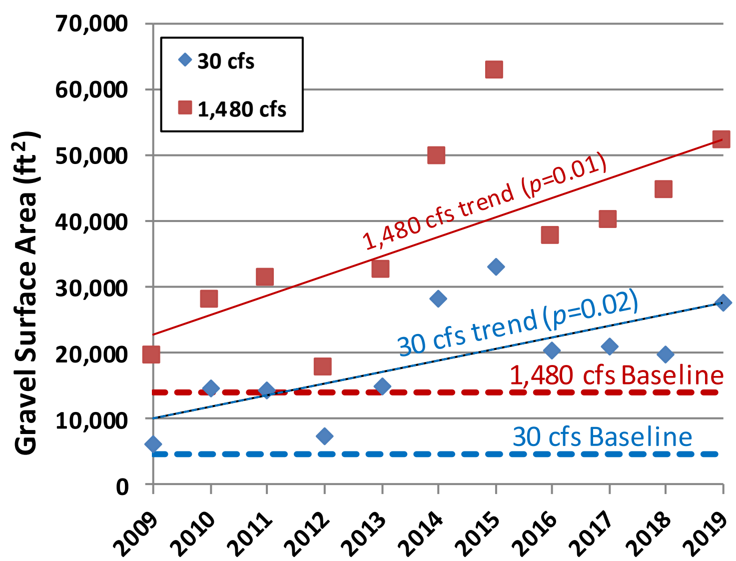

Figure 3. Trends in the Surface Area of Chinook Spawning Gravel Wetted at 30 cfs and 1,480 cfs in Post-Treatment Years. Baseline Surface Areas Are Indicated

7.3 Distribution of Spawning Gravel

7.3.1 Steelhead

In 2019, large accumulations of steelhead spawning gravel were observed immediately downstream of Larson's Bridge, as in previous years (Figure 4). Other accumulations were observed in the river segment between the Southside Bridge and Larson's Bridge and downstream of the Rock Cut Road site. Steelhead gravel accumulations continued to be elevated above baseline levels in the lower 1.5 miles of the river channel (mouth to the Bull Run Powerhouse). This, combined with past years' data, suggests that gravel that has been placed into the Bull Run River channel since 2010 has, in part, moved to the lowest portions of the river and possibly has been passing out of the river since 2014. Figures 5 and 6 compare the longitudinal distribution of steelhead spawning gravel in 2018 with previous post-treatment years and the baseline at flows that bracket the range of flows being evaluated.

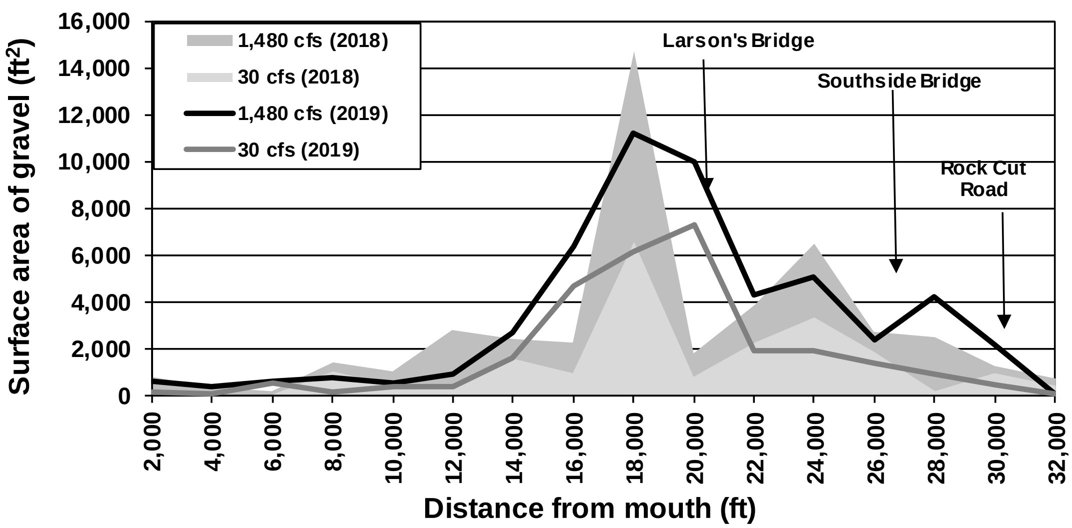

Figure 4. Longitudinal Distribution of Steelhead Spawning-Size Gravel Patches in the Lower Bull Run River in 2019 at 30 cfs and 1,480 cfs Compared to 2018

The largest observed increases in gravel over the baseline occurred in the portion of the channel wetted at relatively low flows (i.e., 120 cfs and less), as shown in Figure 7. The observed increases in the total surface area of steelhead spawning gravel above the baseline in 2019 were near the top of the range of that observed in previous years at all flows. The surface area of steelhead gravel wetted at the lowest flows (120 cfs and less) was between six and seven times the baseline levels.

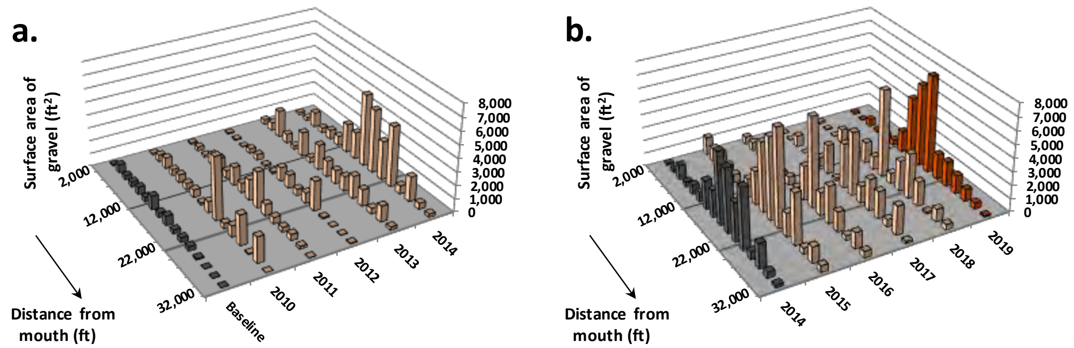

Figure 5. Longitudinal Distribution of Steelhead Spawning-Size Gravel Patches in the Lower Bull Run River through a) Years of High Additions (2010–2014) Compared to the Baseline Average, and b) Years of Reduced Additions (2015–2019) at 30 cfs

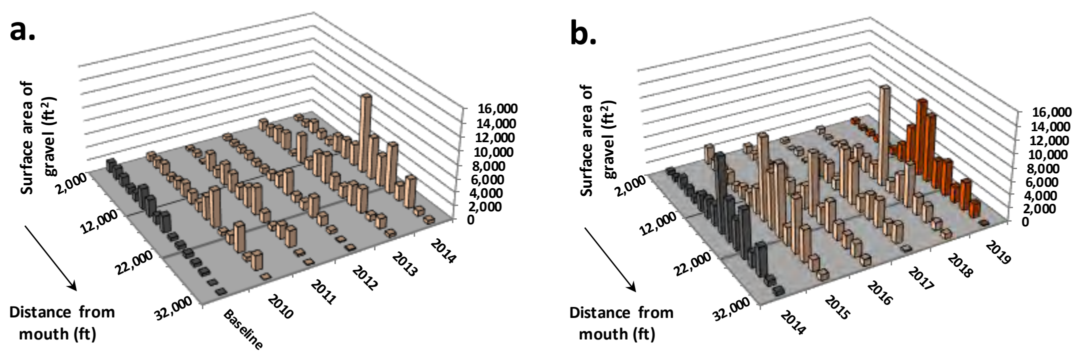

Figure 6. Longitudinal Distribution of Steelhead Spawning-Size Gravel Patches in the Lower Bull Run River through a) Years of High Additions (2010–2014) Compared to the Baseline Average, and b) Years of Reduced Additions (2015–2019) at 1,480 cfs

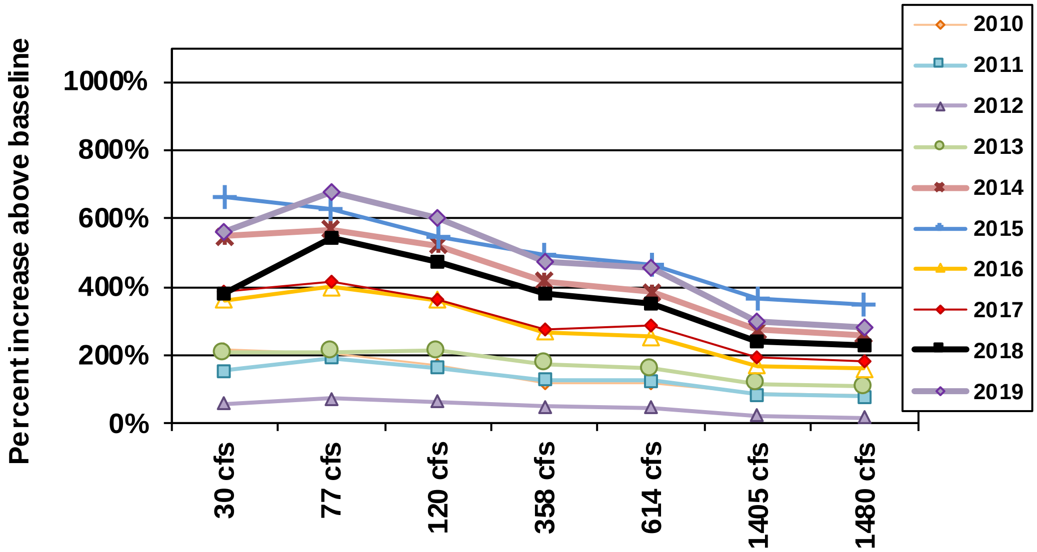

Figure 7. Increase in the Surface Area of Steelhead Spawning-Size Gravel Patches in 2019 above the Baseline Average for Various Flows Compared to Past Years

7.3.2 Chinook

In 2019, large accumulations of Chinook spawning gravel were observed immediately downstream of Larson's Bridge, as in previous years (Figure 8). Other accumulations were observed in the river segment between the Southside Bridge and Larson's Bridge and downstream of the Rock Cut Road site. Chinook gravel accumulations continued to be elevated above baseline levels in the lower 1.5 miles of the river channel (mouth to the Bull Run Powerhouse), as with steelhead gravel. This suggests that gravel that has been placed into the Bull Run River channel since 2010 has, in part, moved to the lowest portions of the river and has possibly been passing out of the river since 2014. Figures 9 and 10 compare the longitudinal distribution of Chinook spawning gravel in 2019 with previous post-treatment years and the baseline at flows that bracket the range of flows being evaluated.

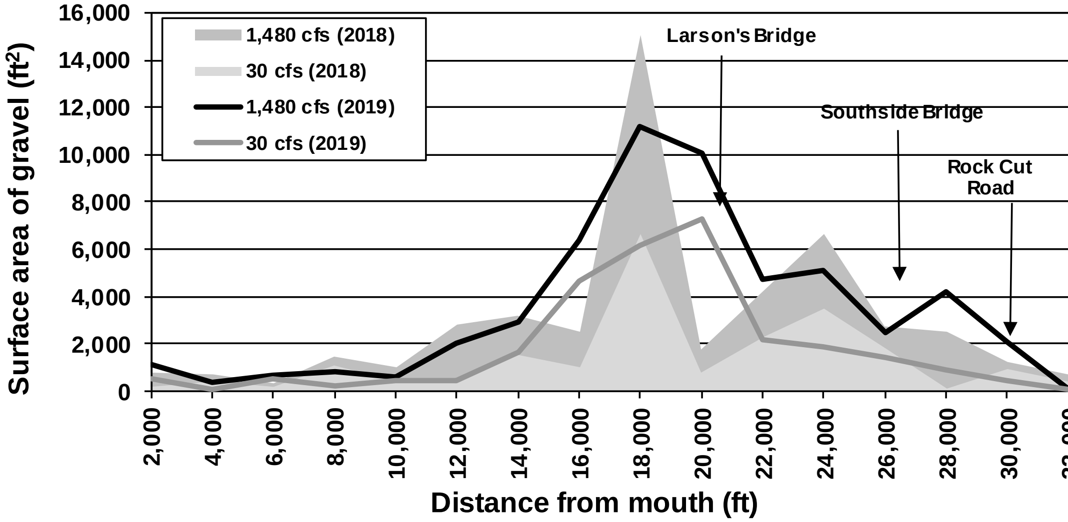

Figure 8. Longitudinal Distribution of Chinook Spawning-Size Gravel Patches in the Lower Bull Run River in 2019 at 30 cfs and 1,480 cfs Compared to 2018

The largest observed increases in gravel over the baseline occurred in the portion of the channel wetted at relatively low flows (i.e., 120 cfs and less), as shown in Figure 11. The observed increases in the total surface area of Chinook spawning gravel in 2019 above the baseline were near the top of the range of what was observed in previous years at all flows. The surface area of Chinook gravel wetted at the lowest flows (30 cfs) was six to seven times the baseline levels.

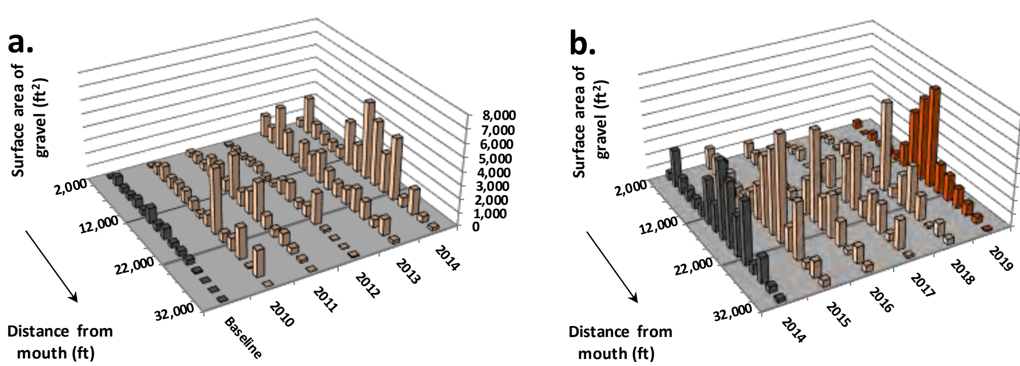

Figure 9. Longitudinal Distribution of Chinook Spawning-Size Gravel Patches in the Lower Bull Run River through a) Years of High Additions (2010–2014) Compared to the Baseline Average, and b) Years of Reduced Additions (2015–2019) at 30 cfs

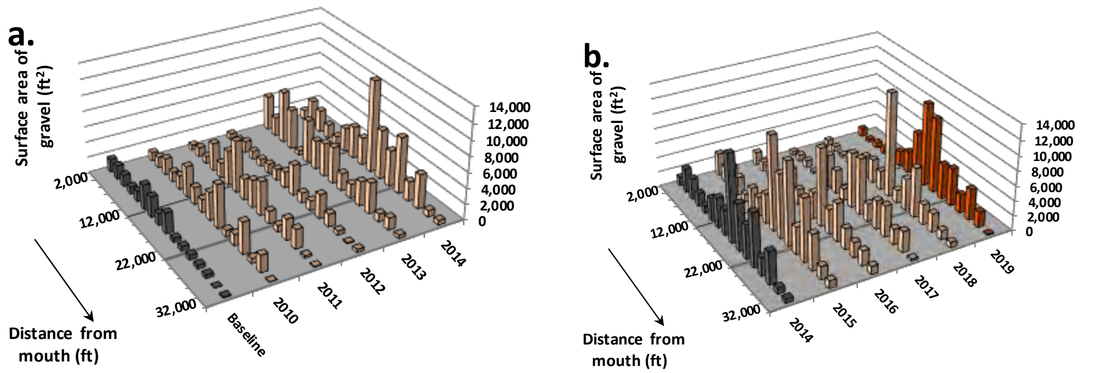

Figure 10. Longitudinal Distribution of Chinook Spawning-Size Gravel Patches in the Lower Bull Run River through a) Years of High Additions (2010–2014) Compared to the Baseline Average, and b) Years of Reduced Additions (2015–2019) at 1,480 cfs

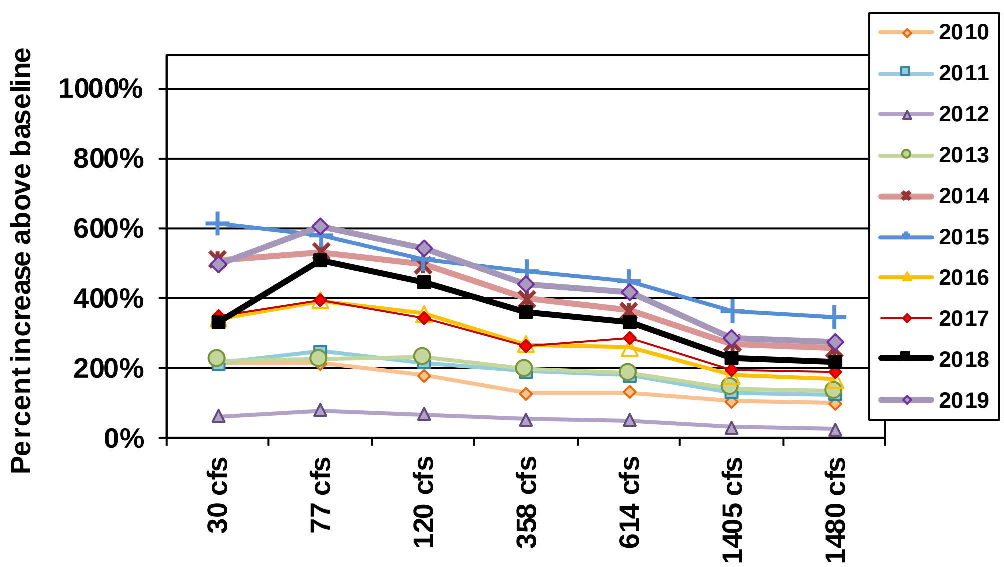

Figure 11. Increase in the Surface Area of Chinook Spawning-Size Gravel Patches in 2019 above the Baseline Average for Various Flows Compared to Past Years

8. Summary and Discussion

The total surface area of spawning-size gravel was significantly greater in 2019 than in baseline years at all flows for both steelhead and Chinook at a 95 percent level of statistical confidence. The total surface area of spawning gravel in 2019 was slightly larger than in 2018 and 2017, but all three years were less than in 2014 and 2015. Gravel was concentrated in portions of the Bull Run River immediately downstream of the three sites where gravel was added, with the largest accumulations downstream of Larson's Bridge. Gravel accumulations in the lowest 1.5 miles of the river were low and similar to what they were shortly after gravel additions first began. Fluctuations in gravel accumulations in the lower 1.5 miles of the river, observed since 2013, may suggest that gravel placed since 2010 has worked its way to the furthest downstream portions of the Bull Run River and may have been passing out of the river since 2014, at least.

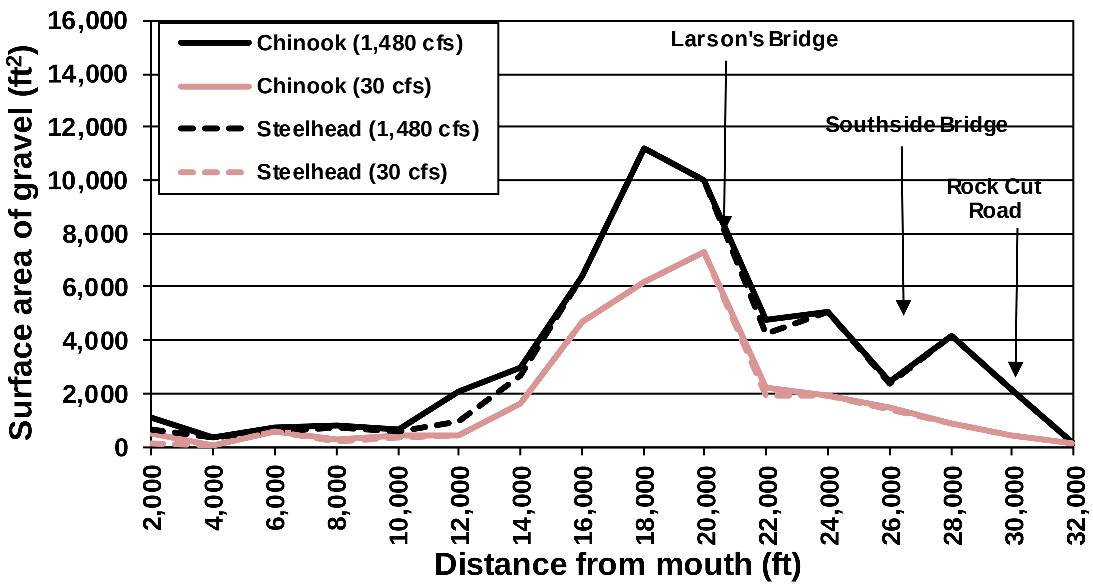

Figure 12. Comparison of Longitudinal Distribution of Chinook and Steelhead Spawning-Size Gravel Patches in the Lower Bull Run River in 2019 at 30 cfs and 1,480 cfs

The largest percentage increases in the surface area of gravel have occurred in the parts of the river that are wetted at relatively low flows. More than half of the total surface area of gravel patches was wetted at flows of 30 cfs at most locations along the lower Bull Run River channel (Figure 12). The surface area of gravel in this part of the channel was four to five times the baseline levels.

The first ten years of gravel additions to the lower Bull Run River have resulted in a significant and sustained increase in the surface area of spawning gravel patches available to Chinook Salmon and steelhead. In the first five years of the HCP, gravel was added at a rate estimated to be double that of the average historical, pre-dam rate (1,200 yd^3/year). During this time, the total surface area of gravel patches in the lower Bull Run River increased to between 260 and 567 percent above baseline levels (depending on flow levels). In the subsequent five years, gravel additions were decreased by 50 percent to match the historical rate of recruitment (600 yd^3/year). The surface area of spawning gravel has fluctuated during this period but remained, on average, between 240 and 532 percent above the baseline average. The peak year was in 2015, the first year after gravel additions were decreased. The large decrease in spawning surface area observed in 2016 from the levels observed in 2015 could be attributable to a combination of the decreased rate of gravel supplementation and the mobilization of gravel into the bottoms of deep pools or out of the river. Since then, gravel levels have generally increased again.

9. Works Cited

CH2M HILL. 2003. Lower Bull Run River Bedload Rate Approximations, Technical Memorandum to Steve Kucas, Portland Bureau of Water Works. February 20, 2003. Portland, Oregon.

R2 Resource Consultants. 1998. Spawning Gravel Survey of the Lower Bull Run River, Oregon. Revised draft report, prepared for the Portland Bureau of Water Works. May 27, 1998. Portland, Oregon.

Portland Water Bureau. 2008. Bull Run Water Supply Habitat Conservation Plan for the Issuance of a Permit to Allow Incidental Take of Threatened and Endangered Species. Portland, Oregon.

Sylte, Traci, and Craig Fischenich. 2002. Techniques for Measuring Substrate Embeddedness. EURPP Technical Notes Collection (ERDC TN-EMRPP-SR-36). U.S. Development Center, Vicksburg, Mississippi.

Appendix D

Bull Run HCP Research Report

Lower Bull Run River Spawning Gravel Scour Research

May 2020

Burke Strobel
City of Portland Water Bureau

Contents

1. Summary

The City of Portland Water Bureau (PWB) was in full compliance with the goals of the Bull Run Water Supply Habitat Conservation Plan in 2019 with regard to spawning gravel scour research in the lower Bull Run River. Ten redds were monitored for gravel scour depth.

Most, but not all, objectives of the spawning gravel scour research were met in 2019. Objectives were to measure mean changes in streambed elevation, mean scour depth, and the percentage of redds scoured to the depth of egg deposition. PWB intended to base these statistics on a sample of ten monitored redds. PWB successfully estimated both the mean scour depth and percentage of redds scoured to the depth of egg deposition. Ten redds were monitored using 20 devices. Only eleven devices from seven redds, however, could be located the following spring. It is believed that most of the missing devices were completely dislodged by scouring flows and washed downstream. Bed elevation at monitored redds was also not measured in 2019 because of the difficulty of transporting the laser level in early winter river flows.

The estimate of mean depth of scour in 2019 was 7.2 inches, with a range of 1.7–12.0 inches. The mean scour depth may have been greater. Three monitoring devices were scoured down to boulders or bedrock, one of which was relocated a short distance downstream. Eight scour monitoring devices could not be relocated despite careful recording of their original location and extensive effort. These devices may have been completely dislodged. At least three of ten redds (33 percent) or three of seven redds with relocated monitoring devices (43 percent) are estimated to have been scoured to the depth of egg deposition and may have been scoured below the maximum depth of egg deposition.

Combined data from 2015, 2017, and 2019 indicate that the depth of scour increases generally with the magnitude of river discharge. The large variability of scour depths at any given discharge, however, renders the relationship statistically insignificant at the range of discharge monitored to date.

The gravel patches used for spawning by Chinook in the Bull Run River appear to be thin. A total of 51 devices were placed to monitor gravel scour in 2015, 2017, and 2019, combined. Of these, nine were at locations where the underlying bedrock or large substrate was shallower than the shallowest depths at which Chinook prefer to bury their eggs. The locations where eggs were actually buried may have been deeper.

Spawning gravel scour studies in 2015, 2017, and 2019 were not able to monitor as many redds as were committed to in the HCP over the course of three years. Scour will be monitored for as many additional winters as necessary to measure the depth of scour at a total of 30 redds.

2. Introduction

The lower Bull Run River experiences high flows during the late fall and winter months when the Bull Run reservoirs are full and natural high flows exceed the withdrawals of water by the City's facilities. These flows can reach levels that are capable of mobilizing streambed substrates and, therefore, are a potential cause of mortality to salmonid eggs and alevins residing in the streambed. Flows of 600 cubic feet per second (cfs) and greater—high enough to begin to mobilize gravels of the size used by spawning Chinook Salmon (Carlson 2003)—have occurred every year in the lower Bull Run River for the last 109 years (USGS Gaging Station 14140000, 1908–2015). In the course of HCP negotiations, the National Marine Fisheries Service identified the scouring of Chinook redds to be of particular concern in the lower Bull Run River.

The City's HCP defines measures to benefit spawning salmon, such as the maintenance of minimum flows in the lower river and the addition of gravel adequately sized for use by spawning salmon (Portland Water Bureau 2008). These efforts can both affect and be affected by the scouring of spawning gravels. This appendix describes sampling methods and protocols for monitoring the effects of high flows on the stability of Chinook Salmon redd gravels in the lower Bull Run River and provides a summary of the resultant findings for the winter of 2018–2019. This was the second year that implementation of the spawning gravel scour monitoring protocols described in the HCP was attempted.

3. Research Objective

The objective of this research effort is to measure the effects of high flows on bed elevation and scour depth for a number of sites used by spawning Chinook Salmon.

4. Key Questions and Hypotheses

The key questions and related null hypotheses (H_o) to be answered by the Bull Run River spawning gravel scour research are described below.

4.1 Change in Bed Elevation

<u>Question 1:</u> What is the mean change in bed elevation each year and its associated variance at the locations of Chinook Salmon redds in the lower Bull Run River?

> H_o: There will be no significant change in bed elevation at the locations of a sample of Chinook Salmon redds.

4.2 Depth of Scour

Question 2: What is the mean depth of scour and its associated standard deviation at the locations of Chinook Salmon redds in the lower Bull Run River?

H_o: The mean depth of scour will not exceed the assumed upper limit of Chinook egg deposition of 8 inches (Schuett-Hames et al. 1996).

4.3 Percentage of Chinook Redds Scoured

Question 3: What is the percentage of monitored Chinook redds that have significant scour?

H_o: The percentage of scoured Chinook redds will not be more than the 40 percent observed in natural gravel patches (Harvey and Lisle 1999).

4.4 Scour Depth vs. Discharge

Question 4: How does scour depth change with increasing discharge?

H_o: Scour depth will not change with discharge.

4.5 Scour Depth vs. Gravel Depth

Question 5: What is the average depth of scour relative to the depth of gravel?

There is no null hypothesis associated with this key question.

5. Methods

5.1 Research Design

Gravel scour was measured using sliding-bead gravel scour monitoring devices and protocols similar to those described in Nawa and Frissell (1993). These monitoring devices consist of a thin cable attached at one end to a sediment anchor and equipped with some sort of stop at the other end. Neutrally buoyant beads are strung on the cable between the sediment anchor and the stop.

Figure 1. Scour Monitoring Device (right) next to Pipe and Push Rod (left) used for Placement

Figure 2. Setting a Scour Monitoring Device. A Rock Drill (lower right corner) is used to Pilot a Path through Gravel to Larger Substrate or Bedrock

For the HCP monitoring, the anchor and cable were inserted vertically into the gravel immediately adjacent to a redd as deeply as possible, using a pipe or tube wide enough to accommodate the beads. The insertion pipe or tube was carefully removed so that the beads were buried in a vertical stack in the sediment. Excess cable was left to protrude from the gravel with a marker attached to facilitate its relocation. The number of beads left above the gravel's surface when each scour monitoring device could not be driven deeper was recorded. As gravel was disturbed by high flows, beads were dislodged and slid to the end of the cable at the stop.

The scour monitoring devices were located again in the spring when river flows had dropped enough to navigate the channel. The locations of monitoring devices were found using detailed descriptions and, if necessary, metal detectors. Once a scour monitoring device was found, the beads at the end of the cable were counted to determine how deep the gravel had been scoured. Scour monitoring devices can be checked intermittently after storms if flows allow navigation of the river channel. Intermittent visits were not possible in the winter of 2018–2019.

Protocols described in the HCP Appendix F called for measuring bed elevation at each redd site using a laser level and a survey rod with a 5-inch base (DeVries and Goold 1999). This process was not done because of the difficulty involved in packing a laser level up the river channel during winter flows.

5.2 Spatial Scale

Chinook redds were monitored in the lower Bull Run River from river mile (RM) 0–3.8. The City surveys this section of the Bull Run River annually for spring and fall Chinook spawning.

5.3 Replication/Duration

Protocols called for ten Chinook redds to be selected per year for monitoring. Based on total redd counts from previous surveys, this amount represents between 10 and 32 percent of the estimated population of Chinook redds.

Monitoring started after HCP Year 5 to allow for five years of gravel placements. The monitoring period covered in this report is from November 20, 2018, to July 15, 2019 (the winter of 2018–19). Monitoring will occur during three years between HCP Years 6 and 10. The three years may not be consecutive.

5.4 Variables

The following variables will be measured for each gravel scour monitoring site, if possible:

Bed Elevation (before and after). Surface elevation in inches below the elevation of a benchmark, which will be established nearby at the time of scour monitoring device placement. Bed elevation will be measured as soon as devices are placed and then as soon as possible after the end of March.

Maximum Scour Depth. Depth in inches below the initial bed elevation from which beads were dislodged.

Maximum Flow. The highest discharge that occurred since the previous time a scour monitoring device was checked.

The following variable will be inferred at each gravel scour monitoring site:

Depth of Gravel. Depth of gravel, inferred from the depth to which gravel scour monitoring device can be driven into the substrate before meeting an unyielding obstruction.

5.5 Sampling Scheme

Chinook redds were identified during Chinook spawning surveys. The lower Bull Run River, from RM 0 to 3.8, was stratified into reaches based on geomorphic characteristics. These reaches corresponded to those used during Chinook spawning surveys. Protocols called for selecting a total of 10 redds each year for monitoring, with their allocation between reaches corresponding to relative reach length. Within each reach, redds were to be chosen as evenly as possible from each of two general categories: redds created in pool tail-outs, riffle crests, and mid-riffle locations and redds created in gravel associated with obstructions in the channel (e.g., boulders or bedrock outcrops). These two categories of redd locations were expected to differ in the degree of scour they experienced, with obstructions contributing to more complex flow patterns and turbulence.

Redds also had to occur in gravel patches extensive enough to place adjacent scour monitoring devices that were not underlain by shallow bedrock or boulders. In practice in 2017, redds that were in gravel patches deep enough and wide enough to accommodate adjacent gravel scour monitoring devices were not distributed evenly enough to select with a frequency corresponding to reach length. Selected redds were distributed as broadly along the length of the river channel as possible. In early 2017, high flows also limited access to much of the Bull Run River channel. Flows were decreased artificially for several hours to allow device placement. Under these conditions and limitations, the number of redds that could be monitored was restricted to seven.

Two scour monitoring devices were inserted into the sediment to either side of each active redd, to avoid egg mortality associated with monitor placement. The intent was to average the results of the two monitors. For five of the seven monitored redds, however, one of the two devices could not be relocated. The resulting scour values were not an average. Scour monitoring device placements occurred after spawning activity was done to avoid shock to the embryos during what is an especially sensitive stage and to prevent further redd creation from disturbing the placed scour monitoring devices.

Figure 3. Scour Monitoring Device Installed in Gravel

The locations of monitored redds and associated scour monitoring devices were recorded. Redd locations were identified for subsequent visits relative to surrounding landmarks using detailed site descriptions.

Protocols called for measuring bed elevation when the sliding-bead scour monitoring devices were placed and again as soon as possible after Chinook had completed their gravel-rearing life stages (early to mid-May). The monitoring devices, however, were installed after the completion of Chinook spawning surveys and difficulties with transporting the laser level and tripod through winter flows, as well as time constraints, prevented the measuring of initial bed elevations in 2019.

Scour monitoring devices were not revisited during the winter of 2018–2019. Although the design of the scour monitoring devices permits repeated readings of scour at successively higher flows, it was not possible to revisit devices after device placement in early January and before lower flows in late spring.

6. Analysis

Data Storage. Data are stored in Microsoft® Excel spreadsheets managed by the City of Portland Water Bureau.

Hypothesis Testing. The hypothesis regarding changes in bed elevation will be tested when data are available using a paired t-test (α=0.05). Mean scour depth will be compared with the estimated 8-inch upper limit for Chinook egg pockets using standard t-tests. The percentage of Chinook redds scoured deeper than 8 inches will simply be compared to the estimate of 40 percent for natural redds in unimpaired streams (Harvey and Lisle 1999).

7. Results

A total of 20 gravel scour monitoring devices were placed at ten redds in the winter of 2018 and 2019. Nine of the devices could not be located the following summer and yielded no data. One device was found a short distance downstream and was recorded as having scoured to the depth of the device's anchor. The maximum flow the Bull Run River experienced while gravel scour monitoring was underway in 2018–2019 was 8,600 cfs.

7.1 Change in Bed Elevation

Bed elevation at monitored redds was not measured during the winter of 2018–2019.

7.2 Depth of Scour

The mean depth of scour at monitored Chinook redds in 2019 was 7.2 inches, with a standard deviation of 3.5 inches and a range of 1.7 to at least 12.0 inches. Mean depth of scour did not exceed the assumed shallow limit of Chinook egg deposition of 8 inches (Schuett-Hames et al., 1996). The scour depth at three locations with the deepest scours, however, could only be assigned a minimum value. Scour at those locations had extended at least to the depth of the sediment anchor of the device but could have been much deeper. Mean scour depths for individual redds are summarized in Figure 4.

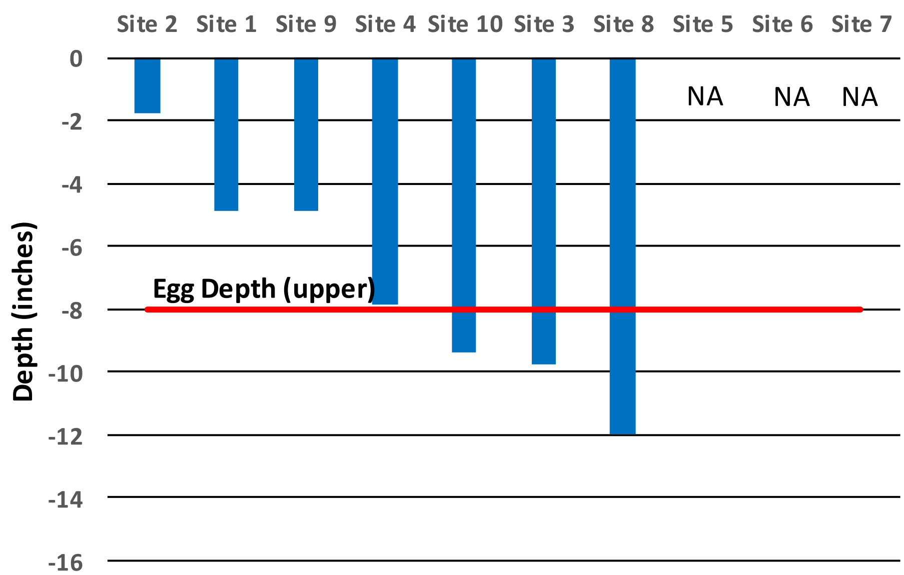

Figure 4. Mean Scour Depths at Seven Chinook Redds Monitored in the Winter of 2018–2019

7.3 Percentage of Chinook Redds Scoured

Three of ten monitored Chinook redds (33 percent), or three of seven monitored Chinook redds with at least one relocated monitoring device (43 percent), were scoured more deeply than eight inches. The scour monitoring devices for three additional redds could not be relocated, despite considerable effort. Those devices may have been scoured below the depth of the sediment anchor and dislodged downstream. If that is true, then a majority of redds could have been scoured deeper than eight inches.

7.4 Scour Depth vs. Discharge

Scour depths observed over three winters increased with maximum experienced discharge. The distribution of depths among monitored devices at each level of discharge was highly variable, but the maximum observed depth increased consistently (Figure 5). The trend in scour depth with discharge was statistically significant over the range of discharges experienced during the three study years ($p=0.004$) despite the high amount of variability.

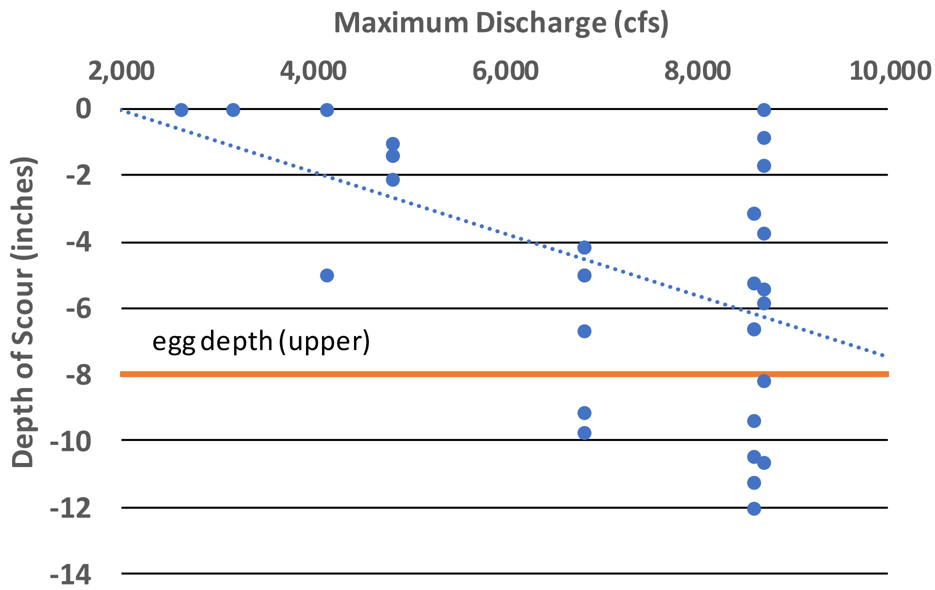

Figure 5. Maximum Scour Depths at 35 Gravel Scour Monitoring Devices Placed in the Winters of 2014–2015, 2016–2017, and 2018–2019

7.5 Scour Depth vs. Gravel Depth

Gravel patches used for spawning by Chinook Salmon in the Bull Run River tend to be thin. Nine of 51 (18 percent) gravel scour devices placed in the winters of 2014–2015, 2016–2017, and 2018–2019 were in gravel that was shallower than the shallowest depths that Chinook prefer to bury their eggs. The estimated depth of gravel is based on how far scour monitoring devices could be driven into substrate. On average, 47 percent of the available gravel depth was scoured at the flows experienced during the gravel studies, based on gravel scour devices that could be located the following spring.

The complete loss of Chinook redds has been observed during higher flows in the Bull Run River when 100 percent of the available gravel depth was scoured. A flow of 11,800 cfs in 2017 in the Bull Run River resulted in a loss of at least 25 of 48 (48 percent) observed redds, where there was a complete removal of gravel down to bedrock or large substrate. A flow of 13,100 cfs in 2013 resulted in an apparent loss of the majority of 123 identified redds.

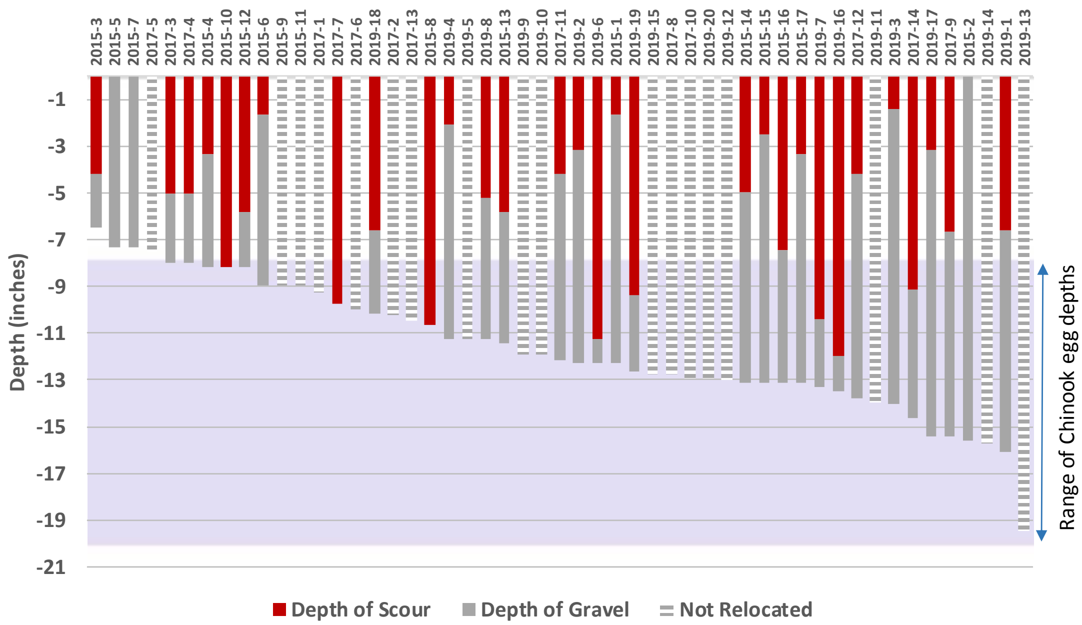

Figure 6. Apparent Gravel Depth and Maximum Scour Depths at Gravel Scour Monitoring Devices Placed in the Winters of 2014–2015, 2016–2017, and 2018–2019

8. Summary and Discussion

Forty-three percent of Chinook redds monitored in 2018–2019 and with at least one relocated monitoring device were scoured to a depth likely to threaten deposited salmon eggs (eight inches, Schuett-Hames et al., 1996). A similar percentage of monitored redds (40%) were scoured deeper than eight inches in 2016–2017, when the peak discharge experienced in the Bull Run River was less (6,830 cfs). A much smaller percentage of monitored redds (22 percent) were scoured in 2014–2015, when the Bull Run River experienced a slightly larger peak discharge (8,700 cfs). This discrepancy is probably due to chance and the highly variable nature of gravel scour. Qualitative observations of changes in gravel patch size and depth suggest that some gravel patches may suffer high rates of particle turnover, with deep scour and subsequently high re-accumulation of gravel particles. The results of the spawning gravel scour research demonstrate that there is a wide variety of localized scour conditions and that large gravel accumulations do not necessarily indicate ideal spawning opportunities.

The depths to which gravel scour monitoring devices could be driven into the substrate in 2014–2015, 2016–2017, and 2018–2018 suggest that even redds that do not experience scour depths greater than eight inches may still be at risk. Gravel patches appear to be fairly shallow in the Bull Run River, and it is likely that it is difficult for Chinook to bury their eggs as deeply as they would prefer. If redds were buried under less than eight inches of gravel, then a higher percentage would be affected by the observed degree of scour. To protect deposited eggs, scour monitoring devices were placed adjacent to monitored salmon redds rather than within the redds. It is possible that the gravel was deeper at the location of egg deposition.

Chinook redds are often subjected to river discharges that are higher than those observed during the two study years and probably experience higher incidences of scour. Observations of redd loss in 2013 and 2017 after much larger flood events showed significant losses of entire gravel patches used for spawning scoured to the underlying bedrock (unpublished observations).

Gravel scour statistics such as the type reported in this research are probably biased, and the actual mean depth of scour and percentage of redds scoured to a given depth are higher. Scour monitoring devices that are scoured to a depth greater than the anchor become dislodged and washed downstream. Some displaced devices are later found a short distance downstream (two in 2014-2015, 1 in 2016–2017, and one in 2018–2019). Devices that are not located are not included in the reported statistics because it is unclear if they were dislodged or simply could not be located because they were buried too deep. A great deal of effort was expended, however, including the use of a metal detector in 2014–2015, to locate monitoring devices. It is more likely that missing devices were simply washed away than buried in a way that they could not be found again.

Because of the difficulties with meeting all research objectives in the winters of 2014–15, 2016–2017, and 2018–2019, PWB will adjust its monitoring objectives for spawning gravel scour research in the Bull Run River. The original intent was to monitor ten redds per year for three years. PWB will instead continue monitoring until gravel scour has been evaluated at a total of at least 30 redds, which will require more than three years of monitoring. Currently, scour has been successfully evaluated at 21 redds.

9. Works Cited

Carlson, K. 2003. Estimated Potential of Salmonid Spawning Gravel Scour in the Lower Bull Run River. Technical Memorandum prepared for Steve Kucas, May 28, 2003. 31 pp. Portland, Oregon.

DeVries, P., and J. Goold. 1999. Leveling Rod base Required for Surveying Gravel River Bed Surface Elevations. *Water Resources Research*, Vol. 35: 2877–79.

Harvey, B.C., and T.E. Lisle. 1999. Scour of Chinook Redds on Suction Dredge Tailings. *N Am J Fish Manag* 19: 613–617.

Nawa, R.K., and C.A. Frissell. 1993. Measuring Scour and Fill with Scour Chains and Sliding Bead Monitors. *N. Am. J. Fish. Manage.* 13: 634–9.

Portland Water Bureau. 2008. Bull Run Water Supply Habitat Conservation Plan for the Issuance of a Permit to Allow Incidental Take of Threatened and Endangered Species. Portland, Oregon.

Schuett-Hames, D., B. Conrad, A. Peus, and K. Lautz. 1996. Literature Review and Monitoring Recommendations for Salmonid Spawning Gravel Scour. Report No. TFW-AM-9-96-001. Washington Timber, Fish, and Wildlife Monitoring Program. Olympia, Washington.

Appendix E

Bull Run HCP Monitoring Report

Lower Bull Run River Shading Monitoring 2019

May 2020
Burke Strobel
City of Portland Water Bureau

Contents

Table

Figures

1. Introduction

In the Bull Run Water Supply Habitat Conservation Plan (HCP), Appendix G, Temperature Management Plan for the Bull Run River, the Portland Water Bureau committed to managing City-owned land along the lower Bull Run River "to protect riparian shade conditions so that their value to protecting instream water temperatures will be maintained." Accompanying this commitment is a requirement to monitor shading of the river channel through time:

> "The Water Bureau will survey and measure shading along the lower Bull Run River with a solar pathfinder once every five years. Results will be reported in an annual report."

The year 2019 is Year 10 of the HCP compliance period. PWB staff visited 12 permanent stations established at evenly distributed intervals in the lower Bull Run River channel to make solar pathfinder measurements

The objective of the Bull Run River shading monitoring is to measure the amount of shading for the lower Bull Run River channel and to determine whether shading changes over time.

2. Methods

Shading was quantified using a Solar Pathfinder. A solar pathfinder uses a convex, semitransparent reflective surface to allow an observer to trace the southern skyline (in the northern hemisphere) over plots of the sun's path, averaged for each month of the year (Figure 1). The combination of the plotted sun path and sketch of where elements of the skyline (e.g., trees, ridges, buildings, etc.) intersect that path provide a means of estimating the degree of shading at any time of year. The resulting measure is termed the "percent of total insolation." A site located in an area without shading of any sort, for example, would receive 100% of total insolation.

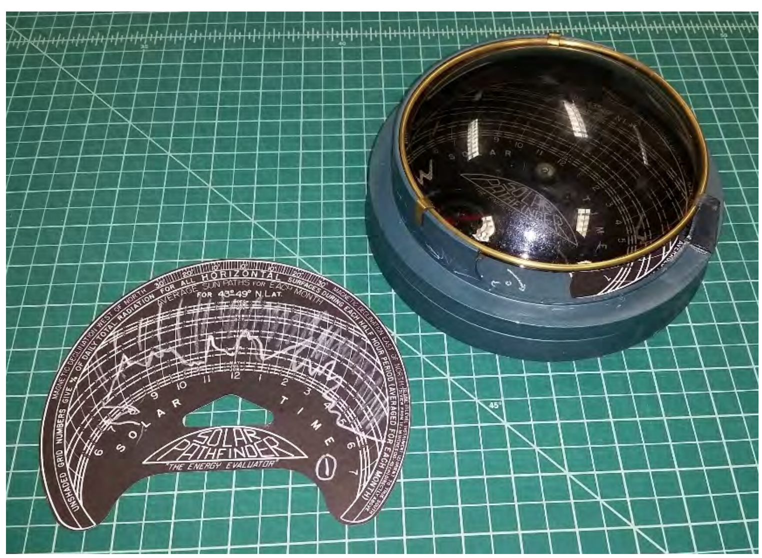

Figure 1. Sun Plot Paper with Skyline (left) and Solar Pathfinder (right)

PWB established 12 permanent stations in the lower Bull Run River channel for taking consistent solar pathfinder measurements. Stations were located every half-mile, starting at river mile (RM) 0.25, between the mouth of the Bull Run River and the Dam 2 spillway at approximately RM 5.8 (Figure 2). A total of 12 stations were established. Table 1 summarizes the active channel width and channel orientation for each station.

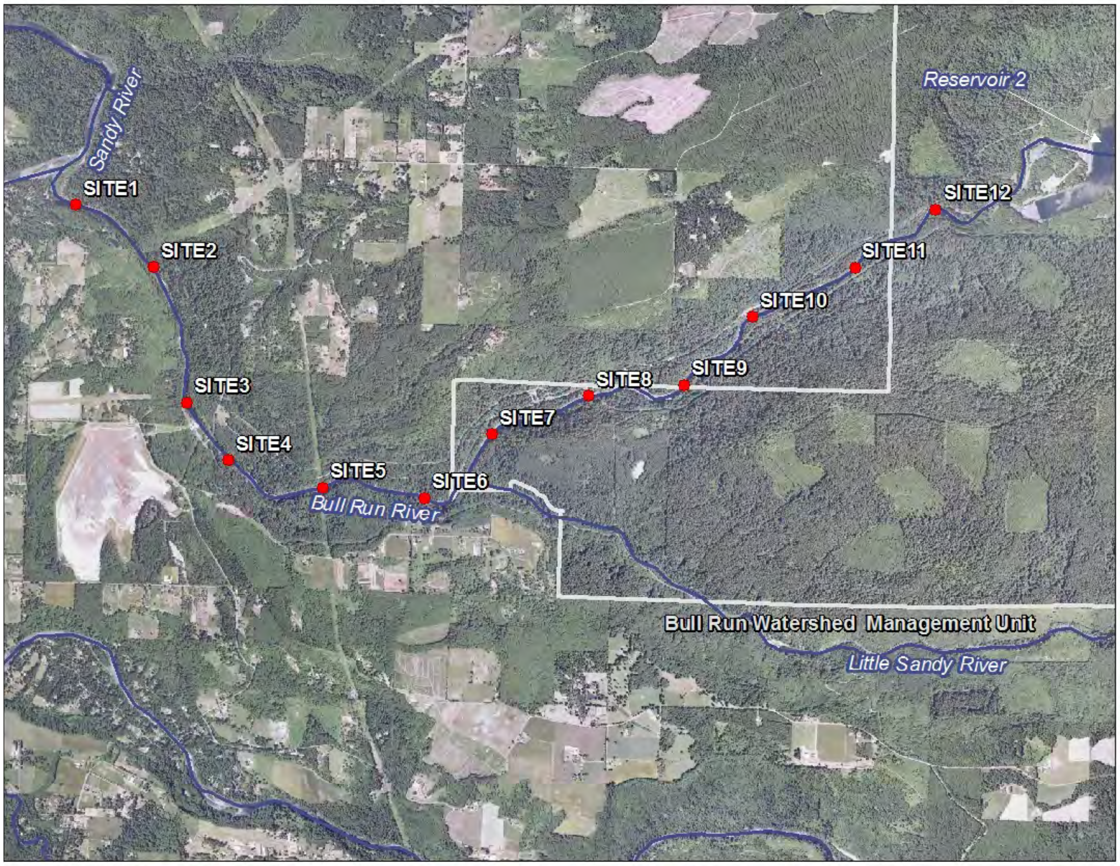

Figure 2. Permanent Solar Pathfinder Measurement Stations, Lower Bull Run River

Stations were marked by placing bolts with stainless steel washers into the tops of selected rocks (Figure 3). Criteria for the selection of rocks included size and durability. Rocks chosen were large enough to endure extreme high flows without moving and near the middle of the river channel. They were of a material that is not easily eroded, such as basalt. A two-inch deep hole was drilled into each rock, and a concrete wedge anchor bolt was set into the hole with a stainless steel washer. The location of each station rock was documented by collecting a Global Positioning System (GPS) waypoint, photographing it in relation to its surrounding, and describing its location.

The time of day is not a factor when collecting solar pathfinder measurements, because it involves tracing only the portion of the skyline that potentially intercepts the sun's path. The time of year, however, is important. Measurements should be made during the late spring through early fall month when deciduous trees are fully in leaf. Solar pathfinder measurements in 2019 were taken July 15 and 16.

Solar pathfinder measurements were taken at each location after establishing the respective station. The solar pathfinder was placed directly onto the rock over the marker bolt and leveled. The skyline was sketched onto the plot paper. The plot paper was later examined in the office to quantify the average percentage of total insolation for the spring and summer months, March through September.

Figure 3. Setting a Solar Pathfinder Station

Solar pathfinder measurements will be repeated over time and analyzed for trends. Measurements made in 2019 will be repeated in 2024 and every five years thereafter for the duration of the HCP term, ending in 2059. The trend analysis will focus on June measurements because that month has a high sun angle and the least amount of shading. The trend analysis will also focus on specific stations in the lower Bull Run River channel where the amount of shading is most likely to be affected by riparian forest changes: Sites 1, 5, 8, and 11. Stations where the majority of shading is provided by valley slopes and cliffs will not be analyzed for trends.

3. Results

The measurements resulting from solar pathfinder measurements taken in 2019 for each site and month are summarized in Figure 4 and Table 1. These measurements are the first in a long-term set. Solar pathfinder measurements will be retaken at each of the 12 stations every five years. The next year that measurements will be taken will be 2024.

Table 1. Monthly Solar Pathfinder Measurements, Lower Bull Run River Channel, March-September

Station	River Mile	Active Channel Width (feet)	Channel Orientation	Percentage of Total Insolation by Month						
				March	April	May	June	July	August	September
Site #1	0.25	149	East>West	24.0%	63.5%	82.0%	80.9%	82.5%	80.0%	33.3%
Site #2	0.75	110	Southeast>Northwest	51.5%	51.8%	59.4%	70.1%	66.5%	51.0%	54.0%
Site #3	1.25	84	East>West	36.0%	34.3%	31.8%	40.2%	34.5%	31.8%	36.5%
Site #4	1.75	95	Southeast>Northwest	20.3%	35.3%	39.5%	42.2%	43.0%	36.0%	29.5%
Site #5	2.25	152	East>West	26.5%	61.0%	61.3%	66.2%	64.3%	62.0%	40.0%
Site #6	2.75	147	East>West	5.5%	39.3%	42.5%	58.6%	53.5%	39.8%	27.3%
Site #7	3.25	103	Northeast>Southwest	22.5%	33.0%	51.0%	50.0%	51.0%	34.8%	27.3%
Site #8	3.75	130	East>West	17.0%	72.0%	80.0%	86.0%	83.3%	82.0%	29.0%
Site #9	4.25	139	Northeast>Southwest	27.5%	29.5%	31.0%	33.6%	33.5%	31.0%	30.3%
Site #10	4.75	107	Northeast>Southwest	12.0%	26.5%	40.0%	46.3%	43.8%	33.8%	14.0%
Site #11	5.25	78	Northeast>Southwest	39.0%	53.0%	58.3%	69.1%	63.8%	57.8%	46.3%
Site #12	5.75	122	East>West	17.3%	34.0%	48.8%	52.7%	53.3%	37.5%	23.8%

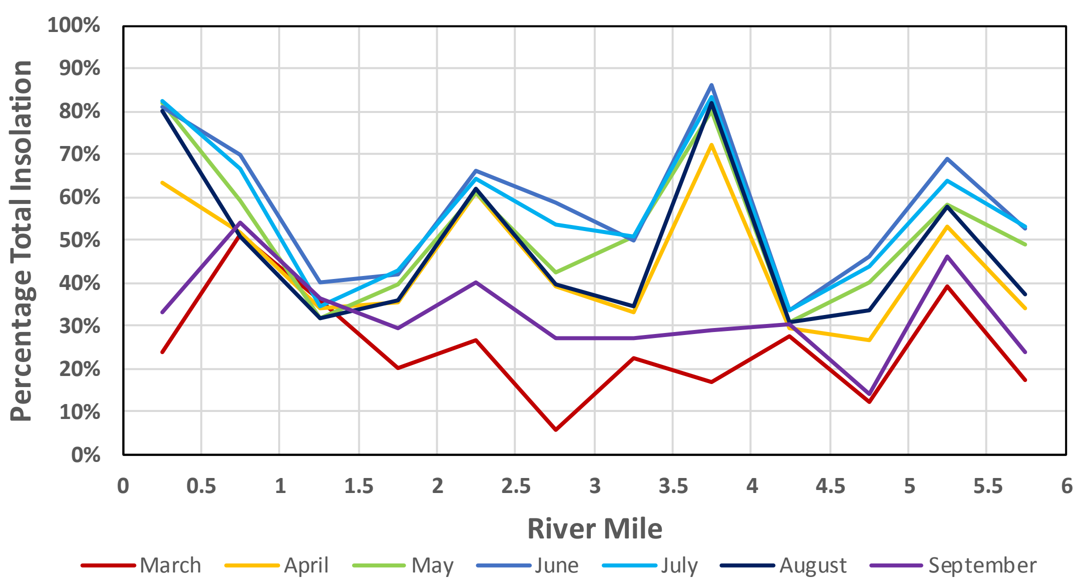

Figure 4. Monthly Solar Pathfinder Measurements, Lower Bull Run River Channel, March–September 2019

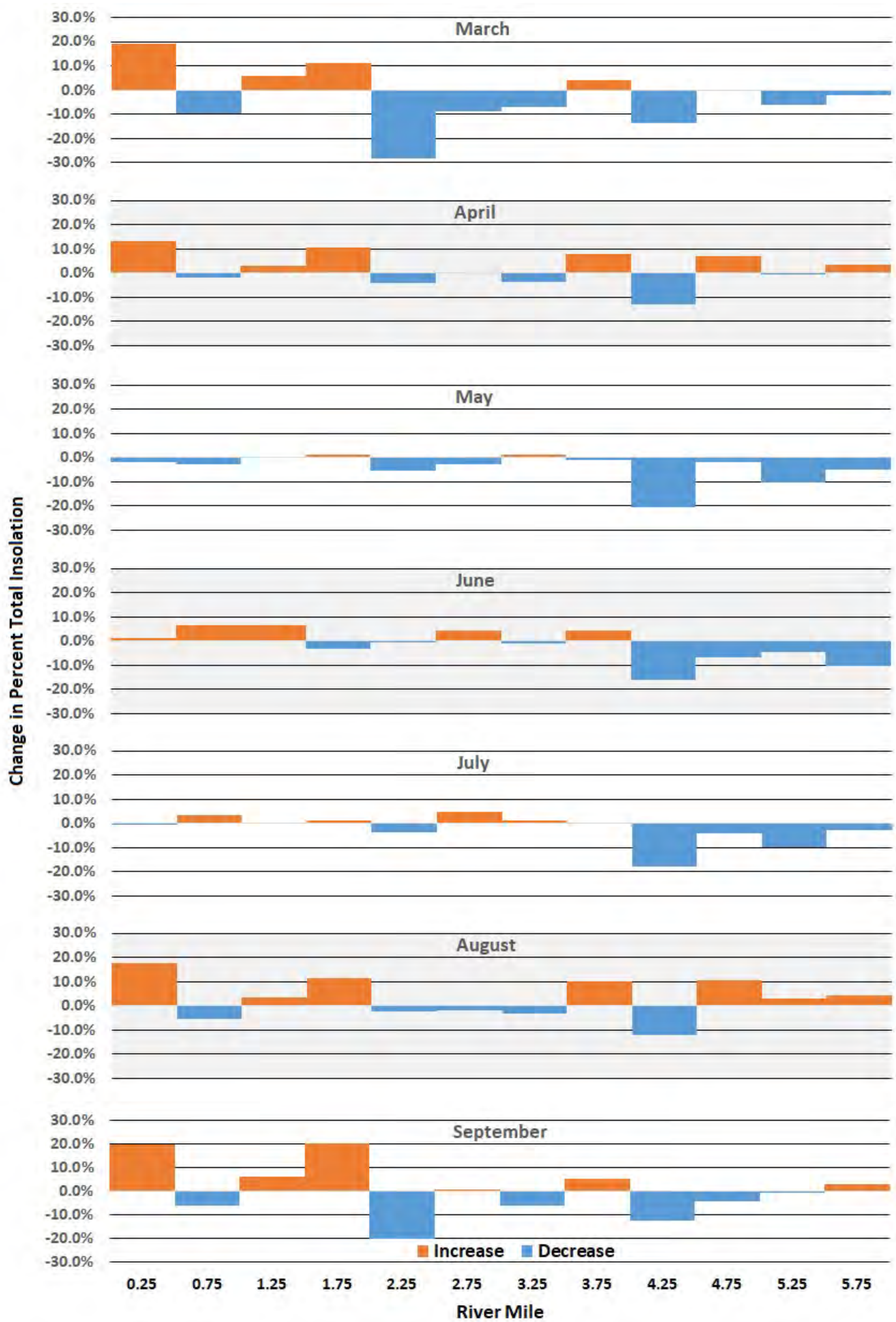

Figure 5. Changes in Estimated Percentage Total Insolation in the Lower Bull Run River Channel From 2014 to 2019, by month

4. Discussion

In the first 10 years of HCP implementation (2010-2019), the City has done little to change riparian shading in the lower Bull Run River. This monitoring will document shading conditions over time.

Measured changes in shading in the lower Bull Run River were modest, varied, and possibly due in part to the variability inherent in the method. Some locations showed small increases in shading, whereas other locations showed slight decreases. Changes were largest in March and September, followed by April and August. These are the months when the sun's path is lowest in the sky and more likely to be intercepted by tree canopy or cliffs. Slight variations in the positioning of the solar pathfinder arising from it being slightly out of level or oriented a degree or two from actual magnetic north could make a measurable difference in the values obtained. The average change in percentage of total insolation across all sites and months was –0.8%, suggesting a slight increase in shading since 2014.

Appendix F

Bull Run HCP Research Report

Total Dissolved Gases in the Bull Run River

May 2020

Burke Strobel
City of Portland Water Bureau

Contents

Tables

Figures

1. Summary

The City of Portland Water Bureau (PWB) was in full compliance with its Habitat Conservation Plan (HCP; Portland Water Bureau 2008) obligations with regard to total dissolved gas (TDG) monitoring in the Bull Run River in 2019. Additional TDG data were collected on two occasions in 2019.

PWB has measured TDG levels in the Bull Run River since 2005. On two occasions at one site and on one occasion at a second site, PWB has measured TDG levels in excess of 110 percent at river flows below the 10-year, 7-day average flood (7Q10) flow. The measurements, however, were made in water that had passed over a spillway and represented only a portion of the total flow in the river at the time. On all of these occasions, the remaining flow had lower TDG levels, and the combined flow had a calculated TDG level below 110 percent.

PWB's TDG monitoring has been affected by modifications of water infrastructure associated with the implementation of another HCP measure. The relationship between TDG levels and spill at the Dam 2 spillway has changed since the removal of a rock weir at the spillway plunge pool tailout. TDG levels of water from the Diversion Pool have also increased since removal of the rock weir. PWB will continue monitoring to describe these changes.

This appendix summarizes the results to date of PWB's TDG monitoring in the Bull Run River.

2. Introduction

The level of total dissolved gas is the sum of the partial pressures of all gases, including water vapor, dissolved in a volume of water. Elevated levels of TDG in water can have various negative impacts on fish, such as the formation of gas bubbles in tissues and the vascular system (gas bubble disease) and over-inflation of the air bladder. Extremely high levels of TDG or long exposure times can lead to immediate or delayed mortality.

Oregon's Water Quality Standards, as enforced by the Oregon Department of Environmental Quality (ODEQ), state that the concentration of TDG relative to local barometric pressure should not exceed 110 percent of saturation [OAR 340-041-0031]. An exception is made when stream flows at a given sampling site exceed the 10-year, 7-day average flood (7Q10), defined as the yearly peak 7-day rolling average high flow that has an average recurrence interval of 10 years.

In 2005, PWB initiated a monitoring plan to check TDG levels associated with the water facilities in the Bull Run Watershed. The plan, developed in consultation with ODEQ, identified sites at risk of elevated TDG levels and established a sampling regime specific to each sampling site, with a set number of data to be collected. Many of these data had already been collected prior to 2012.

The TDG sampling plan developed by PWB has been altered from what was described in the HCP due to two infrastructure modifications in the Bull Run Watershed. These modifications were necessary to comply with another measure in the PWB's HCP—Measure T-2, Post-Infrastructure Temperature Management—and include 1) the removal of a rock weir at river mile (RM) 5.8, completed in 2011, and 2) the installation of a multiple-level intake on one of the Dam 2 intake towers, completed in 2014.

Removal of the rock weir has altered the usefulness of certain TDG monitoring sites and may have changed TDG levels under certain flows. The rock weir slowed the passage of water through the Dam 2 spillway plunge pool. Its removal allows cool water to quickly flow downstream with less warming than before, to the benefit of salmon and trout. In the absence of the rock weir, however, spillway water with high TDG levels and Powerhouse 2 water with lower TDG levels, which meet in the plunge pool, have less opportunity to mix before flowing downstream. As a result, certain TDG sites, selected to monitor fully mixed water, are no longer useful. In addition, without the rock weir, spillway water plunges additional feet to the lowered pool surface. This could change TDG levels at the base of the spillway from what they would have been with the rock weir.

Modifications to the intake tower could lead to a change in TDG levels in water coming from the Diversion Pool. Water that passes from the intake tower through Powerhouse 2 into the Diversion Pool has relatively low TDG levels. This relatively low-TDG water mixes with water from the spillway, decreasing the higher TDG levels of the spillway water. TDG levels entering the Diversion Pool from Powerhouse 2 may have been altered, however, by modification of the intake tower. TDG levels for the water from the Diversion Pool may have been further altered by the removal of the rock weir, which changed the water surface elevation and velocity through the spillway plunge pool. TDG levels greater than 110 percent at flows less than the 7Q10 flow could result.

Alterations have been made to the TDG monitoring plan to accommodate these changing conditions in the Bull Run River. These alterations are described in the 2011 Annual Compliance Report (Portland Water Bureau 2012). This appendix describes results to date for monitoring TDG levels in the lower Bull Run River.

3. Research Objectives

The TDG research results are being used to determine whether there are locations in the lower Bull Run Watershed with elevated concentrations of TDG. The sites are monitored across a range of flows.

4. Key Questions and Hypotheses

There are three key questions to be answered by this TDG monitoring plan. Two of the questions have a null hypothesis (H_o) that will be tested with the monitoring protocol; the third question will be addressed by field observation. The questions are as follows:

Question 1: Do any of the monitoring sites exceed the ODEQ standard of 110 percent saturation of TDG?

> H_o: At each monitoring site, the observed TDG concentration will not exceed 110 percent of saturation within any range of flow, as defined in Table F-7 of the HCP, unless the flow exceeds the 7Q10 for the lower Bull Run River.

Question 2: At sites where TDG levels exceeding 110 percent are observed, are there flow ranges associated with excessive TDG levels?

> H_o: At each site with observed TDG levels in excess of 110 percent, there is no relationship between amount of flow and measured levels of TDG.

Question 3: How quickly do elevated levels of TDG dissipate downstream when they are observed?

This key question does not have an associated null hypothesis. It involves the collection of information to assist in the adaptive management process.

5. Monitoring Design

5.1 Sites

PWB, in conjunction with ODEQ staff, identified all watershed structures associated with City operations that could cause elevated levels of TDG. These structures include the spillways, valves, and turbines in which air bubbles could be brought under sufficient pressure to cause their dissolution in water beyond the level of saturation.

Monitoring locations were established to monitor the effects of each specific structure on TDG levels or to provide information on the persistence of TDG downstream. The monitoring sites, the associated structures that increase the risk of elevated TDG concentrations, and the purposes of measuring each site are summarized in Table 1. Additional sites are also monitored to provide information on the effects of water mixing from various sources and the effects of downstream dissipation on elevated TDG levels. All locations of monitoring sites are shown in Figures 1 and 2.

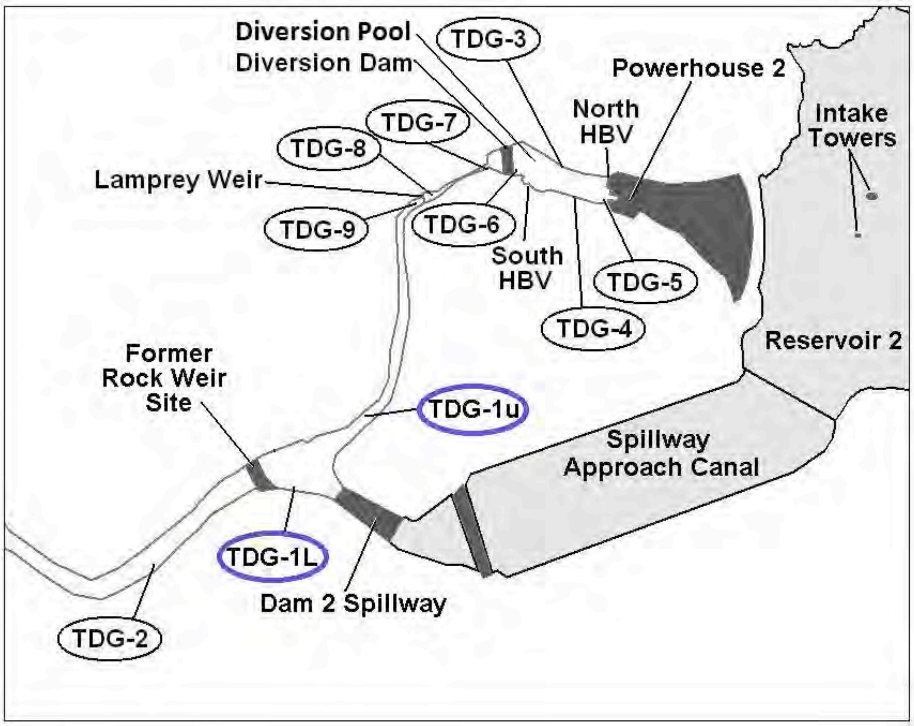

Figure 1. Locations of TDG Monitoring Sites Associated with Dam 2[a]

[a]Monitoring sites TDG-1L and TDG-1u were added in 2011 to replace sites TDG-1 and TDG-1a.

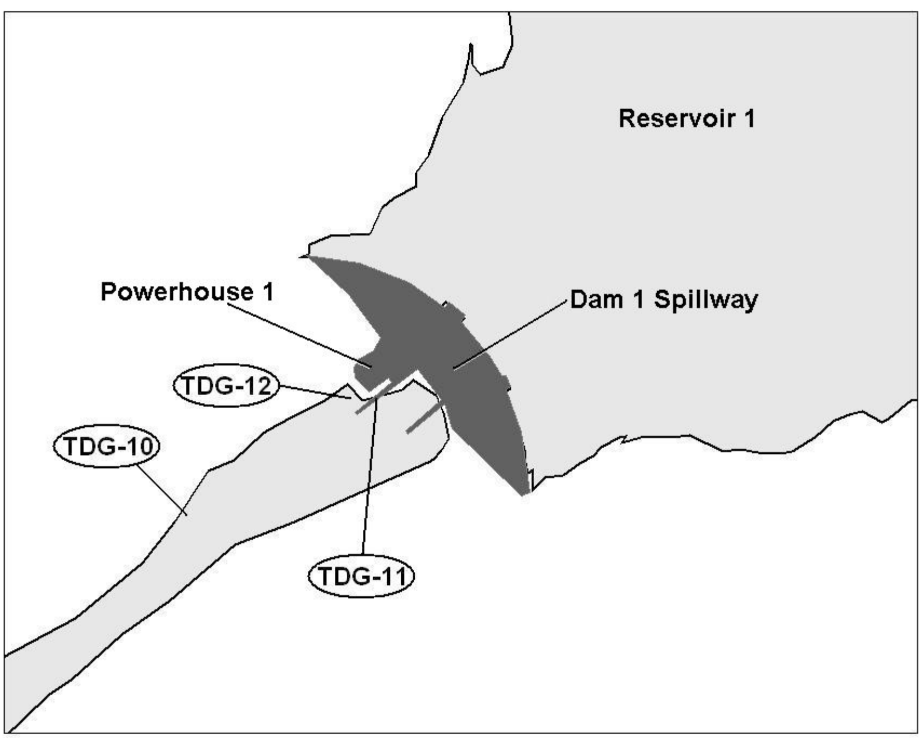

Figure 2. Locations of TDG Monitoring Sites Associated with Dam 1

Two sites listed in Table 1, TDG-1L and TDG-1u, are monitored in tandem and used to calculate a TDG value for mixed water from both the Dam 2 spillway and the Diversion Pool (Powerhouse 2 flow and Howell-Bunger valve flow). The TDG level of mixed flows was originally monitored at site TDG-1a, located immediately downstream of the Dam 2 spillway plunge pool rock weir. After the removal of the rock weir, however, there was no longer an adequate site where fully mixed flows could be monitored before elevated TDG levels had a chance to dissipate. The City replaced TDG-1a by monitoring the two sources of water that mix in the plunge pool and using their relative contribution to calculate a combined-flow TDG value.

Table 1. TDG Monitoring Sites, Associated Structure, and Purpose of Measuring

Monitoring Site	Associated Structure	Purpose
TDG-1L, TDG-1u[a]	Dam 2 Spillway	Structure Effects
TDG-2	Dam 2 Spillway	Downstream Effects
TDG-3	South Howell-Bunger Valve	Structure Effects
TDG-4	North Howell-Bunger Valve	Structure Effects
TDG-5	Powerhouse 2	Structure Effects
TDG-6	Diversion Dam	Structure Effects (Upstream Value)
	Powerhouse 2	Downstream Effects
TDG-7	Diversion Dam	Structure Effects (Downstream Value)
TDG-8	Lamprey Weir	Structure Effects (Upstream Value)
	Diversion Dam	Downstream Effects
TDG-9	Lamprey Weir	Structure Effects (Downstream Value)
TDG-10	Dam 1 Spillway	Downstream Effects
	Powerhouse 1	Downstream Effects
TDG-11	Dam 1 Spillway	Structure Effects
TDG-12	Powerhouse 1	Structure Effects

[a]TDG-1L and TDG-1u sites were added in 2011; TDG-1 and TDG-1a are no longer monitored.

Each site has a unique span of possible flows associated with its longitudinal position along the Bull Run River and its function as a part of the City's water and hydroelectric facilities. Flows passing through each of the two powerhouses are measured by flow sensors in the penstocks and are constrained by the minimum flows required to run the turbines and the maximum flows that the turbines can accommodate. Flows passing over each dam's spillway are estimated by employing stage/discharge rating curves established for each spillway. The flows are constrained only by the range of natural variability in the Bull Run River as modified by the water diversions and withdrawals by PWB.

For most of the structures, the historical span of flows was divided into three equal parts or flow ranges. Each flow range will be sampled with replication. The ranges of flows for each structure in cubic feet per second (cfs) and the number of replicates for sampling are identified in Table 2. Sites located downstream of structures are for the purpose of monitoring the persistence of TDG concentrations and will be sampled on the same day as the associated upstream sites (for example, TDG-10 is downstream of TDG-11, the Dam 1 Spillway, and TDG 12, Powerhouse 1).

Table 2. Flow Ranges and Number of Replicates per Flow Range for Sampling TDG

Structure	Flow Ranges (cfs)	Number of Replicates
Dam 2 Spillway	1,700–6,900	5
	6,900–12,000	5
	12,000–17,200	5
Powerhouse 2	210–700	5
	700–1,200	5
	1,200–1,700	5
South HB Valve[a]	While operating	5
North HB Valve[a]	While operating	5
Diversion Dam	Whenever Powerhouse 2 or HB valve readings are taken	15 to 20
Lamprey Weir	Whenever Powerhouse 2 or HB valve readings are taken	15 to 20
Dam 1 Spillway	2,000–5,500	5
	5,500–8,900	5
	8,900–12,400	5
Powerhouse 1	800–1,200	5
	1,200–1,600	5
	1,600–2,000	5

[a]HB =Howell-Bunger

Two Howell-Bunger (HB) valves at Reservoir 2 provide a route for releasing water that bypasses the hydroelectric turbines and the spillway. The HB valves dissipate energy associated with the head pressure behind the dam. Monitoring sites have been located at the outlet of each HB valve. No range of flows has been established for the HB valves. Each site will be sampled several times when the respective valve is in operation.

The 7Q10 for the lower Bull Run River was calculated from historical records from January 1, 1940, to December 31, 2018; it is currently estimated to be 5,632 cfs. The 7Q10 for the Dam 1 spillway was calculated from historical records from January 1, 1976, to December 31, 2013; it is currently estimated to be 4,461 cfs. When flows of these magnitudes occur or are exceeded, sampling will continue; however, the ODEQ standard of 110 percent saturation for TDG will not apply. PWB will update the 7Q10 flow amounts in all future years when new data are collected.

5.2 Spatial Scale

All data collected on TDG are site-specific. Downstream sites have been included to determine the spatial extent of elevated TDG exposure.

5.3 Replication/Duration

Each site will be monitored until the full set of ranges, as defined in Table 2, has been adequately sampled. Each site will be sampled five times within each flow range. Some sampling has already been conducted. The sites associated with the Diversion Pool dam next to the Headworks facility and the lamprey weir will be sampled as often as possible when the Powerhouse 2 sites are sampled. Downstream sites will be sampled as often as possible when the associated upstream sites are sampled. The HB valve sites will be sampled five times each during valve operation.

Monitoring at all sites associated with the Dam 2 spillway plunge pool was reinitiated after the removal of the rock weir. Once the relationship of TDG percent saturation for each site and set of variables has been established, further monitoring will rely on tracking the environmental variables, such as water temperature and flow, rather than sampling TDG.

5.4 Parameters

On each sampling occasion, the following information is recorded:

- TDG percent saturation
- Water temperature
- Date and time of day
- Flow at the respective structure (e.g., spillway or powerhouse)

5.5 Sampling

TDG percent saturation and water temperature are measured using a Point Four Systems PT4 Tracker Total Dissolved Gas Pressure (TDGP) meter. Flow at the time of measurement is obtained from data gathered at PWB's water facilities by staff.

6. Analysis

Linear regression is used to explore the relationship between TDG levels and flow at each of the dam spillways. In those instances in which the 110 percent TDG criterion is exceeded, a regression model is developed that predicts the conditions under which TDG concentrations might exceed 110 percent at each site. In the future, nonlinear multiple regression may be used to try to use water temperature as a covariate to better model the relationship between flow and TDG concentrations.

The dissipation of elevated TDG concentrations downstream of their sources will be characterized and evaluated across levels of flow using Analysis of Covariance (ANCOVA) of log-transformed data.

7. Results

7.1 Data Collected

TDG data were collected on two occasions in the Bull Run River in 2019. Table 3 summarizes the structures in the lower Bull Run River that are being monitored for TDG and the number of data points that remain to be collected for various flows. The remaining number of replicates for the Dam 2 spillway reflects the fact that monitoring for this structure was reinitiated in 2011 following the removal of the rock weir. All TDG data collected to date are summarized in Exhibit A at the end of this report.

Table 3. Flow Range for Each Structure and Number of TDG Measurements Yet to be Collected

Structure	Flow Ranges (cfs)	Remaining Number of Replicates
Dam 2 Spillway	1,700–6,900	0
	6,900–12,000	4
	12,000–17,200	5
Powerhouse 2	210–700	4
	700–1,200	5
	1,200–1,700	0
South HB Valve	While operating	0
North HB Valve	While operating	3
Diversion Dam	Whenever Powerhouse 2 or HB valve readings are taken	3

Table 3. Flow Range for Each Structure and Number of TDG Measurements Yet to be Collected

Structure	Flow Ranges (cfs)	Remaining Number of Replicates
Lamprey Weir	Whenever Powerhouse 2 or HB valve readings are taken	0
Dam 1 Spillway	2,000–5,500	0
	5,500–8,900	5
	8,900–12,400	4
Powerhouse 1	800–1,200	5
	1,200–1,600	5
	1,600–2,000	0

[a]HB=Howell-Bunger

TDG levels of greater than 110 percent saturation have been measured at three of the monitoring sites illustrated in Figures 1 and 2 in the last nine years when the total flow of the river was greater than the 7Q10 flow: the Dam 2 spillway on the left bank (TDG-1L), downstream of TDG-1L (TDG-2), and the Dam 1 spillway (TDG-11).

There is the potential for TDG levels to be greater than 110 percent saturation even if the flows are less than the 7Q10 amount. If the total river flow were under the 7Q10 flow for the sites and all flow went over the spillways at either Dam 1 or 2, the levels could be greater than 110 percent. The highest TDG level observed at these sites during spillway flows less than the 7Q10 flow has been 114 percent. On all of these occasions, however, a portion of the total flow of the river had passed through the Dam 1 and Dam 2 powerhouses, and the combined flows are calculated to have had TDG levels less than 110 percent.

Subsection 7.2 describes the spillway flow at which the 110 percent threshold is predicted to be exceeded in relationship to the 7Q10 flows for each spillway. Subsection 7.3 describes the calculated effects of mixing of spillway flows and powerhouse flows on TDG levels in the Bull Run River.

7.2 TDG/Spillway Flow Relationships

Because TDG saturation greater than 110 percent has been measured at two of the locations listed in Table 2 (the spillways associated with Dam 1 and Dam 2), PWB studied the relationship between spillway flows and TDG levels. At the Dam 2 spillway, there was a relationship (R^2=0.81) between flow over the Dam 2 spillway and TDG measurements at the foot of the spillway (TDG-1L). After the rock weir was removed, that relationship changed. At the Dam 1 spillway, there is no clear relationship between TDG saturation and spillway flow.

After the removal of the rock weir below the Dam 2 spillway, the threshold of 110 percent TDG saturation was predicted to be exceeded at TDG-1L at a spill of approximately 2,668 cfs, as shown in Figure 3. This left a range of flows between 2,727 and 5,632 cfs for which this site had the potential of being in violation of ODEQ's TDG standards if all of the Bull Run flow were to pass over the spillway. This range of flows is larger than it was prior to the removal of the rock weir when this site had the potential to be in violation of TDG standards between 3,740 cfs and 5,702 cfs. The TDG level at TDG-1L is predicted to be 114 percent at the 7Q10 flow if all of that flow is passing over the spillway and none of it is passing through Powerhouse 2 or the Howell-Bunger valves into the Diversion Pool. The flow at which TDG levels are predicted to be 110% has decreased, and the TDG level predicted at the 7Q10 flow has increased with the addition of the 2019 data point (collected on 4/8/19). The new data point was unexpectedly high (spillway flow=6,300; TDG=118%).

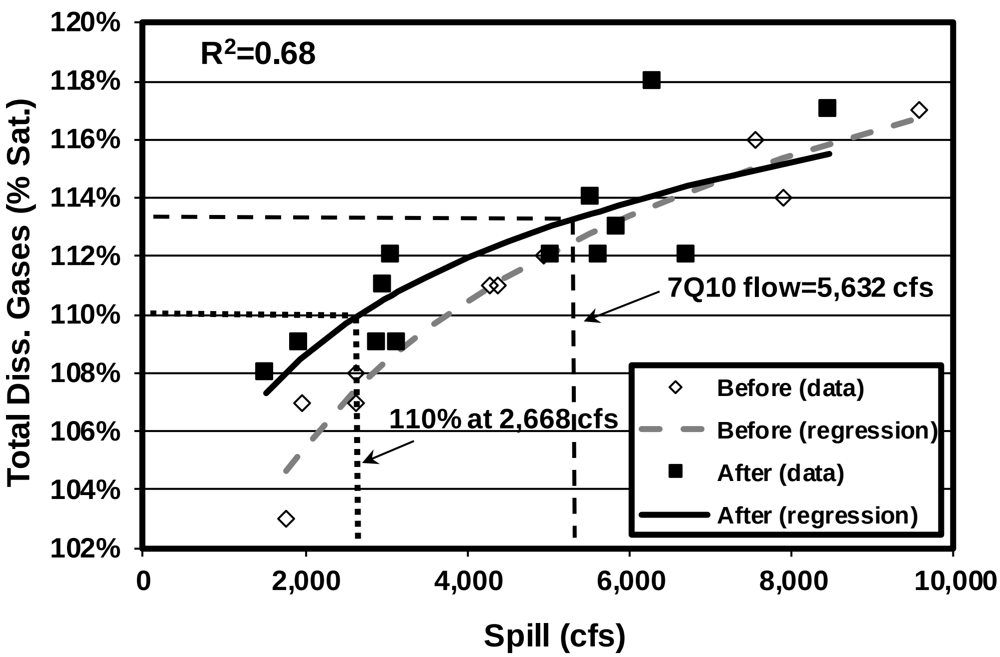

Figure 3. Relationship of TDG Percent Saturation to Flow over the Dam 2 Spillway (TDG-1L) after Rock Weir Removal Compared to Relationship after Rock Weir Removal

Figure 4 illustrates the observed effects of Dam 1 spillway flows on measured TDG values. There is no apparent relationship between flow over the Dam 1 spillway and TDG measurements. TDG values in excess of 110 percent saturation have been measured twice in the Dam 1 spillway, at spillway flows of 2,177 cfs and 2,804 cfs. Spillway flows much higher than these (e.g., 10,158 cfs), however, resulted in TDG measurements below 110 percent. The large variation in TDG measurements at this site could result from the extreme water turbulence in the Dam 1 spillway, making it difficult to obtain a reliable measurement.

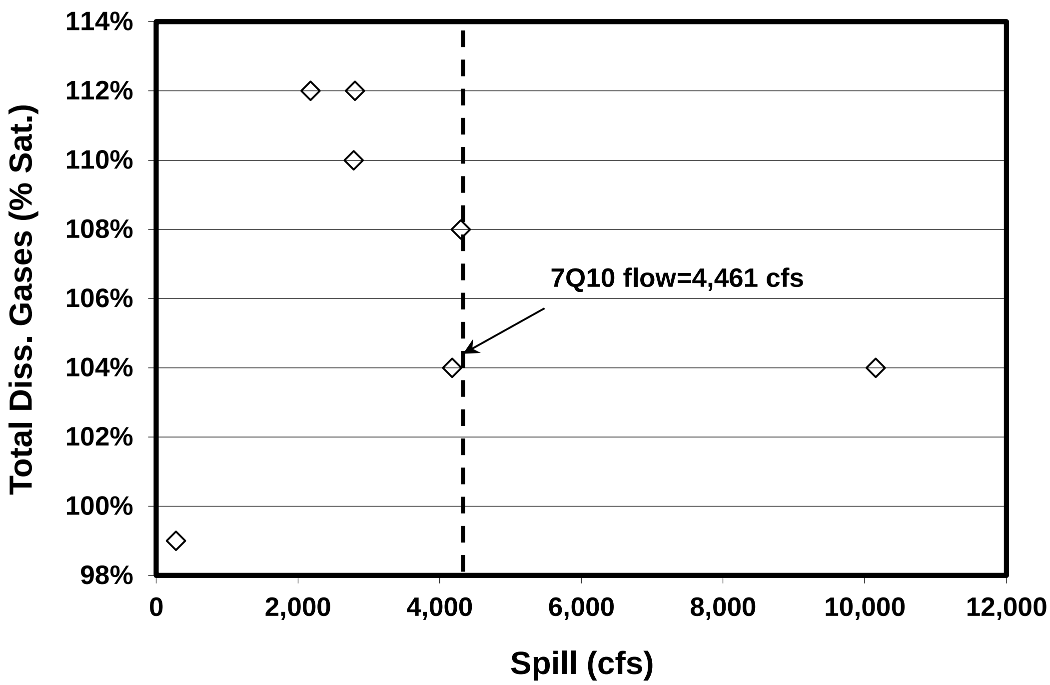

Figure 4. Relationship of TDG Percent Saturation to Flow over the Dam 1 Spillway (TDG-11)

7.3 Effects of Hydropower Water on TDG

The flows from Powerhouse 2, with their lower TDG levels, are expected to reduce the overall TDG level of the flow when combined with Dam 2 spillway flows, similar to what has occurred under previous conditions. Even though TDG levels have exceeded 110 percent at two Bull Run structures, monitoring data indicate that normal water supply operations prior to removal of the rock weir probably had reduced those concentrations through the mixing of powerhouse and spillway water at flows below the 7Q10.

The diluting effect of the water from Powerhouse 2 appears to have changed since the removal of the rock weir. The Bull Run Dam 2 powerhouse diverts a maximum of 1,700 cfs for electricity generation. Typically, this powerhouse has operated at close to maximum capacity when flows in the Bull Run River are high enough to allow it. Prior to rock weir removal, the diverted water downstream of Powerhouse 2 had an average TDG level of 103 percent saturation just before it mixed with water from the Dam 2 spillway. This diverted water had modified the TDG/flow relationships discussed in Section 7.2 and brought the calculated combined TDG level down to below 110 percent at the 7Q10 flow. Since the removal of the rock weir, however, the diverted water downstream of Powerhouse 2 has had an average TDG level of 105.2 percent saturation just before it mixed with water from the Dam 2 spillway. When Powerhouse 2 is operating at full capacity, the water that is diverted is now calculated to decrease the TDG level of the combined flow (powerhouse + spillway) to 110.2 percent saturation at the 7Q10 flow, as shown in Figure 4. The TDG level of the combined flow is predicted to exceed 110 percent saturation above 5,506 cfs. TDG saturation of the combined flow is predicted to exceed 110 percent in the narrow window between 5,506 cfs and the 7Q10 flow (5,632) by up to 0.2% provided the powerhouse is operating at full capacity.

The reason for the observed increase in TDG levels in water from the Diversion Pool is unclear. The City began using a new TDG meter in 2012, but the new meter has measured values similar to the old meter (Figure 5) at locations where there have been no infrastructure changes, such as the Dam 1 Powerhouse (TDG-12). Upstream structures such as the lamprey weir have also shown no corresponding TDG level increase. It is possible that the removal of the rock weir has inadvertently increased TDG levels in water originating from the Diversion Pool by lowering the water surface of the spillway plunge pool. The accompanying increase in the plunge of water from a cascade immediately upstream of TDG-1u and increased velocity of water from that location to where it joins the water from the Dam 2 spillway may have increased TDG levels slightly and reduced the opportunity for off-gassing.

Figure 5. TDG Meter—in Use since 2012—below the Dam 2 Spillway.

The relationship between combined TDG levels and combined flows might change if the TDG level of flows from Powerhouse 2 change further under current conditions with a modified intake tower. There have been only three measurements of TDG at TDG-1u while the Dam 2 Powerhouse was in operation after the modification of the intake tower. These measurements are insufficient to determine whether the intake tower modifications will have an effect on the water from the Diversion Pool. The relationship illustrated in Figure 6 will also change if Powerhouse 2 is operated at less than maximum capacity.

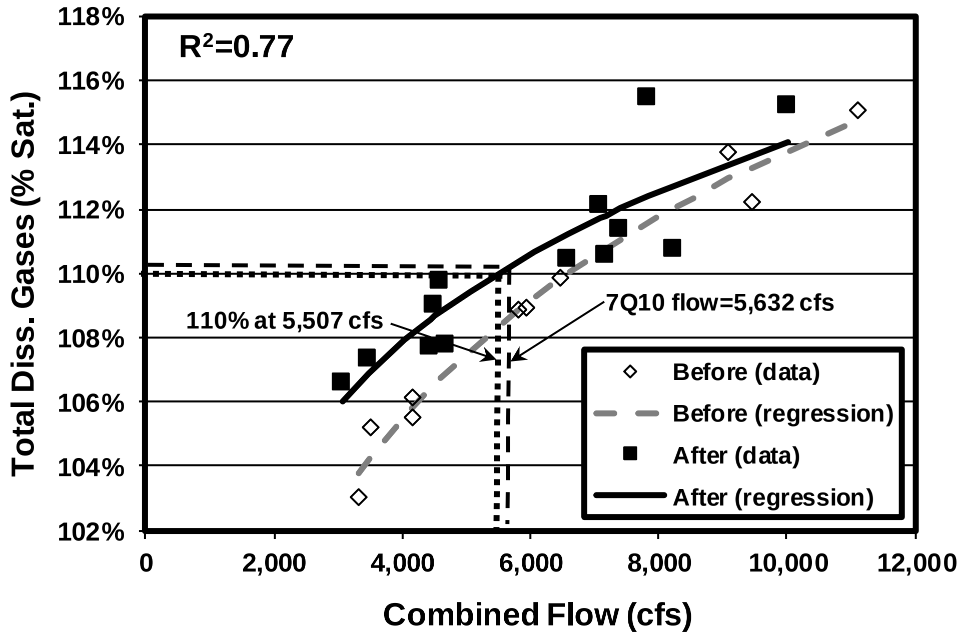

Figure 6. Relationship of TDG Percent Saturation to the Combined Flow of the Dam 2 Spillway and Powerhouse 2 after Rock Weir Removal Compared to Before Rock Weir Removal

The Bull Run Dam 1 powerhouse generally diverts a maximum of 2,300 cfs for electricity generation. Typically, this powerhouse operates at close to maximum capacity when flows in the Bull Run River are high enough to allow it. Diverted water in the tailrace of Powerhouse 1 has an average TDG level of 108 percent saturation. This diverted water modifies the TDG/flow relationships discussed in Section 7.2. When Powerhouse 1 is operating at full capacity, the calculated TDG levels of the combined powerhouse and spillway flows do not show any relationship to amount of flow, but no TDG levels above 110 percent have occurred below the 7Q10 flow for the site according to calculations, as indicated in Figure 7.

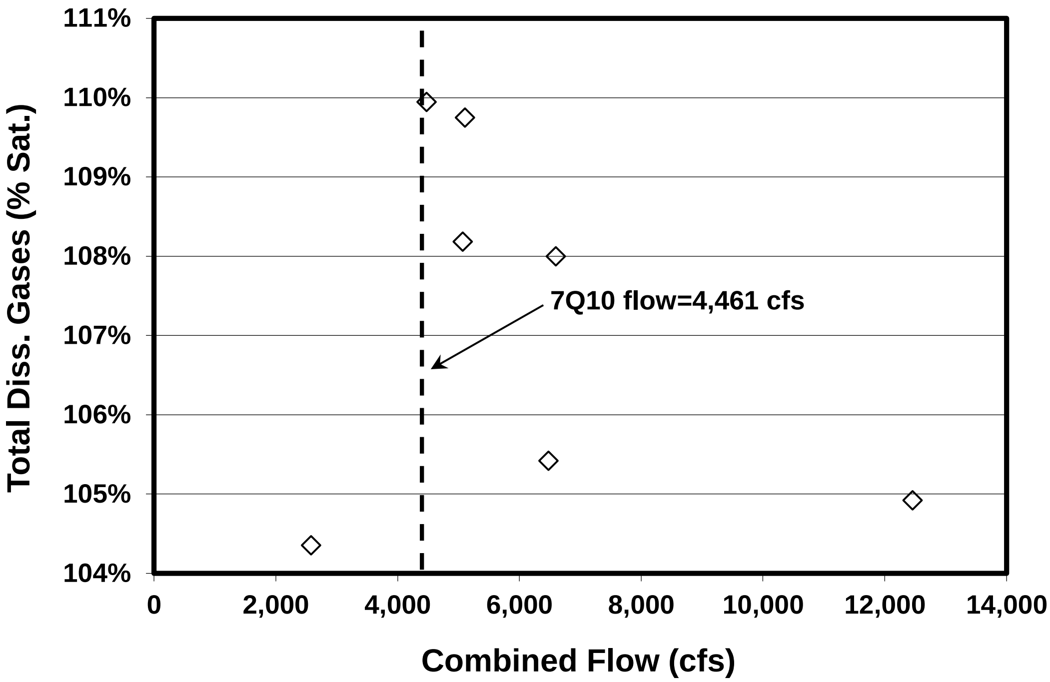

Figure 7. Relationship of TDG Percent Saturation to Combined Flow of the Dam 1 Spillway and Powerhouse 1

PWB does not have a good site to measure the TDG levels of fully mixed water at either the Dam 1 or the Dam 2 spillways, so in 2012, PWB started using data from both spillways and both powerhouse inputs to calculate the TDG of the combined flows. For Dam 1, the flows from the spillway and Powerhouse 1 do not appear to be fully mixed at TDG-10. An island in the middle of the river channel downstream of the Dam 1 spillway pool allows the flow from Powerhouse 1 and the adjacent spillway to remain partly separate until significant off-gassing is expected to have occurred. For the Dam 2 spillway, in the absence of the rock weir, flows from Powerhouse 2 and the spillway do not appear to mix fully until they have moved further downstream than TDG-2 and some off-gassing has occurred.

Because of these complications, PWB believes that the most meaningful way of estimating the initial TDG of the combined flows at both sites is to calculate TDG using the discharge amount and respective TDG measurements from each powerhouse and each spillway just before they combine.

7.4 Downstream Dissipation of Elevated TDG

Under the terms of the HCP, PWB monitors the dissipation of TDG levels downstream of the Dam 2 spillway and rock weir structure due to off-gassing. PWB will continue to monitor dissipation rates for various flows above and below the 7Q10 flow to establish rates that can be applied to flows approximately equal to the 7Q10 flow level.

To date, downstream dissipation of TDG levels has been monitored at six flow levels—15,508 cfs (11/7/2006), 6,631 cfs (2/16/2007), 6,097 cfs (12/3/2007), 11,315 cfs (11/13/2008), 6,151 cfs (11/20/2012), and 10,172 cfs (12/2/2013). All of the monitored flows were above the 7Q10 flow for the lower Bull Run River. Two of the monitoring occasions occurred after the removal of the rock weir. No additional data were collected in 2019 to analyze downstream dissipation.

The natural log of TDG percent saturation above equilibrium (i.e., TDG percent saturation minus 100 percent) initially decreased roughly linearly with distance, as depicted in Figure 8. Table 4 summarizes the average distances downstream at which various elevated TDG levels are predicted to dissipate to 110 percent.

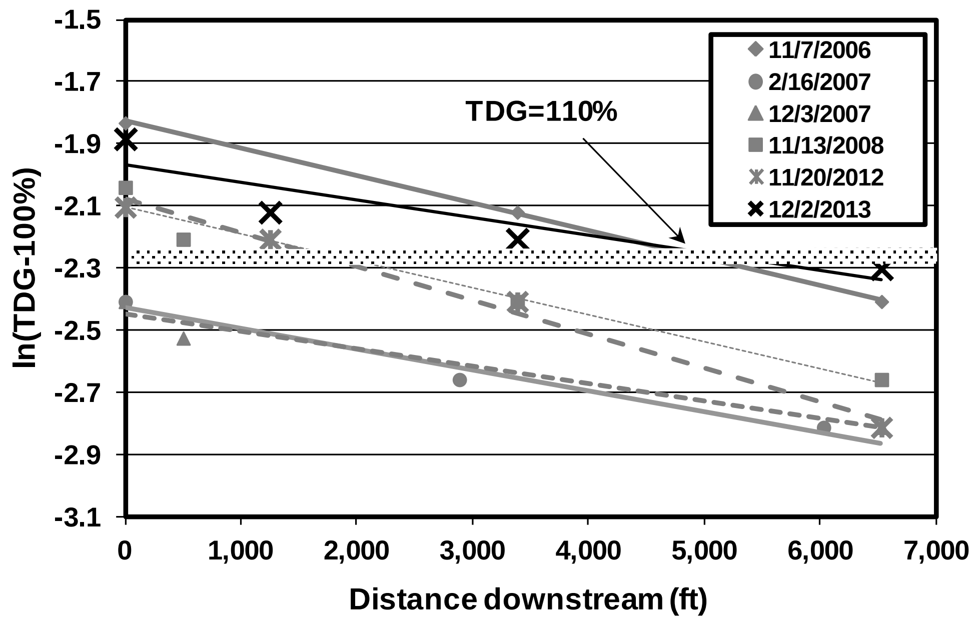

Figure 8. Dissipation of TDG Downstream of the Site of the Rock Weir at the Dam 2 Spillway Plunge Pool on Four Dates

Table 4. Average Distances Downstream at which Various Elevated TDG Levels are Predicted to Dissipate to 110 Percent

Initial TDG Saturation	Approximate Distance Downstream at which TDG Dissipates to 110%
115%	4,624 feet
114%	3,732 feet
113%	2,774 feet
112%	1,739 feet
111%	613 feet

PWB will continue to monitor the dissipation of TDG levels downstream of the Dam 2 spillway. Future monitoring will focus on lower Bull Run River flows below the 7Q10 level.

8. Conclusions

The monitoring conclusions are organized based on the key questions presented in Section 4.

1. Do any of the monitoring sites exceed the ODEQ standard of 110 percent saturation of TDG?

TDG levels have exceeded 110 percent locally at one site on two occasions and at another site on one occasion when spillway flows were below the 7Q10 flow, but the combined flow over the spillway and in the river was above the 7Q10 flow.

2. At sites where elevated TDG levels exceeding 110 percent are observed, are there flow ranges associated with excessive TDG levels?

Under current conditions, after removal of the rock weir, TDG levels are predicted to exceed 110 percent at the base of the Dam 2 spillway at a spillway flow above 2,668 cfs.

TDG levels downstream of the spillways are reduced by mixing with water from the powerhouses, which has lower TDG levels than water from the spillways. During normal high-flow conditions in the winter and spring, water is diverted from Reservoirs 1 and 2 and routed through the powerhouses at the base of each dam. If the total river flow is greater than the capacity of the powerhouses, the additional flow goes over the spillways. TDG levels at the Dam 1 and 2 spillway sites are normally reduced by mixing with powerhouse flows downstream of both the Dam 1 and 2 spillways. TDG levels in the water from Powerhouse 2 appear to have increased slightly after the removal of the rock weir, decreasing the diluting benefits of mixing powerhouse with spillway flows. After removal of the rock weir and with anticipated mixing from Powerhouse 2, TDG levels immediately downstream of the Dam 2 spillway are now calculated to exceed 110 percent at a total river flow of 5,507 cfs, which is slightly below the 7Q10 flow for the lower river.

There is no apparent relationship between spillway flow and TDG levels at the base of the Dam 1 spillway. TDG levels have exceeded 110 percent saturation at the base of the Dam 1 at flows of 2,177 cfs and 2,804 cfs, but higher flows than these have had lower measured levels of TDG.

3. How quickly do elevated levels of TDG dissipate downstream when they are observed?

If the TDG level is 111 to 115 percent of saturation below the site of the Dam 2 spillway plunge pool rock weir, it dissipates to less than 110 percent at between 613 and 4,624 feet downstream. As of the end of 2018, TDG saturation in excess of 110 percent has not been measured below the Dam 2 spillway plunge pool at total river flows below the 7Q10 flow for the site.

9. Works Cited

Portland Water Bureau. 2008. Bull Run Water Supply Habitat Conservation Plan for the Issuance of a Permit to Allow Incidental Take of Threatened and Endangered Species. Portland, Oregon.

Portland Water Bureau. 2012. Bull Run Water Supply Habitat Conservation Plan Annual Compliance Report 2011—Year 2, Final. Portland, Oregon.

Exhibit A. TDG Data Associated with Bull Run Dams 2 and 1

Table A-1. Total Dissolved Gases (TDG) Data Associated with Bull Run Dam 2

Date	Monitoring Site	Percent Saturation	Spillway Flow[a] (cfs)	Powerhouse or HBV[b] Flow (cfs)
1/18/2005	TDG-1	107%	1,959	1,695
1/18/2005	TDG-1	108%	2,624	1,695
12/28/2005	TDG-1	111%	4,380	1,690
1/10/2006	TDG-1	116%	7,550	1,690
11/14/2006	TDG-1	103%	1,770	1,714
12/14/2006	TDG-1	107%	2,624	1,700
2/16/2007	TDG-1	112%	4,932	1,699
12/3/2007	TDG-1	111%	4268	1,690
11/13/2008	TDG-1	114%	7,897	1,560
11/13/2008	TDG-1	117%	9,568	1,560
11/23/2011	TDG-1	105%	2,042	1,585
12/29/2011	TDG-1	111%	3,274	1,596
12/14/2006	TDG-1L	111%	4,346	1,700
2/16/2007	TDG-1L	113%	5,464	1,684
12/3/2007	TDG-1L	111%	3,855	1,710
11/13/2008	TDG-1L	120%	10,611	1,560
11/23/2011	TDG-1L	108%	2,042	1,585
1/19/2012	TDG-1L	112%	3,718	1566
3/16/2012	TDG-1L	111%	3,616	1583
3/30/2012	TDG-1L	112%	6,418	1560
3/31/2012	TDG-1L	109%	2,504	1587
10/29/2012	TDG-1L	112%	5,816	100 (HBV)
11/20/2012	TDG-1L	114%	5,541	510 (HBV)
12/4/2012	TDG-1L	109%	3,155	530 (HBV)
12/2/2013	TDG-1L	117%	8,472	1,700
11/18/2015	TDG-1L	113%	5,855	620 (HBV)
12/9/2015	TDG-1L	112%	6,705	1,503
12/18/2018	TDG-1L	109%	2,901	1,429

Table A-1. Total Dissolved Gases (TDG) Data Associated with Bull Run Dam 2

Date	Monitoring Site	Percent Saturation	Spillway Flow[a] (cfs)	Powerhouse or HBV[b] Flow (cfs)
4/8/2019	TDG-1L	118%	6,300	1,500
12/28/2005	TDG-1a	109%	4,380	1,690
11/7/2006	TDG-1a	116%	14,160	1,645
11/14/2006	TDG-1a	102%	1,717	1,714
12/14/2006	TDG-1a	103%	2,746	1,700
2/16/2007	TDG-1a	107%	4,932	1,699
12/3/2007	TDG-1a	109%	4,397	1,700
11/13/2008	TDG-1a	113%	7,766	1,560
11/13/2008	TDG-1a	114%	9,755	1,560
11/23/2011	TDG-1a	104%	1,959	1,585
12/29/2011	TDG-1a	109%	3,274	1,596
12/14/2006	TDG-1u	102%		1,700
2/16/2007	TDG-1u	103%		1,699
12/3/2007	TDG-1u	103%		1,700
11/13/2008	TDG-1u	104%		1,560
11/23/2011	TDG-1u	105%		1,596
3/16/2012	TDG-1u	107%		1,583
3/30/2012	TDG-1u	105%		1,560
3/31/2012	TDG-1u	104%		1,587
10/29/2012	TDG-1u	105%		100 (HBV)
11/20/2012	TDG-1u	106%		510 (HBV)
12/4/2012	TDG-1u	106%		530 (HBV)
12/2/2013	TDG-1u	107%		1,700
11/18/2015	TDG-1u	102%		620 (HBV)
12/9/2015	TDG-1u	104%		1,525
12/18/2018	TDG-1u	106%		1,425
4/8/2019	TDG-1u	105%		1,500
1/18/2005	TDG-2	104%	2,444	1,695
11/7/2006	TDG-2	112%	12,155	1,645
11/14/2006	TDG-2	101%	1,797	1,714
12/14/2006	TDG-2	104%	4,046	1,700

Table A-1. Total Dissolved Gases (TDG) Data Associated with Bull Run Dam 2

Date	Monitoring Site	Percent Saturation	Spillway Flow[a] (cfs)	Powerhouse or HBV[b] Flow (cfs)
2/16/2007	TDG-2	109%	5,464	1,684
12/3/2007	TDG-2	108%	3,924	1,720
11/13/2008	TDG-2	115%	10,323	1,560
11/23/2011	TDG-2	105%	1,932	1,596
1/19/2012	TDG-2	112%	3,873	1566
10/29/2012	TDG-2	114%	5,698	100 (HBV)
11/20/2012	TDG-2	114%	5,503	510 (HBV)
12/4/2012	TDG-2	107%	3,219	530 (HBV)
12/2/2013	TDG-2	115%	8,161	1,700
11/18/2015	TDG-2	109%	5,737	620 (HBV)
12/9/2015	TDG-2	111%	6,623	1,503
2/3/2005	TDG-3	103%		113 (HBV)
3/25/2008	TDG-3	103%		282 (HBV)
7/2/2008	TDG-3	106%		700 (HBV)
11/20/2012	TDG-3	105%		510 (HBV)
11/18/2015	TDG-3	103%		620 (HBV)
2/3/2005	TDG-4	102%		118 (HBV)
7/2/2008	TDG-4	107%		1,300 (HBV)
12/29/2004	TDG-5	102%		409
12/28/2005	TDG-5	102%		1,690
11/14/2006	TDG-5	100%		1,714
2/16/2007	TDG-5	101%		1,681
12/3/2007	TDG-5	100%		1,700
7/2/2008	TDG-5	109%		1,200
7/2/2008	TDG-5	108%		1,300
7/2/2008	TDG-5	108%		1,700
7/2/2008	TDG-5	108%		1,750
3/16/2012	TDG-5	106%		1,583
3/30/2012	TDG-5	104%		1,560
3/31/2012	TDG-5	106%		1,587
12/2/2013	TDG-5	106%		1,700
4/10/2019	TDG-5	105%		1,500

Table A-1. Total Dissolved Gases (TDG) Data Associated with Bull Run Dam 2

Date	Monitoring Site	Percent Saturation	Spillway Flow[a] (cfs)	Powerhouse or HBV[b] Flow (cfs)
5/19/2005	TDG-6	104%		1,725
12/28/2005	TDG-6	102%		1,690
11/14/2006	TDG-6	100%		1,714
2/16/2007	TDG-6	101%		1,681
7/2/2008	TDG-6	107%		2,000 (HBV)
7/2/2008	TDG-6	108%		1,820
3/16/2012	TDG-6	107%		1,583
3/30/2012	TDG-6	106%		1,560
3/31/2012	TDG-6	105%		1,587
11/20/2012	TDG-6	106%		510 (HBV)
12/2/2013	TDG-6	106%		1,700
4/10/2019	TDG-6	107%		1,500
5/19/2005	TDG-7	104%		1,725
11/14/2006	TDG-7	102%		1,714
7/2/2008	TDG-7	106%		1,820
3/16/2012	TDG-7	106%		1,583
3/30/2012	TDG-7	104%		1,560
3/31/2012	TDG-7	104%		1,587
11/20/2012	TDG-7	104%		510 (HBV)
12/2/2012	TDG-7	106%		1,700
4/10/2019	TDG-7	104%		1,500
12/28/2005	TDG-8	103%		1,690
11/14/2006	TDG-8	101%		1,714
2/16/2007	TDG-8	102%		1,681
12/3/2007	TDG-8	102%		1,700
7/2/2008	TDG-8	105%		2,000 (HBV)
3/16/2012	TDG-8	106%		1,583
3/30/2012	TDG-8	106%		1,560
3/31/2012	TDG-8	105%		1,587
10/29/2012	TDG-8	103%		100
11/20/2012	TDG-8	104%		510 (HBV)

Table A-1. Total Dissolved Gases (TDG) Data Associated with Bull Run Dam 2

Date	Monitoring Site	Percent Saturation	Spillway Flow[a] (cfs)	Powerhouse or HBV[b] Flow (cfs)
12/2/2013	TDG-8	106%		1,700
11/18/2015	TDG-8	102%		620 (HBV)
12/9/2015	TDG-8	104%		1,515
12/18/2018	TDG-8	104%		1,500
4/10/2019	TDG-8	105%		1,500
11/14/2006	TDG-9	100%		1,714
2/16/2007	TDG-9	103%		1,699
12/3/2007	TDG-9	104%		1,700
3/16/2012	TDG-9	106%		1,583
3/30/2012	TDG-9	105%		1,560
3/31/2012	TDG-9	104%		1,587
10/29/2012	TDG-9	103%		100
11/20/2012	TDG-9	104%		510 (HBV)
12/2/2013	TDG-9	107%		1,700
11/18/2015	TDG-9	102%		620 (HBV)
12/9/2015	TDG-9	104%		1,525
12/18/2018	TDG-9	104%		1,425

[a]Blank space indicates that spillway flows are not applicable to this monitoring site.

[b]HBV: Howell Bunger valve. If flow refers to HBV flow, then datum is labeled with (HBV).

Table A-2. Total Dissolved Gases (TDG) Data Associated with Bull Run Dam 1

Date	Monitoring Site	Percent Saturation	Spillway Flow (cfs)	Powerhouse Flow (cfs)
1/18/2005	TDG-10	104%	2,000	2,000
12/28/2005	TDG-10	108%	2,340	2,250
1/10/2006	TDG-10	109%	4,801	2,250
11/7/2006	TDG-10	109%	9,851	2,200
2/16/2007	TDG-10	107%	2,042	2,200
12/3/2007	TDG-10	107%	2,834	2,200
11/13/2008	TDG-10	108%	4,111	2,560
3/16/2012	TDG-10	108%	1,059	2,562

Table A-2. Total Dissolved Gases (TDG) Data Associated with Bull Run Dam 1

Date	Monitoring Site	Percent Saturation	Spillway Flow (cfs)	Powerhouse Flow (cfs)
12/2/2013	TDG-10	105%	2,909	2,200
11/18/2015	TDG-10	107%	4,178	0
4/8/2019	TDG-10	107%	5,467	2,600
11/7/2006	TDG-11	104%	10,158	2,200
11/14/2006	TDG-11	99%	278	2,200
2/16/2007	TDG-11	112%	2,177	2,200
12/3/2007	TDG-11	112%	2,804	2,200
11/13/2008	TDG-11	108%	4,300	2,560
12/2/2013	TDG-11	110%	2,769	2,200
11/18/2015	TDG-11	104%	4,178	0
1/4/2005	TDG-12	103%	0	1,385
12/28/2005	TDG-12	108%	2,145	2,250
11/7/2006	TDG-12	109%	9,667	2,200
11/14/2006	TDG-12	105%	278	2,200
2/16/2007	TDG-12	108%	2,062	2,200
12/3/2007	TDG-12	107%	2,822	2,200
11/13/2008	TDG-12	108%	4,286	2,560
3/16/2012	TDG-12	107%	1,059	2,562
12/2/2013	TDG-12	105%	3,004	2,200
4/8/2019	TDG-12	108%	5,467	2,600

Appendix G

Bull Run HCP Research Report

Lower Bull Run River Adult Chinook Population

May 2020

Burke Strobel
City of Portland Water Bureau

Contents

Tables

Figures

1. Summary

The City of Portland Water Bureau (PWB) was in full compliance with its Bull Run Water Supply Habitat Conservation Plan (HCP; Portland Water Bureau 2008) obligations in 2019 regarding lower Bull Run River adult Chinook Salmon population research. Three snorkel surveys of holding adult Chinook Salmon were conducted through the summer, and weekly walking surveys of spawning and holding Chinook Salmon (spawning surveys) were conducted from mid-September through early December. The snorkeled portion of the lower Bull Run River included the lower river from its mouth to Larson's Falls (river mile [RM] 3.7). The portion of the river surveyed while walking included the entire lower river from its mouth to the base of the Bull Run diversion dam at Headworks (river mile [RM] 6.0). In 2019, spawning surveys could not be conducted on two occasions because of staffing issues and high flows. The peak adult Chinook count and minimum escapement[1] for spring Chinook in 2019 were the lowest ever recorded, but for fall Chinook were in the middle of the range of past years' estimates. The cumulative redd count, however, was the third-highest ever observed in the lower Bull Run River, with redds attributed to spring Chinook falling in the middle of the range of past years' estimates, and the fall Chinook redd count being the second-highest ever observed. For the first time, fall Chinook redds outnumbered spring Chinook redds. This year's two missed surveys were near the peak of the season and may have affected peak counts and minimum escapement estimates, but probably not the cumulative redd counts. One redd identified late in the season at the upstream end of the survey reaches was analyzed using eDNA and found likely to have been made by summer steelhead. One prespawning mortality of a hatchery fish was observed in 2019 despite the summer being characterized by relatively cool water.

The snorkel surveys conducted during the summer followed protocols modified from the survey protocol described in the HCP. These additional surveys were necessary to evaluate efforts by the Oregon Department of Fish and Wildlife (ODFW) to use an adult fish weir and trap near the mouth of the river to prevent adult hatchery Chinook from entering the lower Bull Run River. The modified survey protocols included snorkeling large portions of the river to better count adults holding in deep pools and to attempt to determine whether live fish had clipped or intact adipose fins. A relatively small number of adult hatchery Chinook were observed during snorkel surveys; these are likely to have entered the lower Bull Run River before the ODFW weir was installed in late May. Variations in adult counts between snorkel surveys in 2019 are probably a result of adults escaping observation at times in deep pools or among large boulders common in the Bull Run River channel.

[1] Escapement is the number of fish that avoid or escape all harvest and return to spawn in their home streams.

2. Introduction

This section describes the results of surveys of spawning Chinook Salmon adults and redds in the lower Bull Run River. Both spring and fall runs of Chinook Salmon spawn in the lower Bull Run River.

Various agencies have conducted surveys of Chinook adults and redds in the Sandy River Basin since the 1980s. ODFW has conducted surveys of spring Chinook adults and redds in the Sandy River Basin by boat and on foot from 1996 to the present. They conducted surveys of fall Chinook adults and redds by boat and on foot in index reaches in the lower Sandy River Basin from 1984 to 2013 and followed probabilistic sampling protocols from 2012 to the present. These surveys, however, have not included the lower Bull Run River. ODFW conducted weekly surveys of spawning spring and fall Chinook Salmon and redds in the lower Bull Run River (RM 0–RM 5.8) in 1997. PWB continued weekly surveys from RM 1.5 to RM 5.8 in 1998 and 1999. An index reach of the lower Bull Run River (RM 1.5–RM 3.7) was surveyed by PWB in 2005 and 2006. This index reach was expanded to include RM 0–RM 3.7 for surveys conducted from 2007 to 2009 and further expanded to a full census of the lower river, including RM 0–RM 6.0, for all subsequent survey years.

For HCP Years 1–20 (2010–2029), PWB will count spawning Chinook Salmon and redds in the lower Bull Run River annually. The lower Bull Run River Chinook population research is designed to provide biologists with meaningful data within a 20-year time frame to evaluate the long-term trend in adult Chinook abundance for the Bull Run. The Bull Run data could then be used with information gathered by other agencies to determine the status of federally listed Sandy River Chinook populations.

In addition to meeting its HCP obligations, PWB added a new monitoring consideration in 2013, which it retained in 2019. This new consideration assesses the effects of an ODFW program, begun in 2011, to acclimate and release hatchery Chinook smolts in the lower Bull Run River. Adult Chinook belonging to those acclimated cohorts began returning to the Bull Run River in 2013. PWB was concerned that many adult hatchery Chinook might begin returning to the Bull Run River. The percentage of hatchery spring Chinook adults on the spawning grounds in the upper Sandy Basin is considered acceptable if it is below 10 percent (ODFW 2011). A large return of hatchery fish could quickly exceed that threshold in the Bull Run River, undermining the City's restoration efforts. ODFW began installing a river channel-spanning weir near the mouth of the Bull Run River in 2013 to remove hatchery Chinook adults while allowing wild Chinook adults to enter the river. The weir was also installed in late May 2019. Spawning survey protocols were adjusted in 2019 to evaluate ODFW's efforts to prevent adult hatchery Chinook from entering the Bull Run River.

PWB also assessed prespawning mortality of spring Chinook Salmon in 2019. Hot, dry weather conditions such as those experienced in the Bull Run Watershed in recent years can heat streams. Warm stream temperatures can result in an increase in mortality among adult salmon before they have had the chance to spawn. PWB wishes to determine whether prespawning mortality in the Bull Run River is related to stream temperatures.

3. Research Objectives

In 2019 and continuing through HCP Year 20, PWB will conduct annual counts of spawning Chinook Salmon and redds in the lower Bull Run River from RM 0–RM 6.0.

The objectives of the lower Bull Run River Chinook population research are to

- document use of the lower Bull Run River by spring and fall Chinook Salmon, and
- contribute to ODFW's annual assessment of spring Chinook in the Sandy River Basin.

4. Key Questions and Hypotheses

The key questions to be answered by the research are the following:

- How many Chinook Salmon adults enter the Bull Run River to spawn each year? This key question does not have an associated null hypothesis (H_o).
- How many Chinook Salmon redds are built in the Bull Run River each year? This key question has been added since PWB's adoption of the HCP and does not have an associated null hypothesis.
- What is the long-term trend (20 years) in spawning Chinook Salmon abundance?

    H_o: The abundance of spawning Chinook Salmon will not change significantly over the long term (20 years, α=0.05, β=0.20).

- What is the timing (range of dates and peak date) of adult Chinook presence and redd creation in the lower Bull Run River? This key question does not have an associated null hypothesis.
- What percentage of the spawning Chinook Salmon are of hatchery origin?[2] This key question does not have an associated null hypothesis.

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[2] The protocols followed by PWB provide the proportion of carcasses found with clipped adipose fins. The proportion of unclipped carcasses that are of hatchery origin will be provided by ODFW analysis of otoliths. Otoliths are tiny bones that form a portion of a fish's inner ear. A fish lays down new bone material on the otolith's edge as it grows, forming bands that record the fish's growth rate over time. ODFW thermally "marks" otoliths in hatchery Chinook by exposing juvenile fish to varying water temperatures. Because fish growth increases in warm water and decreases in cold water, characteristic banding patterns are created, which provide an indication of fish origin (Schroeder et al. 2005).

Four additional key questions to be answered by the lower Bull Run River adult Chinook population research were pursued in 2019:

- What percentage of spring Chinook Salmon holding in the Bull Run River while the ODFW weir is in operation are of hatchery origin? This key question does not have an associated null hypothesis.
- What percentage of spawning spring Chinook Salmon are of hatchery origin? Spring Chinook represent only a portion of the Chinook adults observed in the lower Bull Run River and are expected to have a different hatchery proportion than the aggregate population of both spring Chinook and fall Chinook. This key question does not have an associated null hypothesis.
- What was the rate of prespawning mortality in 2019 for spring Chinook Salmon, and is there a relationship between the yearly maximum 7-day average of daily maximum stream temperature in the Bull Run River and observed prespawning mortality? This key question does not have an associated null hypothesis.
- Does the number of adipose-clipped spring Chinook in the Bull Run River increase while the ODFW weir is in operation?

The City also collects otolith,[2] tissue, and scale samples from adult carcasses found in the lower Bull Run River. The City sends the samples to ODFW to assist in ODFW's assessment of spring Chinook in the Sandy River Basin. In return, PWB will receive information from ODFW at a future date about the proportion of unclipped Chinook Salmon that are of hatchery origin, the relative number of spring and fall Chinook Salmon in the lower Bull Run River, and the proportion of Chinook adults showing aspects of various life history types.[3] The compilation of this information, however, depends on analyses conducted by ODFW and is therefore not reflected in the key questions.

The City conducts surveys throughout the spawning season for both spring Chinook and fall Chinook, but several of the statistics associated with the key questions and hypotheses apply primarily to spring Chinook. The spring Chinook run in the Bull Run River generally tapers off by the end of October, at about the time the fall Chinook run is beginning. There is undoubtedly overlap between the two runs, although the degree of overlap has not been quantified. ODFW uses October 31 as a cutoff date to distinguish between the two runs in the Bull Run River. The dates for peak counts have consistently occurred before October 31 and, for this reason, have in the past reflected the spring Chinook run. Other statistics, such as cumulative redd count and percentage of hatchery fish, have been influenced to varying degrees by the inclusion of fall Chinook. The cutoff

[3]A Chinook salmon's life history type is defined by when, where, and how it lives over the course of its lifetime. This includes the number of years that it spent in freshwater and in saltwater before returning to freshwater to spawn.

date of October 31 was applied in 2019 to estimate peak counts, minimum escapement estimates, and redd counts for both spring Chinook and fall Chinook.

5. Methods

The study design for the lower Bull Run River Chinook population research uses weekly surveys to count live Chinook adults, Chinook Salmon carcasses, and newly created redds. The surveys are coordinated with operators at the City's Headworks facility and the EWEB-operated powerhouses at Bull Run Dam 1 and Dam 2. During surveys, operators maintain flows of 100 cubic feet per second (cfs) or less above the Little Sandy confluence as often as possible. This is the level of flow necessary for safety and for accurate counts. No surveys are conducted if flows of 300 cfs or less cannot be maintained. The HCP allows for departures from minimum flow criteria in the lower Bull Run River (Measures F-1 and F-2) to make Chinook spawning surveys possible.

5.1 Spatial Scale

The lower Bull Run River was divided into the following reaches to provide greater spatial resolution of counts than a simple count of the entire river would provide and to reflect the reaches used in previous surveys for comparison:

<u>Reach 1</u>: The confluence of the Bull Run River with the Sandy River to the upstream end of the large pool adjacent to the Bull Run PGE Powerhouse (RM 0–RM 1.5)

<u>Reach 2</u>: The upstream end of the large pool adjacent to the Bull Run PGE Powerhouse to Bowman's Bridge (RM 1.5–RM 2.3)

<u>Reach 3</u>: Bowman's Bridge to the upstream end of the pool at the confluence with the Little Sandy River (RM 2.3–RM 2.8)

<u>Reach 4</u>: The upstream end of the Little Sandy River confluence pool to the upstream end of the pool at Larson's Bridge (RM 2.8–RM 3.7)

<u>Reach 5</u>: The upstream end of the pool at Larson's Bridge to the Road 14 bridge (RM 3.7–RM 4.8)

<u>Reach 6</u>: The Road 14 bridge to the Headworks diversion dam (RM 4.8—RM 6.0)

These reaches correspond to those used for the HCP Chinook spawning gravel research (see Appendix C, Lower Bull Run River Spawning Gravel Research), with the exception that spawning gravel research is not conducted between RM 5.8 and RM 6.0. Reaches 2, 3, and 4 are also the reaches used in previous Chinook spawning surveys conducted by ODFW and PWB. Reach 4 corresponds to one of ODFW's probabilistic, randomly selected reaches for the Sandy River Basin steelhead and coho spawning surveys and snorkel surveys. Reaches 5 and 6 were not believed to be used by spawning Chinook salmon prior to 2011. These reaches were surveyed twice in 2010 to confirm whether they were being used; one spawning Coho Salmon was observed. Based on this result, starting in 2011, Reaches 5 and 6 were surveyed every week after October 1. They were not surveyed earlier in the year because low summer flows make it very unlikely that salmon would be able to pass Larson's Falls at RM 3.7.[4]

Adult and redd abundance and timing information is summarized at the reach scale. The percentage of hatchery fish is summarized at the scale of the entire lower Bull Run River.

5.2 Replication/Duration

The City is committed to funding the Chinook population research in the lower Bull Run River for the first 20 years of the HCP. Annual surveys of spawning Chinook Salmon and redds are conducted.

Weekly surveys in 2019 were conducted from mid-September through mid-December. Two weeks were missed because of staffing difficulties and high flows. Three additional snorkel surveys were conducted: one in June, one in July, and one in August. There was no spatial replication because the entire channel was surveyed.

5.3 Parameters

The following information and samples were collected during each survey.

- Live Adults
  - Number of adults and number of jacks
  - Species
  - Reach
  - Additional behavioral information (e.g., spawning, defending a redd)
- Carcasses
  - Species
  - Reach
  - Length (both total length from the snout-tip to the fork of the tail and the middle-of-eye-to-posterior-scale [MEPS] length, in centimeters)
  - Sex
    - If a female, whether it died before spawning
  - Presence of adipose fin

[4] Flows generally begin increasing with the autumn rains in October, making it possible, though difficult, for salmon to pass Larson's Falls.

    - ♦ If no adipose fin, whether it has coded-wire tags (CWT). If CWT were present, researchers collected the snout
    - ♦ If an adipose fin was present and the date was October 31 or earlier, researchers collected
      - an otolith sample (for ODFW determination of hatchery origin)
      - a tissue sample (for National Marine Fisheries Service distinction of spring from fall Chinook)
      - a scale sample (for ODFW determination of age and life history)
  - Additional information (e.g., whether the individual appeared to be eaten by scavengers or was found in the riparian zone)
- Redds
  - Reach
  - Species (researchers assumed the individual was Chinook unless another species was seen creating or defending it)
  - Size (length x width, in square feet, including excavated pot and gravel mound)
  - Substrate size range (visual estimate of the range from approximately the 10th to the 90th percentile of substrate sizes, in inches, focusing on gravel mound)[5]
  - Channel feature retaining the original gravel patch (e.g., whether the redd is behind a boulder or bedrock, a pool-tail or riffle margin)
  - Evidence of superimposition over a previous redd
- Environmental data
  - Weather (description)
  - Water clarity/visibility
  - Flow (determined from U.S. Geological Survey [USGS] Gage No. 14140000)

5.4 Sampling

Sampling methods have been altered slightly from those proposed in the HCP. The City intended to conduct spawning surveys by walking the river channel in flows of up to 150 cfs. This was regarded as the maximum flow that would still allow for safe navigation by surveyors on foot wearing waders. Between flows of 150 and 500 cfs, PWB intended to survey while floating the river with kayaks. An initial trial run with kayaks

[5] Substrate sizes are discussed in the HCP, Appendix F. The HCP is available at www.portlandoregon.gov/water/46157.

conducted by PWB before 2010 at 400 cfs, however, convinced PWB that this method would not produce reliable data and was not a safe survey approach.

Instead, surveys were conducted by two observers walking downstream on each side of the channel (Figure 1). Between flows of 150 and 400 cfs (which included contributions from the Little Sandy River), surveyors wore dry suits and life vests. This enabled them to swim safely through otherwise impassable areas. If the combined flows of the Bull Run River and Little Sandy River could not be maintained below 400 cfs, surveys were canceled.

Live adults and jacks were counted, and their locations recorded. Any carcasses that were found with an intact tail were counted. All carcasses that could be retrieved were measured, and their sex was recorded. Females were opened to check for eggs, which would determine whether they died before spawning. All carcasses were checked for the presence of an adipose fin. All carcasses with adipose fins found on or before November 1 (corresponding to an approximate date of October 31 used by ODFW to distinguish between live spring and fall Chinook—ODFW has an interest only in samples collected from the earlier, spring-run fish) were sampled for otoliths, tissue, and scales. After November 1, no samples were collected from Chinook carcasses.

ODFW also conducted several independent surveys of adults and carcasses on portions of the lower Bull Run River in September and October of 2018. ODFW carcass counts and carcass data were added to PWB data for the nearest PWB survey date.

Redds were counted, and their locations recorded. The approximate surface area of each redd and the size of its substrate were visually estimated. Once these and other data had been collected, each redd was marked with a flag with the date attached to the bank adjacent to the redd. The following week, if there were no signs of adult fish that could still be building the redd, a painted rock comparable in size to those comprising the redd was placed on the redd. The painted rock helped distinguish new redds from old ones. Painted rocks from previous surveys that had been dislodged or buried indicated that further spawning activity had occurred at that location. The flag on the bank aided in confirming the presence of an old redd if the painted rock was missing. If live adults

Figure 1. Surveyors Walk Both River-Banks Looking for Live Fish, Redds, and Carcasses

were still observed on or near a redd after two weeks, it was assumed that a new redd was in the process of being built superimposed on the old redd. No rock was placed, but the bank was flagged. If no adults were observed the following week, a rock was placed at that time, and a note of it was made.

Figure 2. Measuring the Length of a Male Chinook Salmon Carcass

The City employed a technique in 2019 to identify certain redds of unknown species origin by sampling for environmental DNA (eDNA). Analysis of waterborne eDNA collected in the field is a rapidly developing technique used primarily to test for the presence of organisms. The City explored a technique in 2013 (Strobel et al., 2017) to use the relative quantity of eDNA in water samples drawn from the interstitial spaces of redds to identify the species that made the redd. Two unknown redds were identified near the upstream end of the surveyed portion of the river in December. One of these redds was sampled for eDNA to determine which species had made it.

Three surveys were conducted in 2019 following an adjusted protocol to provide data to ODFW personnel to evaluate ODFW's efforts to prevent adult hatchery Chinook from entering the lower Bull Run River. The purpose of the additional surveys was to determine whether adult hatchery Chinook had entered the Bull Run River before ODFW installed its weir or despite the weir. Under the modified protocols, as much of the lower Bull Run River as possible (Reaches 1-4) was snorkeled. Snorkelers counted adult Chinook and identified whether each observed fish had a clipped or intact adipose fin or whether the adipose fin status could not be determined. Snorkelers did not look for redds in snorkeled portions of the river. Portions of the river that were too shallow to snorkel effectively were surveyed according to the regular protocols described above. These modified surveys were conducted on June 11, July 18, and August 21.

6. Analysis

Data Storage: Monitoring data collected during the HCP Chinook Population Research were entered by PWB in a Microsoft® Excel spreadsheet and stored with spreadsheets containing data from previous years' surveys.

Hypothesis Testing: The number and timing of Chinook Salmon in the lower Bull Run in a given year were compared to the number and timing of Chinook Salmon in other years. Individual years were not compared statistically, however, because of the lack of replication.

The trend in peak spawner count (live + dead fish on a given date) and minimum escapement estimate (peak count of live fish on a given date plus cumulative carcass count up to and including that date) were calculated for all surveys to date using linear regression (α=0.05).

The percentage of hatchery fish in the lower Bull Run in a given year was compared to the percentage of hatchery fish in other years. Individual years were not compared statistically, however, because of the lack of replication.

The percentage of hatchery fish in the spring Chinook population, as opposed to the percentage of hatchery fish in the aggregate population of spring and fall Chinook, was estimated by applying a cutoff date of November 1 for distinguishing between carcasses that were considered to be spring Chinook (carcasses of fish that could have spawned on or before October 31) or fall Chinook (carcasses of fish that probably spawned in November or later).

7. Results and Discussion

7.1 Surveys

Fifteen surveys were conducted in 2019 between June 11 and December 11; three followed modified protocols, which included snorkeling, and 12 followed standard protocols (Figure 3). Surveys were canceled on October 16 due to staffing issues and October 23 due to high flows. Three redds were observed during the last survey, indicating that a small amount of spawning activity at the end of the season may have been missed.

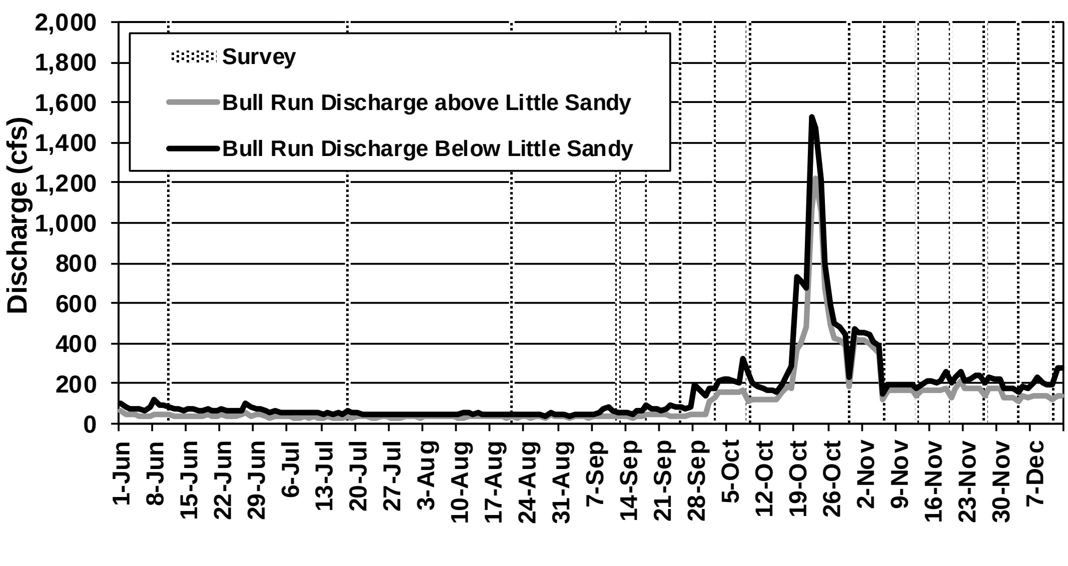

Figure 3. Bull Run River Discharge above and below the Little Sandy Confluence and Dates of Chinook Spawning Surveys in 2019

7.2 Live Adults

7.2.1 Peak Counts and Minimum Escapement Estimates

The peak count and minimum escapement estimate for Chinook Salmon in the lower Bull Run River in 2019 were the lowest ever observed since the removal of Marmot Dam in 2007. These counts, however, contrasted with the cumulative redd count, which was the third-highest ever recorded, as indicated in Table 1.

Table 1. Summary Statistics for Chinook Spawning Runs in the Lower Bull Run River, 2007–2019[a]

Year	Peak Count	Minimum Escapement	Cumulative Redd Count	% Hatchery (n)[b]	% Female (n)
2019	20	32	98	17.4% (23)	75.0% (24)
2018	32	48	133	80.0% (35)	59.5% (37)
2017	24	42	59	78.4% (37)	67.6% (34)
2016[c]	63	63	59	39.1% (23)	64.0% (25)
2015	37	76	85	27.0% (63)	47.5% (61)
2014	21	37	67	3.7% (27)	37.0% (27)
2013	54	69	124	16.3% (48)	64.6% (47)
2012	30	33	31	60.0% (5)	40.0% (5)
2011	84	99	94	43.1% (72)	54.7% (75)
2010	70	77	43	36.8% (19)	75.0% (16)
2009	61	70	89	11.8% (34)	52.9% (34)
2008	31	38	37	11.5% (26)	73.1% (26)
2007	34	39	62	41.7% (12)	76.9% (13)

[a]Includes peak count, minimum escapement estimate, percent of identifiable carcasses with clipped adipose fins (n=number of carcasses where the state of the adipose fin could be determined), and percent of identifiable carcasses that were female (n=number of carcasses where the sex could be determined).

[b]Fish with clipped adipose fins. A small portion of unclipped fish may also be of hatchery origin. Determined from carcass data only. Up to 93% of adults observed while snorkeling were adipose-clipped. These fish are not included in the % Hatchery estimate because the survey protocols were not comparable to other dates and other years.

[c]Peak Count and Minimum Escapement have been changed from those reported from 2016. The 2016 Compliance Report included the results from snorkel surveys when calculating Peak Count and Minimum Escapement. Snorkel surveys, however, follow different protocols that should not be combined with data collected during walking spawning surveys.

Peak adult counts continue to be lower, on average, than they had been prior to the Marmot Dam removal in 2007 ($\text{t-test}_{\text{one-tailed}}$, p=0.004, df=8, assuming unequal variances), but with a large amount of variation, as indicated in Figure 4. The average peak count prior to removal was 129 (±103%–95% confidence interval). In the years after decommissioning, the average has been 43 (±94%–95% confidence interval). There is no trend in the data observed between 2007 and 2019 (p=0.22).

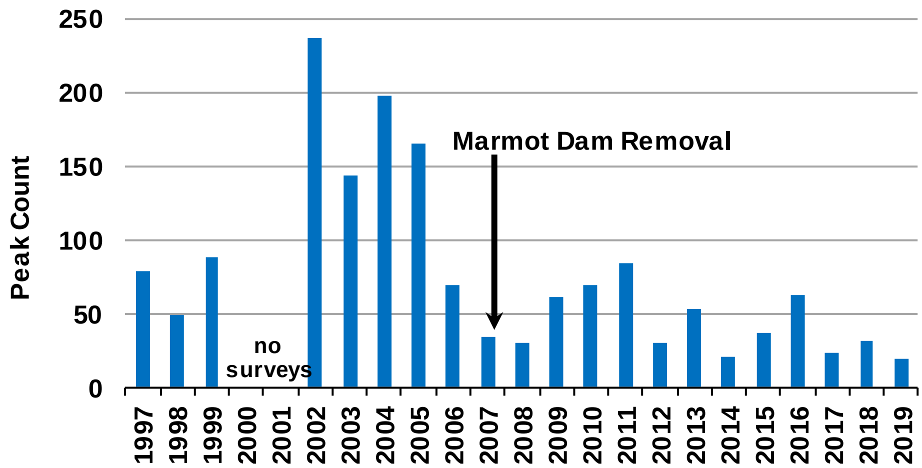

Figure 4. Chinook Salmon Peak Counts for All Years when Surveys Were Conducted

The peak count statistic generally reflects the status of spring Chinook, whereas minimum escapement, cumulative redd count, percent hatchery, and percent female reflect the combined total for spring Chinook and fall Chinook. Dates for peak counts have consistently occurred in October, at the height of spring Chinook spawning activity and before fall Chinook are believed to be present in the river in significant numbers. In 2019, however, the peak count occurred on November 6. It included the presence of fall Chinook, spring Chinook carcasses, and possibly some remnant live spring Chinook adults. Having the peak count variously affected by the presence of two separate runs complicates comparisons across years. 2019 was the first year when the peak count did not occur before November 1 and was assumed to include a significant proportion of fall Chinook. The peak count before November 1 was 11 (on October 30), a likewise low number.

It is difficult to distinguish between spring Chinook and fall Chinook redds and carcasses because of overlap in their run timing at the end of October and early November. ODFW has used November 1 as an approximate date for distinguishing between spring Chinook and fall Chinook. Spawning activity prior to November 1 is assigned to the spring run, and spawning activity observed on or after November 1 is assigned to the fall run. Carcasses recovered on November 1 are assigned to the spring run. Tables 2 and 3 summarize statistics for Chinook assigned to the spring and fall spawning runs, respectively. In the future, genetic analysis may help to distinguish these two runs.

Table 2. Summary Statistics for Assigned Spring Chinook (before November 1) Spawning in the Lower Bull Run River, 2007–2019[a]

Year	Peak Count	Minimum Escapement	Cumulative Redd Count	% Hatchery (n)[b]	% Female (n)

Table 2. Summary Statistics for Assigned Spring Chinook (before November 1) Spawning in the Lower Bull Run River, 2007–2019[a]

Year	Peak Count	Minimum Escapement	Cumulative Redd Count	% Hatchery (n)[b]	% Female (n)
2019	11	15	43	22.2% (9)	55.6% (9)
2018	32	48	70	87.1% (31)	62.5% (32)
2017	24	46	48	80.0% (35)	66.0% (32)
2016	63	63	45	52.9% (17)	64.7% (17)
2015	37	66	55	37.2% (51)	41.5% (41)
2014	21	37	35	5.3% (21)	15.8% (19)
2013	52	62	95	25.0% (33)	61.3% (31)
2012	30	33	28	60.0% (5)	40.0% (5)
2011	84	85	63	50.9% (55)	52.5% (59)
2010	70	77	42	46.7% (15)	75.0% (11)
2009	61	70	61	21.1% (19)	42.1% (19)
2008	31	38	22	18.8% (16)	68.8% (16)
2007	34	39	37	40.0% (10)	70.0% (10)

[a]Includes peak count, minimum escapement estimate, percent of identifiable carcasses with clipped adipose fins (n=number of carcasses where the state of the adipose fin could be determined), and percent of identifiable carcasses that were female (n=number of carcasses where the sex could be determined).

[b]Fish with clipped adipose fins. A small portion of unclipped fish may also be of hatchery origin. Determined from carcass data only. Up to 100% of adults observed while snorkeling were adipose-clipped. These fish are not included in the % Hatchery estimate because the survey protocols were not comparable to other dates and other years.

Table 3. Summary Statistics for Assigned Fall Chinook (November 1 and after) Spawning in the Lower Bull Run River, 2007–2019[a]

Year	Peak Count	Minimum Escapement	Cumulative Redd Count	% Hatchery (n)[b]	% Female (n)
2019	20	22	55	14.3% (14)	86.7% (18)
2018	17	17	63	25.0% (4)	40.0% (5)
2017	11	11	11	50.0% (2)	100.0% (2)
2016	8	8	14	0.0% (6)	62.5% (8)
2015	32	32	30	5.0% (20)	60.0% (20)
2014	7	14	32	0.0% (6)	43.8% (16)
2013	35	35	29	0.0% (17)	70.6% (17)
2012[c]	ND	ND	3	ND	ND
2011	23	40	31	17.7% (17)	62.5% (16)
2010	5	6	1	0.0% (4)	80.0% (5)

Table 2. Summary Statistics for Assigned Spring Chinook (before November 1) Spawning in the Lower Bull Run River, 2007–2019[a]

Year	Peak Count	Minimum Escapement	Cumulative Redd Count	% Hatchery (n)[b]	% Female (n)
2009	18	18	28	0.0% (15)	66.7% (15)
2008	8	10	10	0.0% (10)	80.0% (10)
2007	13	15	25	50.0% (2)	100.0% (3)

[a]Includes peak count, minimum escapement estimate, percent of identifiable carcasses with clipped adipose fins (n=number of carcasses where the state of the adipose fin could be determined), and percent of identifiable carcasses that were female (n=number of carcasses where the sex could be determined).

[b]Fish with clipped adipose fins. A small portion of unclipped fish may also be of hatchery origin. Determined from carcass data only.

[c]ND=No Data. No fish were observed, but too few surveys were conducted to conclude none were present.

The relative size of the peak count of spring Chinook in the Bull Run River in 2019 does not necessarily reflect the relative size of the spring Chinook escapement to the Sandy River in general. Since the removal of Marmot dam, there has been no correlation between the Bull Run River peak Chinook counts and the Sandy River Basin spring Chinook escapement estimates for the respective years. Prior to the removal of Marmot Dam, adult Chinook counts in the Bull Run River reflected trends in the greater Sandy River Basin.

Marmot Dam diverted Sandy River water to the adjacent Little Sandy River Basin, where it was further diverted by way of Roslyn Lake to the Bull Run River at RM 1.5. Following chemical cues in the water, a portion of adult Chinook Salmon intent on returning to their natal streams in the upper Sandy River Basin apparently strayed into the Bull Run River by mistake. During these years, lower Bull Run adult Chinook peak counts showed a significant positive correlation (R^2=0.72, p=0.008) with the estimated spring Chinook run size upstream of Marmot Dam (Sandy spring Chinook data 2007 and after from ODFW; Kirk Schroeder and Luke Whitman, pers. comm. Data prior to 2007 from PGE. See Figure 5). After Sandy River water was no longer diverted into the Bull Run River, adult Chinook peak counts declined dramatically and showed no significant correlation with Sandy River spring Chinook counts (R^2=0.01, p=0.81 for years 2007–2018; see Figures 3 and 4).

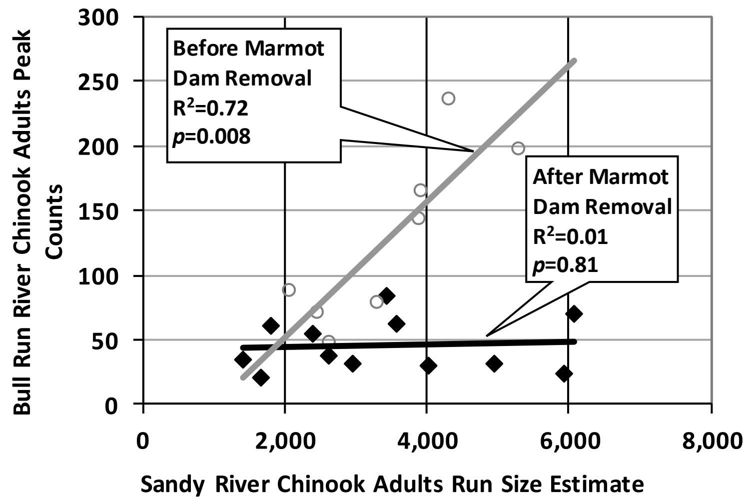

Figure 5. Relationship of Peak Counts of Adult Chinook in the Lower Bull Run River with Estimated Run Size of Spring Chinook in the Upper Sandy River Basin before and after the Removal of Marmot Dam

7.2.2 Timing

Adult Chinook Salmon were observed during walking surveys in the Bull Run River until late November with a fresh carcass being found on December 11, but counts peaked in early November (Table 4). The date of the minimum escapement estimate was in mid-November.

Table 4. Timing of Adult Chinook Peak Counts, Highest Minimum Escapement Estimate, and Peak Redd Count, 2007–2019

Year	Peak Count	Minimum Escapement	Peak Redd Count
2019	Nov. 6	Nov. 13	Oct. 30
2018	Sep. 25	Nov. 7	Nov. 7
2017	Oct. 3	Nov. 1	Oct. 3 and 18
2016	Sep. 20	Sep. 20	Oct. 25
2015	Oct. 27	Nov. 12	Nov. 12
2014	Oct. 28	Oct.28	Oct. 28
2013	Oct. 23	Nov. 14	Oct. 16
2012	Oct. 24	Oct. 24	Oct. 24
2011	Oct. 5	Nov. 10	Oct. 5
2010	Oct. 20	Oct. 20	Oct. 20
2009	Oct. 21	Oct. 21	Oct. 21
2008	Oct. 22	Oct. 29	Oct. 15 and 22
2007	Oct. 24	Oct. 24	Oct. 18

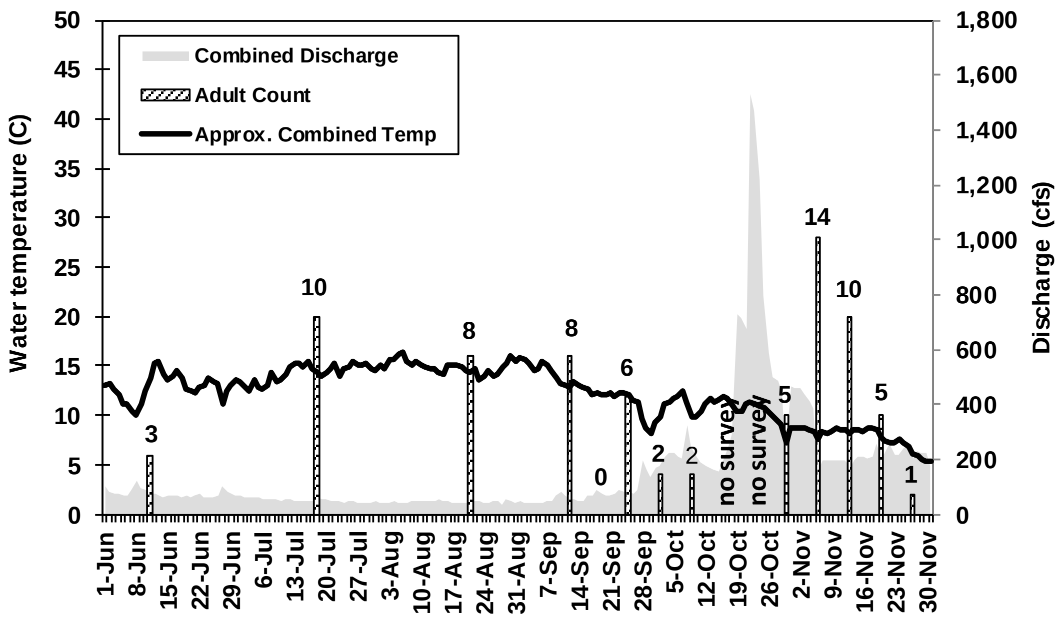

Figure 6. Environmental Variables[a] that May Be Useful in Explaining Chinook Salmon Run Timing in the Lower Bull Run River in 2019

[a]Includes the estimated mean daily water temperature near the mouth and discharge near the mouth.

7.3 Redds

7.3.1 Cumulative Count

The cumulative Chinook Salmon redd count in the lower Bull Run River was the third highest it has been since Marmot Dam was removed in 2007 (Table 1). The cumulative redd count is probably a better measure of spawning activity in the Bull Run River than either peak count or minimum escapement estimate because redds remain visible for weeks after spawning adult Chinook have died and can no longer be observed. Redds that cannot be seen under poor-visibility conditions can also be observed and added to the cumulative total at later dates. The total redd counts attributed to spring Chinook was in the middle of the range of previous years' redd counts, but the fall Chinook redd count was the highest on record (Figure 8). The majority of redds assigned to the spring Chinook run were identified on October 30. A portion of these redds may have actually been fall Chinook redds.

Figure 7. Redds Generally Appear as Areas of Clean Gravel with a Depression and Downstream Pile of Gravel

Several redds were also observed that were not attributed to Chinook Salmon. Two Coho redds were identified during surveys, one on November 6 and one on December 4. Fifteen redds were observed, mostly in November and December, that could not confidently be assigned to species. Two additional redds were assigned to species based on the results of eDNA analysis. These two redds were identified near the upstream end of the surveyed reaches in an area where redds have never before been observed. They were too small to have been made by Chinook or Coho Salmon. Analysis of eDNA in water samples drawn from the interstitial spaces of one of the redds confirmed that the redds were probably constructed by summer steelhead, though nearly a month earlier than what had been expected for that species.

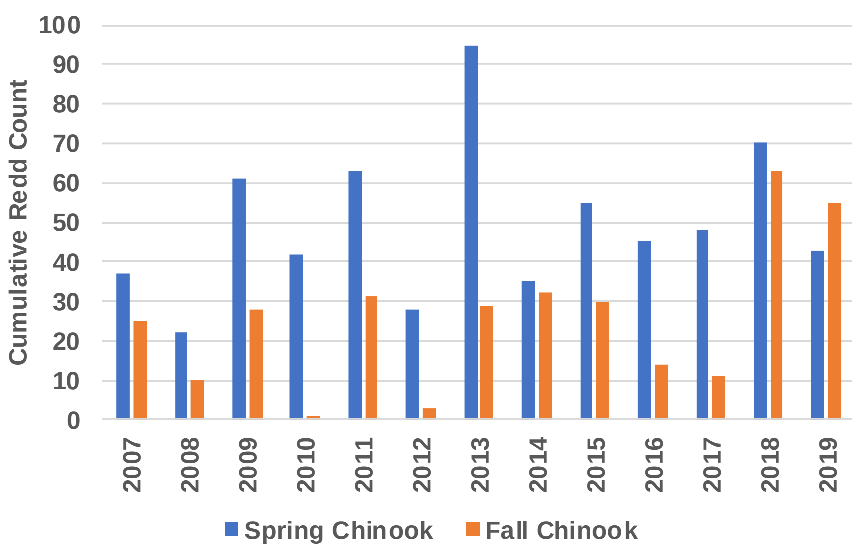

Figure 8. Spring and Fall Chinook Cumulative Redd Counts, 2007–2019

7.3.2 Timing

Chinook Salmon redds were observed in the Bull Run River between September 25 and November 27. The peak number of new redds (30) was observed on October 30. Figure 9 summarizes the timing of redd construction and compares it to the timing of adults observed in the lower Bull Run River. Figure 7 also includes the cumulative redd count. The peak redd count occurred directly after two weeks of missed surveys. It is possible that a portion of the redds observed on that date had been created more than a week prior to their identification.

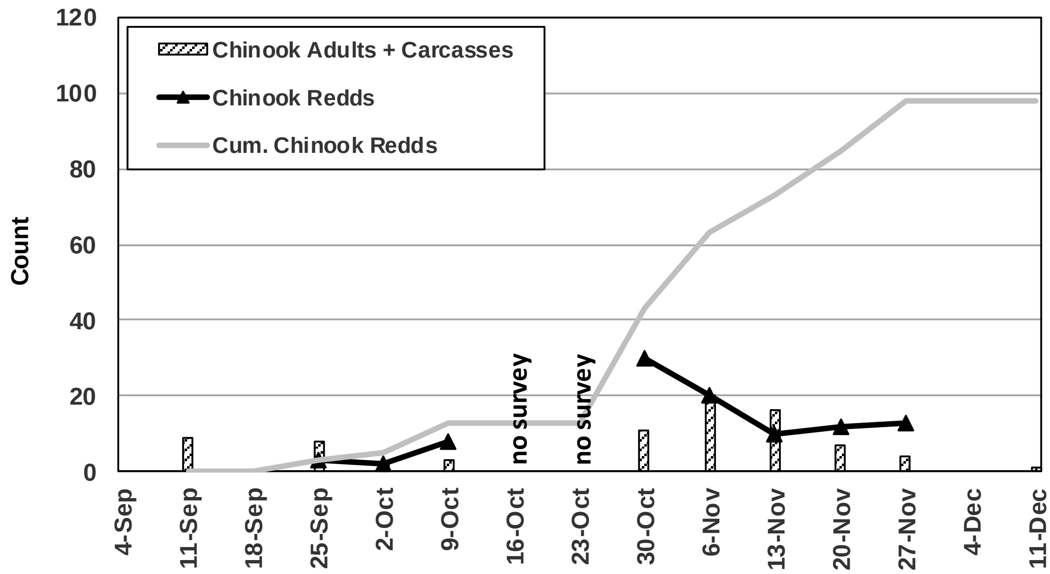

Figure 9. Comparison of the Timing of the Presence of Adult Chinook Salmon and the Construction of Redds in 2019

7.4 Carcasses

7.4.1 Hatchery Fish

The percentage of Chinook carcasses of both spring and fall runs, combined, in the lower Bull Run River that were of hatchery origin was much lower in 2019 (17.4% of 23 carcasses) than in the previous three years. Comparatively few hatchery adult fish appeared to enter the Bull Run River prior to installation of the weir in 2019, and the weir was effective at preventing passage of additional clipped fish during the period it was in place. The actual proportion of hatchery fish may have been higher than observed. A small proportion of Chinook have inadequately clipped adipose fins or their fins grow back. For this reason, ODFW collects otolith samples from spring Chinook Salmon carcasses with adipose fins. The percentage of unclipped fish that are of hatchery origin can be determined from the growth structure of these otoliths. The percentage of unclipped Chinook Salmon carcasses that were of hatchery origin in the Bull Run River was not available at the writing of this report.

In 2019, the percentage of hatchery spring Chinook was lower than it had been in the last three years. The percentage of carcasses considered to be spring Chinook carcasses in 2019 that were of hatchery origin was 22.2% percent, based on a sample size of 9 carcasses. The full Bull Run spawning survey record of percent hatchery fish assigned to the spring Chinook run is summarized in Figure 10.

Most of the hatchery adult Chinook observed during summer snorkel surveys are believed to have passed upstream of the ODFW weir before its installation on May 29, but PWB does not have empirical data to support that assumption.

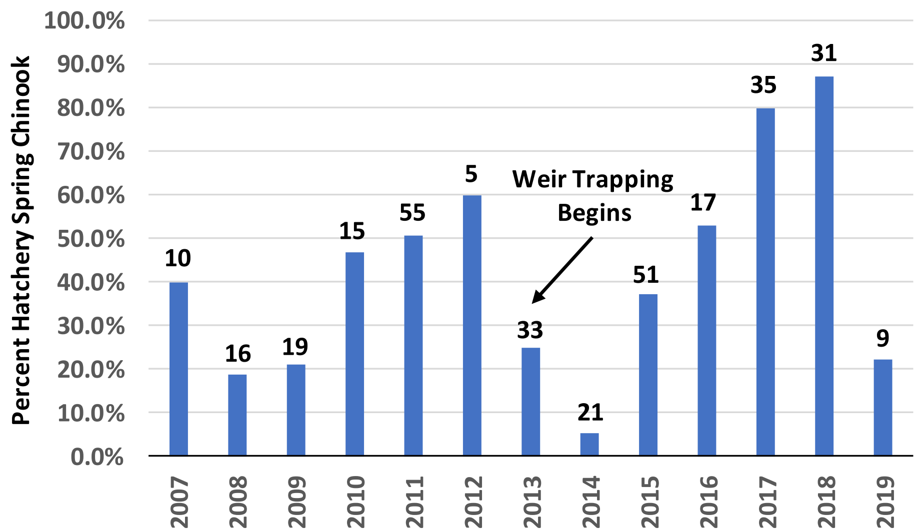

Figure 10. Estimated Percent Hatchery Spring Chinook Adults Spawning in the Bull Run River over Time based on Carcass Recoveries; the Number of Carcasses Incorporated into Each Estimate is Given above the Respective Column

7.4.2 Sex Ratio

Three-quarters of the Chinook carcasses recovered in 2019 were female. Of the 28 Chinook carcasses observed in the Bull Run River in 2019, 24 were intact enough to determine sex. Of these, 18 (75.0 percent) were female.

Females have tended to make up a larger percentage of carcasses recovered in the lower Bull Run River in the past. The percentage of female carcasses has ranged between 52.9 percent and 76.9 percent in ten out of thirteen survey years. The only years when males made up a larger percentage of recovered carcasses were 2015, 2014, and 2012. The reason for the asymmetries observed in the past is unknown. The asymmetries may reflect actual difference between the sexes or differences in the detectability of their carcasses. Females, for instance, appear to remain near their redds for longer periods of time than males and may die, on average, in shallower water where they are more readily found by surveyors. Actual differences in sex ratio can arise through differences between the sexes in marine survival, life history differences, or other factors such as gender reversal.

Significant differences in size, which can influence marine survival, were not observed between sexes in the Bull Run Watershed in 2019 as they have been in previous years.

Female Chinook carcasses had an average middle-of-eye-to-posterior-scale (MEPS) length of 64.6 cm, and male carcasses had an average MEPS length of 61.8 cm.

Life history differences can, in theory, lead to differences in sex ratio if, for example, a significant number of one gender returns at a different age than the other. A portion of male Chinook Salmon returns to spawn after only one year in the ocean. These are called jacks. If a large number of males in a given cohort of Chinook return as jacks, returning adults the following year may show a reduced percentage of males. Large numbers of mini-jacks were observed in the Bull Run River in 2015 and 2016, but not in 2017 (the year when returning mini-jacks would have contributed to a smaller adult return in 2019).

Gender reversal, generally male to female, can occur when developing embryos are exposed to high water temperatures or estrogen-imitating chemicals in the environment (Olsen et al., 2006). The possible role of either of these factors in influencing the Chinook Salmon sex ratio in the Bull Run River cannot be evaluated with current data.

Given the small number of carcasses typically recovered in the Bull Run River, it is also possible that the biased sex ratios observed in the past few years in the Bull Run River are entirely due to chance.

7.4.3 Prespawning Mortality

One Chinook Salmon carcass was recovered in the Bull Run River in 2019 that had died before spawning. This year appears to have been an exception to the previously observed relationship between water temperature and prespawning mortality of spring Chinook Salmon in the Bull Run River, whereby prespawning mortality increases when the annual maximum seven-day average of daily maximum stream temperature is above 19.5 °C (Figure 11, Table 5). The annual seven-day average of daily maximum stream temperature is a commonly used statistic for characterizing stream temperatures in an ecologically relevant way. Whereas salmon can endure relatively high water temperatures for short periods of time, the seven-day average of daily maximum stream temperature is a measure of chronic environmental conditions that can affect growth and survival. The maximum seven-day average of daily maximum stream temperature in the lower Bull Run River in 2019 was 17.1 °C between August 15 through October 31.

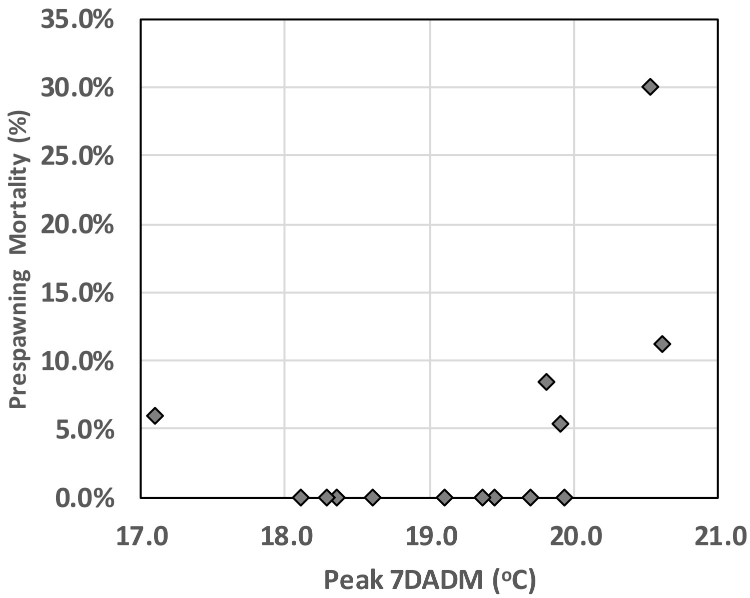

Figure 11. Relationship between Peak Seven-Day Average Daily Maximum Stream Temperature (7DADM) and Prespawning Mortality in the Lower Bull Run River, 2006–2019

Table 5. Peak 7DADM and Corresponding Observed Prespawning Mortality, 2006–2019

Year	Peak 7DADM (Aug 15–Oct 31; °C)	Prespawning Mortality	Spring Chinook Minimum Escapement Estimate
2006	19.8	8.3%	82
2007	20.5	30.0%	39
2008	18.6	0.0%	38
2009	19.4	0.0%	70
2010	19.7	0.0%	77
2011	19.4	0.0%	85
2012	20.6	11.1%	33
2013	19.9	0.0%	64
2014	18.4	0.0%	37
2015	18.3	0.0%	66
2016	18.1	0.0%	63
2017	19.1	0.0%	42
2018	19.9	5.3%	48
2019	17.1	5.9%	15

7.5 ODFW Weir and Holding Adult Chinook

Although snorkel counts of adult Chinook holding in the lower Bull Run River during the summer of 2019 increased between the first and second surveys, the ODFW weir located at Dodge Park appeared to be effective at capturing adult fish while in operation. The weir was installed on May 29. Three snorkel surveys were conducted in the lower Bull Run River during the summer after installation of the weir. Their results are summarized in Table 6. Between the first and second snorkel surveys, the count of adult Chinook holding in the lower Bull Run River increased from 3 to 10. The snorkelers, however, felt that it was quite possible that seven fish could have been missed during the first survey despite excellent visibility, due to the depth of many of the pools and the amount of large substrate cover in the lower river. The weir was inspected daily by ODFW personnel, showed no apparent gaps, and continued to catch adult fish throughout the summer (Table 7).

Table 6. Chinook Adult Counts from Summer Snorkel Surveys Conducted in the Lower Bull Run River in 2019

Date	# Hatchery Adults	# Wild Adults	# Unknown Adults
June 11	0	0	3
July 18	10	0	0
August 21	6	0	2

Table 7. Weekly Captures at ODFW Weir at Dodge Park in 2019

Week	Chinook (Wild)	Chinook (Hatchery)	Coho (Wild)	Coho (Hatchery)	Steelhead (Wild)	Steelhead (Hatchery)
5/27/2019	0	11	0	0	0	0
6/3/2019	0	10	0	0	0	0
6/10/2019	0	26	0	0	0	0
6/17/2019	0	18	0	0	0	0
6/24/2019	0	34	0	0	1	0
7/1/2019	1	35	0	0	0	0
7/8/2019	0	60	0	0	0	0
7/15/2019	2	49	0	0	0	0
7/22/2019	1	42	0	0	0	0
7/29/2019	8	35	0	0	0	0
8/5/2019	7	31	0	0	0	0
8/12/2019	1	13	0	0	1	0

8/19/2019	3	9	0	1	1	0
8/26/2019	4	13	0	0	1	0
9/2/2019	22	28	1	2	0	0
9/9/2019	15	18	0	0	0	0
9/16/2019	12	23	4	1	0	0
9/23/2019	12	13	5	0	2	0
Total	88	468	10	4	6	0

8. Findings and Conclusions

The findings and conclusions directly address the key questions posed in Section 4.0:

- **How many Chinook Salmon adults enter the Bull Run River to spawn each year?**

  At least 32 adult Chinook Salmon entered the Bull Run River upstream of the ODFW weir to spawn in 2019. The peak daily count of live adults plus carcasses during walking surveys was 20. These were the lowest values for the two statistics ever observed in the lower Bull Run River.

- **How many Chinook Salmon redds are built in the Bull Run River each year?**

  A total of 98 Chinook redds were identified in the Bull Run River in 2019.

- **What is the long-term trend (20 years) in spawning Chinook Salmon abundance?**

  The long-term (20-year) trend in spawning Chinook Salmon abundance will be calculated in 2028. The number of spawning Chinook Salmon in the lower Bull Run River shows no significant trend since the Marmot Dam removal in 2007.

- **What is the timing (range of dates and peak date) of adult Chinook presence and redd creation in the lower Bull Run River?**

  Live adult Chinook Salmon were observed in the Bull Run River between June11 and November 27, 2019. The peak date was November 6, 2019. Chinook redds were observed between September 25 and November 27, 2019. The peak date for redd observation was October 30.

- **What percentage of the spawning Chinook Salmon are of hatchery origin (clipped adipose fin), and what percentage are female?**

  In 2019, the percentage of hatchery (clipped adipose fin) fish among the observed Chinook Salmon carcasses in which the condition of the adipose fin could be determined was 17.4 percent. The percentage of females among the observed Chinook Salmon carcasses in which sex could be determined was 75.0 percent.

- **What percentage of spring Chinook Salmon holding in the Bull Run River while the ODFW weir is in operation are of hatchery origin?**

  The largest percentage of hatchery fish observed among adult spring Chinook holding in Bull Run River during snorkel surveys was 100 percent of 10 fish, observed on July 18.

- **Is the ODFW weir effective at excluding hatchery spring Chinook from the Bull Run River?**

  In 2019, only ten hatchery spring Chinook were observed holding the Bull Run River during the summer, presumably having entered the river before the ODFW weir was installed. The number of spring Chinook (hatchery, wild, and unknown) observed during snorkel surveys remained between 3 and 10. This suggests that the weir was installed before large numbers of fish were able to enter the river and that the weir was effective at excluding them while in operation.

- **What percentage of the spawning spring Chinook Salmon are of hatchery origin (clipped adipose fin)?**

  In 2019, the percent of hatchery (clipped adipose fin) fish among the observed Chinook Salmon carcasses—for which the condition of the adipose fin could be determined and assuming that only carcasses observed on or before November 1 were spring Chinook—was 22.2 percent (of nine carcasses). This was among the lowest percentages ever observed in the lower Bull Run River.

- **Was prespawning mortality of spring Chinook Salmon observed in 2019? What is the relationship between stream temperature and observed prespawning mortality in the lower Bull Run River?**

  Of the 17 female spring Chinook carcasses recovered in 2019 for which spawning status could be determined, one was a prespawning mortality (5.9 percent). This was the first year when prespawning mortality among female Chinook Salmon was observed when the seven-day average of daily maximum stream temperature was below 19.5 °C. The highest seven-day average observed in the Bull Run in 2019 was 17.1 °C between August 15 and October 31. The female Chinook that died before having the opportunity to spawn was of hatchery origin.

9. Works Cited

Olsen, Jeffrey B., Steve J. Miller, Ken Harper, Kevin Van Hatten, Kellie Whitton, James J. Nagler, and John K. Wenburg. "Sex Ratios of Juvenile and Adult Chinook Salmon in the Kuskokwim and Yukon Rivers." *U.S. Fish and Wildlife Service*, 2006.

Oregon Department of Fish and Wildlife. “Final Hatchery and Genetic Management Plan: Spring Chinook.” 2011.

Portland Water Bureau. “Bull Run Water Supply Habitat Conservation Plan for the Issuance of a Permit to Allow Incidental Take of Threatened and Endangered Species.” 2008.

Schroeder, R. Kirk, Ken R. Kenaston, and Lisa K. Krentz. “Spring Chinook Salmon in the Willamette and Sandy Rivers.” Oregon Department of Fish and Wildlife *Fish Research Report* F-163-R-10 (2005).

Appendix H

Bull Run HCP Monitoring Report

Sandy River Basin Smolt Monitoring

April 2020

Burke Strobel
City of Portland Water Bureau

Photo (left) of Mount Hood and Sandy River provided by Josh Kling/Western Rivers Conservancy

Photo (right) of the Still Creek smolt trap provided by Greg Wanner/U.S. Forest Service

Contents

Tables

Figures

1. Summary

The Portland Water Bureau, the U.S. Forest Service, and the Oregon Department of Fish and Wildlife collaborated in 2019 to continue a long-term study monitoring steelhead and Coho smolt production for the Sandy River Basin in Oregon. The study, initiated in 2009, is intended to detect declines or increases in abundance and productivity of smolts at the basin scale and to provide useful data at the tributary scale to guide restoration efforts. The sampling design involves monitoring different sets of tributaries every year. Some tributaries are monitored every year; others are monitored on an irregularly rotating basis. The study is intended to provide basin-scale trends after 20 years.

Smolt numbers, fork length, condition factors, and emigration timing were monitored using rotary smolt traps in seven streams: Clear Fork Sandy, Zigzag River, Still Creek, Little Sandy River, Bull Run River, Gordon Creek, and Beaver Creek. Population estimates, fork length distributions, and emigration statistics were calculated for steelhead and Coho smolts in all seven streams. Monitoring on Cedar Creek, usually conducted every year, did not take place in 2019 due to landowner conflicts. The average age of smolts was calculated by aging fish using fish scale samples collected between 2009 and 2018.

Trapping efforts were hampered somewhat in 2019 by a release of hatchery Chinook smolts from an acclimation pond upstream of one trap and high-flow and low-flow periods in all streams.

Preliminary Sandy River Basin-level population estimates were calculated for each year from 2009 to 2019. Freshwater productivity (smolts per adult) was also estimated, with the help of age data, for steelhead adult year classes 2010 to 2017 and for Coho adult year classes 2007 to 2017.

Steelhead and Coho smolts from different streams in the Sandy River Basin showed significant differences in weighted mean fork length of smolts. Coho showed a decrease in weighted average fork length with increasing stream elevation in 2019. There was no clear relationship between stream elevation and mean fork length for steelhead.

Steelhead and Coho smolts from different streams in the Sandy River Basin also showed significant differences in mean condition factors. Condition factors declined significantly with increasing fork length across streams for both Coho and age-2 steelhead. The decline of condition factor with increasing fork length in steelhead was similar across streams to that observed within streams.

Steelhead smolts emigrated earlier than Coho smolts, on average, in all streams but Little Sandy. Neither Coho nor steelhead smolts showed a tendency to emigrate from low-elevation streams earlier than from high-elevation streams, as has been observed often in the past.

High-elevation streams had a larger proportion of older-age steelhead and Coho smolts than low-elevation streams. Length-at-age calculations revealed that steelhead smolt fork lengths tend to be shorter on average for a given age in higher-elevation streams than in lower elevation streams, but this fact is masked by their older average age.

2. Introduction

2.1 Background

In 2019, the Portland Water Bureau (PWB), the Mt. Hood National Forest (U.S. Forest Service [USFS]), and the Oregon Department of Fish and Wildlife (ODFW) continued collaboration on a long-term study, monitoring steelhead and Coho smolt production throughout the Sandy River Basin in Oregon. The Sandy River enters the lower Columbia River just east of Portland, Oregon, and includes several large tributaries—the Bull Run, Salmon, and Zigzag rivers—as well as many smaller tributaries such as Beaver, Cedar, Clear, Gordon, and Lost creeks, and the Clear Fork Sandy River.

Smolt monitoring has been conducted in various Sandy River tributaries in the past. The USFS has monitored smolt production continuously in Still Creek, a tributary of the Zigzag River, since 1989 and sporadically in the Clear Fork Sandy River, Lost Creek, and the Salmon River. The purpose of these efforts originally included monitoring the benefits of stream restoration projects and, more recently, supporting efforts to evaluate the effects of the removal of Marmot Dam in 2007. The USFS also operated a smolt trap on the Little Sandy River in 2007 and 2008, upstream of a diversion dam operated as part of Portland General Electric's Bull Run Hydroelectric Project. The Portland Water Bureau has operated a smolt trap in the Bull Run River near its mouth since 2008 and assumed the management of the Little Sandy River trap in 2009.

Two related factors led to an expansion of salmonid smolt monitoring in the Sandy River Basin, beginning in 2009. The first was the formation of the Sandy River Basin Partners in 1999—a group intended to coordinate the fish and fish habitat management efforts of various agencies and groups. This coordination led to a broadening of the monitoring focus to better correspond with an emerging holistic approach to watershed restoration and to mesh with other programs that collect biological information at a basin scale. The second factor was that PWB created the Bull Run Water Supply Habitat Conservation Plan (HCP; Portland Water Bureau 2008) in 2008 to bring its municipal water supply operations in the Bull Run River into compliance with the Endangered Species Act and the Clean Water Act.[1] Among the many measures detailed in the HCP is a commitment to contribute resources toward smolt monitoring in the Sandy River Basin.

[1] To learn more about the HCP, visit http://www.portlandoregon.gov/water/55040.

Monitoring smolt production can benefit a number of management efforts on many spatial scales, including viability analyses and adaptive restoration. Given limited resources, however, managers face potential tradeoffs between collecting smolt information that is meaningful at the population scale (that is, enumerating smolts at the mouths of large rivers) and collecting smolt information at a scale that is most meaningful to individual restoration efforts (that is, enumerating smolts in tributaries). The sampling plan adopted by the monitoring subgroup of the Sandy River Basin Partners is intended to provide information at both scales in order to maximize the usefulness of the data-collection effort. The sampling plan is summarized in the HCP Appendix F (Portland Water Bureau 2008).

2.2 Goal and Objectives

The goal of the Sandy River smolt monitoring project is to contribute to the viability assessment of salmonid stocks in the Sandy River Basin and support their adaptive management. The objectives of the Sandy River Smolt Monitoring project are to

- collect information to assess the long-term (20-year) trend in steelhead and Coho smolt populations for as much of the Sandy River Basin as possible (population scale),
- collect information to assess the long-term (20-year) trend in steelhead and Coho smolt populations at the scale of individual tributaries (tributary scale),
- evaluate steelhead and Coho smolt production of individual tributaries relative to one another (tributary scale),
- evaluate steelhead and Coho smolt physical quality from individual tributaries relative to one another (tributary scale), and
- determine the values of various life-history characteristics at the scale of individual tributaries in the Sandy River Basin (tributary scale).

The proximate objectives each year will be to determine the values for the following variables for each stream that is trapped:

- Smolt population (for every salmonid species possible)
- Mean fork length (by species)
- Mean condition factor ((weight/(fork length^3))×100,000)
- Mean date of emigration (by species)

Beginning in 2014, a collaboration between PWB and ODFW provided age information from scale samples collected by PWB, USFS, and ODFW between 2009 and 2018. This information allowed the pursuit of an additional life-history objective:

- Determine the mean age at emigration for steelhead and Coho smolts

2.3 Sample Area and Scope

2.3.1 Study Area

The portions of the Sandy River Basin that are accessible to anadromous fish include approximately 190 miles of streams and rivers spanning a wide range of environments from cold, high-elevation, high-gradient streams in wilderness areas to warm, low-gradient, and tidally influenced streams within the Portland urban growth boundary, as indicated in Figure 2. About 30 percent of these stream miles are influenced by glacial runoff, often with high turbidity (Portland Water Bureau 2008).

2.3.2 Sample Area

Not all of the Sandy River Basin that is accessible to anadromous fish is included in the sample area. Streams selected for smolt sampling total 106 miles, or 56 percent of the total habitat in the Sandy River accessible to anadromous fish. More than 80 percent of the clear water stream miles are included. Clear water streams are streams not influenced by glacial runoff. These are the streams expected to contribute most to total smolt production due to the suitability of spawning habitat (Suring et al. 2006) and relatively greater primary productivity and ease of locating prey. The remaining clear water streams are generally small, have relatively high gradients, and are not expected to produce a large number of salmon or steelhead smolts. This sample area covers nearly the full range of environmental conditions that salmon and steelhead encounter in the Sandy River Basin and is considered by the Sandy River Basin Partners monitoring group to constitute a representative index for the entire basin for steelhead and Coho. It also closely corresponds with the area for which steelhead and Coho spawner counts are developed annually by the Oregon Department of Fish and Wildlife (ODFW; Suring et al. 2006, Hutchinson et al. 2007). The sample area covered by the Sandy River Basin Smolt Monitoring effort is henceforth referred to as the Sandy River Basin Index Area. The products of this effort eventually will be applicable to the entire index area. Information that is collected will be immediately applicable at the scale of individual tributaries.

Figure 1. PWB Personnel Check the Little Sandy Trap

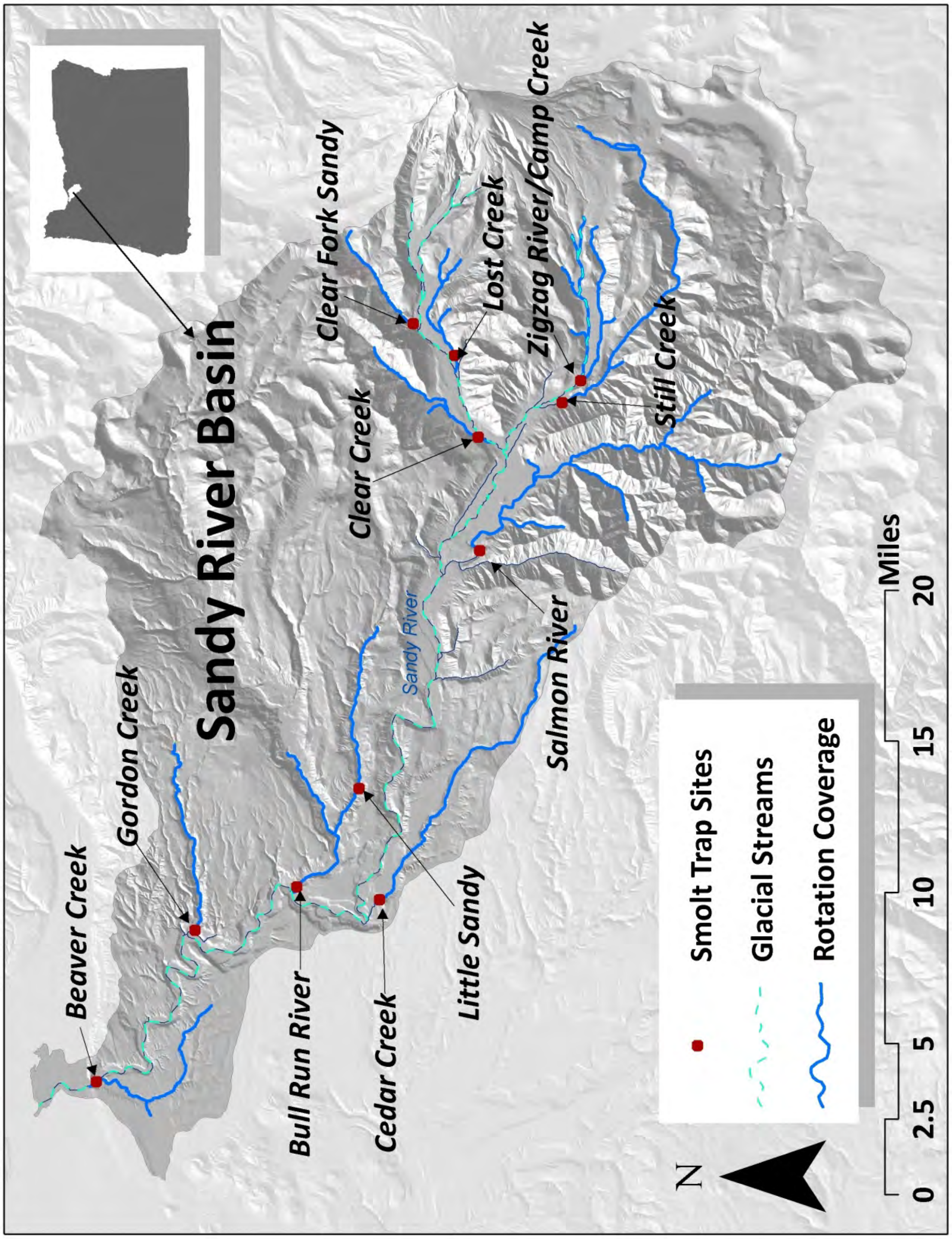

Figure 2. Sandy River Basin—Smolt Trap Sites, Streams Covered by Rotating Smolt Trap Study, and Streams Receiving Glacial Runoff

3. Methods

3.1 Sampling

Juvenile outmigrant (JOM) sampling in the Sandy River Basin is implemented following a carefully coordinated, long-term sampling schedule using methods that are consistent across geography and time.

3.1.1 Sampling Schedule

Eleven streams were identified by the monitoring subgroup as being feasible and appropriate for operating a smolt trap. These streams are summarized in Table 1.

Table 1. Streams Sampled for Salmon and Steelhead Smolts, with Sampling Category, Range of Elevations of Anadromous Reaches, and Average Gradient

Stream	Miles Used by Anadromous Fish	Sampling Category[a]	Anadromous Elevation Range (feet above mean sea level)	Average Gradient
Bull Run River (without the Little Sandy River)	7.5	Fixed	240–700	1.3%
Little Sandy River	5.9	Fixed	430–1,600	2.9%
Cedar Creek	13.2	Fixed	360–3,240	4.1%
Clear Fork Sandy River	4.3	Rotation	2,130–3,390	5.4%
Lost Creek	4.9	Rotation	1,770–2,660	3.7%
Clear Creek	5.5	Rotation	1,440–2,780	4.6%
Still Creek	8.7	Rotation	1,580–3,120	3.1%
Zigzag River/Camp Creek	16.4	Rotation	1,840–3,360	4.1%
Salmon River	24.0	Rotation	1,010–1,850	1.2%
Gordon Creek	7.4	Rotation	100–1,630	4.0%
Beaver Creek	7.7	Rotation	20–550	1.3%

[a]Sampling category: Fixed = sampled annually, Rotation = sampled according to rotating schedule

It is anticipated that at least seven smolt traps will be operated each year. The provisional sampling schedule is summarized in Table 2. Three trap locations are fixed and operated every year because of additional monitoring needs. The Bull Run River and Little Sandy River are monitored annually to meet specific commitments in the HCP. Cedar Creek has been monitored annually to document recolonization by salmon and steelhead since 2010 when adult salmon and steelhead were again allowed access to historical habitat blocked by the ODFW hatchery at river mile 1.5.

Table 2. Provisional Schedule for Sampling Major Tributaries in the Sandy River Basin [a]

Year	Cedar Creek	Little Sandy River	Bull Run River	Clear Fork Sandy River	Lost Creek	Clear Creek	Still Creek	Zigzag River/ Camp Creek	Salmon River	Gordon Creek	Beaver Creek
2009		x	x		x	x	x			x	
2010		x	x	x				x	x		x
2011		x	x		x		x	x		x	
2012		x	x				x	x	x		x
2013	x	x	x	x	x				x	x	
2014	x	x	x			x	x	x			x
2015	x	x	x	x	x		x				x
2016	x	x	x			x			x	x	x
2017	x	x	x		x	x			x		
2018	x	x	x		x	x			x		x
2019	x	x	x	x			x	x		x	
2020	x	x	x	x	x	x					x
2021	x	x	x	x		x		x		x	
2022	x	x	x	x			x		x	x	
2023	x	x	x				x		x	x	x
2024	x	x	x	x		x	x		x		
2025	x	x	x		x	x		x		x	
2026	x	x	x	x	x			x			x
2027	x	x	x		x			x		x	x
2028	x	x	x	x		x	x		x		

[a]Schedules for years 2009, 2010, 2018, 2019, 2027, and 2028 (shaded gray) are fixed, but the remaining years may be changed to accommodate other monitoring needs as long as all sites scheduled for a given year remain grouped together as a unit.

This smolt-monitoring plan extends the reference area of the remaining four traps by rotating them among eight streams according to the following constraints (assuming that Camp Creek and the Zigzag River are combined):

- Each site will be trapped, on average, every other year.

- All sites will be trapped once in the first two years, once in the middle two years, and once in the last two years of a 20-year period.

Rotated sites will be trapped according to a schedule that maximizes the pair-wise comparisons between them.

The original provisional smolt trap rotation schedule established in 2009 was adjusted in 2011 to accommodate logistical needs. The group of traps scheduled for 2011 was traded with that scheduled for 2021. Table 2 reflects the new schedule. Additional sites may also be trapped if resources allow. For instance, Still Creek has been trapped every year because of the particular value of the resulting data. Since 2016, both Beaver Creek and Gordon Creek also have been trapped every year.

3.1.2 Sampling in 2019

Smolt production was monitored in the Clear Fork Sandy River, Zigzag River, Still Creek, the Little Sandy River, the Bull Run River, Gordon Creek, and Beaver Creek in 2019. An eight-foot-diameter rotary trap was used on the Bull Run River. Five-foot-diameter rotary screw traps were used on all other streams. Screw traps modified with wooden pontoons and other trap parts were used on Gordon Creek and Beaver Creek to discourage metal theft. A motor was added to the Beaver Creek trap in 2015 to continue trapping despite low stream flows. The Clear Fork Sandy, Zigzag River, and Still Creek traps were checked and maintained by USFS Zigzag Ranger District staff and volunteers. PWB staff checked and maintained the Little Sandy River, Bull Run River, Gordon Creek, and Beaver Creek traps. All traps were operated seven days a week throughout the season to the maximum extent possible. The periods of operation for each site are summarized in Table 3 together with the number of days that each trap was not in operation due to scheduling, high or low flows, or other considerations.

Figure 3. The Little Sandy Trap Pulled to the Side in High Flows

A variety of factors contributed to time periods when traps were not in operation in 2019. High flows and wind storms led to traps being pulled for several days on all streams. An unusually high flow in early April led to the loss of the Bull Run trap and a 15-day data gap. Low flows hampered trapping in Beaver Creek. An additional four days were missed on the Bull Run River to avoid capturing hatchery Chinook smolts released upstream from an acclimation pond.

The Cedar Creek trap was not operated in 2019 because of a conflict with a neighboring landowner.

The trapping season ended early in Little Sandy, Bull Run, Gordon Creek, and Beaver Creek because of low water and a lack of smolts.

Table 3. Dates of Operation and the Number of Days Traps Did Not Operate in the Sandy River Basin in 2019

Stream[a]	Trap In	Trap Out	Down Time (Days)
Clear Fork Sandy River	April 20	June 12	3
Zigzag River	April 21	June 21	0
Still Creek	March 26	June 21	9
Little Sandy River	March 12	June 5	9
Bull Run River (without the Little Sandy River)	March 12	June 3	20
Gordon Creek	March 12	June 5	8
Beaver Creek	March 12	May 31	8

[a]Streams are presented in order from highest-elevation Clear Fork Sandy to lowest-elevation Beaver Creek.

3.1.3 Data Collection

Traps were checked daily, and all fish were removed from the trap's live well. Fish were anesthetized using Alka-Seltzer Gold™ (buffered sodium bicarbonate). The following data were collected for most fish:

- Species
- Life-stage (smolt, juvenile, fry, or adults)
- Fork length (mm)
- Weight (g)
- Fin marks given or observed (see Mark-Recapture Study section below)
- Comments (e.g., injuries, pathogens, etc.

Life stage was determined using external characteristics. Smolts show a general silvering, fading of parr marks, and a darkening of the posterior edge of the caudal fin. Juveniles are small fish, but they are larger than 50 millimeters (mm) and show none of the above smolt characteristics. Fry are 50 mm or less. At times, and especially early in the season, steelhead smolts were just beginning to develop their characteristics and could be difficult to distinguish from juveniles. In these borderline cases, the following rule set was applied:

> If a steelhead is longer than 130-mm fork length, consider it a smolt unless there are absolutely no signs that smoltification may have begun, in which case consider it a juvenile. If a steelhead is 130 mm or less, consider it a juvenile, unless there are clearly signs of it being a smolt.

Tissue and scale samples were collected from steelhead and Coho smolts at all sites. Scale samples were collected from 10 individual fish in each 10-millimeter fork-length increment throughout the fork length range of both steelhead and coho smolts at each trap site. Approximately 50 steelhead and 50 Coho tissue samples are collected each year from each monitored trap site.

The ages of sampled fish are determined from scale samples by the ODFW Fish Life History Analysis Project laboratory in Corvallis, Oregon. The ages of smolts sampled between 2009 and 2018 were determined and are incorporated into this report.

3.1.4 Mark–Recapture Study

An ongoing trap efficiency study was conducted throughout the trapping season to determine the proportion of the outmigration that was being captured in the traps. Following a modified mark–recapture protocol, up to 25 smolts of each species at each site each day were given a fin mark specific to the day of the week. Marked fish were subsequently released from approximately 0.1 to 1.5 miles upstream of the trap, depending on access to appropriate release sites. Fins were marked either with small clips or injected dye. Captured fish were sorted each day to look for fin marks from previous days' releases.

In deciding to mark fish for the trap efficiency study with only seven specific fin-clip markings—one for each weekday—researchers assumed that all marked fish would travel from the release point to the trap within seven days. An analysis of the recapture data appears to bear this assumption out. Most fish appeared to be recaptured after one to three days, with very few indicating a travel time of four or more days. The consequences of some fish taking more than seven days to travel from the release point to the trap are reduced by pooling adjacent weeks together into two-week mark–recapture periods.

Figure 4. USFS Personnel Process Fish at the Zigzag River Trap

3.2 Assumptions

The mark–recapture procedures are subject to the same limitations inherent to all similar studies. The model assumes the following:

- The target species and life-stages are actively moving downstream (equivalent to the "closed population" requirement of the Peterson estimator, discussed in Volkhardt et al. 2007).
- All fish in a capture period (stratum) of a given species and life stage have equal probability of first-time capture.
- Marking fish does not affect their catchability (that is, they do not suffer mortality between marking and potential recapture).
- Marked and unmarked fish traveling together have an equal probability of recapture (that is, fish do not become "trap-shy" or "trap-happy," leading to overestimated or underestimated populations, respectively).
- Fish do not lose their marks.
- All recaptured marked fish are recognized.

3.3 Data Analysis

3.3.1 Smolt Population Estimation

Smolt population sizes for individual streams are estimated using Darroch Analysis with Rank Reduction for R (DARR 2.0.2, Bjorkstedt 2010), a program provided by the National Marine Fisheries Service.[2] DARR 2.0.2 relies on a stratified Peterson estimator for mark–recapture data. Prior to calculation of the estimate, however, time periods are aggregated following rules designed to avoid the pitfalls associated with small populations and low recapture rates.

In the Sandy River Basin, fish total captures (C) and marks (M) are stratified by two-week time periods to reduce variation associated with flows, water temperature, and changing fish behavior. The associated recaptures (R) are identified by both the time period in which they originated and the time period in which they are recaptured, resulting in a recapture matrix. The Darroch estimator uses the recapture matrix to estimate the number of marked fish passing the trap during a given time period. The total estimate is the sum of the individual time period estimates. Details of the calculation of the total estimate and its variance are fully described in Bjorkstedt (2005).

For the special cases in which all recaptures occur in the same stratum from which they originated (all non-zero values occur along the middle diagonal of the recapture matrix),

[2] The program is available on the NMFS site: http://swfsc.noaa.gov/textblock.aspx?Division=FED&id=3346.

the Darroch estimator reduces to a simple Peterson estimator (where N refers to population estimate, and the subscript s refers to the stratum):

$$\text{Stratum estimate } (N_s) = C_s\ (M_s / R_s) \qquad \text{(Equation 1)}$$

There were several days at each site when certain smolt traps were not in operation because of damage, potential damage, or scheduling issues (see Table 3). For these days, the daily smolt output was estimated using a two-week running average of daily population estimates (daily total capture without recaptures ÷ trap $\text{efficiency}_{\text{stratum}}$; with trap efficiency provided by DARR 2.0.2). Only days with actual captures within seven days before and after a particular date were included in the running average of daily population estimates. The variance of downtime estimates was calculated by adding the variances of each daily estimate, which, in turn, was added to the variance provided by DARR to produce 95 percent confidence intervals for each smolt population estimate.

The Sandy River Basin Smolt Monitoring Plan is designed to produce Sandy River Basin-level (index area) smolt populations estimates, population trend estimates, and freshwater productivity estimates (smolts per adult) after 20 years of annual smolt monitoring. Preliminary calculations, however, can be made now. The preliminary calculations illustrate the process of filling gaps in each time series of subbasin estimates and the process of adding individual subbasin population estimates in a given year together to produce a Sandy River Basin-level estimate.

The Sandy River Basin Smolt Monitoring Plan sampling schedule (Table 2) results in gaps that must be filled in each subbasin's time series of population estimates. These gaps were filled on a demonstration basis in 2019 by using the average and the associated variance of all past population estimates for each respective subbasin. The number used to fill gaps in a given trap's time series of population estimates is henceforth referred to as a "gap estimate." For each year between 2009 and 2019, all subbasin smolt trap estimates and gap estimates were summed by species to calculate Sandy River Basin-level population estimates for steelhead and Coho smolts. The variances associated with each smolt trap estimate and each gap estimate were similarly summed by species to calculate a variance for each Sandy River Basin-level population estimate. Gap estimates will be recalculated in the future, once more subbasin estimates are available, to retroactively produce refined Sandy River Basin-level smolt population estimates.

Estimates of the number of adult steelhead and Coho spawners in the Sandy River Basin for each parent generation that produced the steelhead and Coho smolts monitored in 2009 through 2017 were used to tentatively calculate freshwater productivity (smolts per adult) for as many adult spawner years as possible. Adult steelhead and Coho spawner estimates were obtained from the ODFW Oregon Adult Salmonid Inventory and Sampling (OASIS) Program. The adult steelhead and Coho spawner estimates correspond to approximately the same geographic reference frame (index area) as the Sandy River Basin Smolt Monitoring Plan.

3.3.2 Smolt Fork Lengths

Weighted average fork lengths for all smolt populations were calculated. Smolt fork lengths for each site were compiled and then weighted by capture stratum using trap efficiency (provided by DARR 2.0.2). If trap efficiency for a given stratum was low, the weights for fish captured in that stratum were weighted more heavily. This prevented strata with few fish but high trap efficiencies, for example, from influencing the average more than strata with many fish but low trap efficiencies. Fork lengths of actual captures were compared among streams using analysis of variance (ANOVA). If the resulting *F* statistic was found to be significant at an α level of 0.05, a Tukey test was applied to all combinations of pairs of streams to determine how average fork lengths of captured fish differed from one another.

3.3.3 Smolt Condition Factors

Condition factors (K) were determined for all steelhead and coho smolts by basin using weights (W) and fork lengths (L) according to the following formula:

$$K=(W/L^3)*100{,}000 \qquad \textbf{(Equation 2)}$$

Condition factors give an indication of how thin or fat a fish is. Condition factors were compared among basins by statistically testing for differences using ANOVA. If the resulting *F* statistic was found to be significant at an α level of 0.05, a Tukey test was applied to determine how mean condition factors differed from each other. Condition factors were not weighted by capture stratum using trap efficiency because of the analytical complexities involved.

3.3.4 Emigration Dates

Steelhead and Coho smolt mean and peak emigration dates were calculated for each site. The mean emigration date was defined as the sum of the product of daily captures corrected for stratum efficiency (C) and the date of capture (D) on any given day (i for days 1-k), divided by the sum of corrected captures using the following formula:

$$\sum_{i=1}^{k}(CD)_i \Big/ \sum_{i=1}^{k} C_i \qquad \textbf{(Equation 3)}$$

The peak emigration date was defined as the day when most fish of a species and condition were estimated to have passed the trap site (daily captures corrected for stratum trap efficiency).

4. Results

4.1 Smolt Population Estimation

4.1.1 Trap Efficiencies

The efficiencies of traps varied across sites and time. Trap efficiencies are summarized in Table 4 for each site and two-week trapping period. Period 1 for each site started the Sunday of the week that trapping began for the respective site (see Table 3 for start dates). Given a certain number of marked fish, the higher the trap efficiency, the more precise the population estimate. A trap efficiency of at least 0.1 and preferably closer to 0.25 is desirable.

Table 4. Trap Efficiencies for Each Site, Species, and Two-Week Trap Period in 2019

		Period						
Site[a]	**Species**	**1**	**2**	**3**	**4**	**5**	**6**[b]	**7**[b]
Clear Fork	Steelhead	0.545	0.545	0.714	0.714	0.714	—	—
	Coho	0.500	0.476	0.774	0.504	0.389	—	—
Zigzag River	Steelhead	0.304	0.304	0.391	0.286	0.286	—	—
	Coho	0.205	0.205	0.494	0.364	0.308	—	—
Still Creek	Steelhead	0.256	0.214	0.232	0.218	0.250	0.250	0.250
	Coho	0.205	0.283	0.188	0.422	0.420	0.377	0.238
Little Sandy River	Steelhead	0.053	0.053	0.053	0.053	0.043	0.043	—
	Coho	0.054	0.054	0.054	0.054	0.054	0.129	—
Bull Run (without Little Sandy River)	Steelhead	0.031	0.031	0.031	0.031	0.064	0.190	—
	Coho	0.139	0.139	0.139	0.139	0.139	0.169	—
Gordon Creek	Steelhead	0.175	0.056	0.056	0.056	0.190	0.190	—
	Coho	0.136	0.136	0.167	0.250	0.336	0.333	—
Beaver Creek	Steelhead	0.035	0.035	0.035	0.035	0.080	0.093	—
	Coho	0.103	0.103	0.103	0.103	0.327	0.073	—

[a]Streams are presented in order from highest-elevation Clear Fork to lowest-elevation Beaver Creek.

[b]There were no sixth or seventh two-week trapping periods in some stream because those traps were not operated long enough due to low flows, lack of fish, or other factors.

4.1.2 Subbasin Population Estimates

Monitored smolt production was moderate to relatively high for steelhead and Coho in 2019. The Bull Run River had the highest number of steelhead smolts and Still Creek had the highest number of Coho smolts of any streams monitored in 2019 (Table 5). The Zigzag River produced more steelhead smolts than in any previous monitored year (Table 9). All other streams produced moderate numbers of steelhead smolts, except for Beaver Creek, which produced the lowest number of steelhead smolts since population estimates began in 2014. Zigzag River, Little Sandy, and Gordon Creek all produced more Coho smolts in 2019 than in any previous year (Table 10). Coho production in the other streams was moderate. Exhibit A summarizes the total captures at all trap sites.

A portion of the emigration of smolts from several streams may have been missed. A small number of steelhead smolts were caught on the first day of trapping in Gordon Creek, and Coho smolts were caught on the first day of trapping in the Zigzag River, Still Creek, and Gordon Creek. Coho smolts were captured on the last day of trapping in the Clear Fork, Zigzag River, and Still Creek. Trapping in each of these streams in 2019 coincided with the period of spring smolt emigration observed in the past, so it is likely that the proportion of the population that was missed was small. Unusually high flows were experienced in early April 2019, and no data were collected on the Bull Run River for 15 days. No downtime estimate could be calculated for three of those days, and it is unknown if the downtime estimates for the remaining 12 days, based on captures immediately before and after the 15-day period, is an accurate estimate of what was missed given the highly unusual circumstances.

The variances associated with estimates in several streams were large relative to the estimates themselves in 2019. Steelhead estimates tended to be less precise than Coho estimates, given similar population sizes, because of lower trap efficiencies for steelhead than for Coho (see Table 4). The Little Sandy estimates were the least precise for both steelhead and Coho. Lack of precision was generally due to a combination of low marking rates due to small population sizes and low trap efficiencies.

Table 5. Steelhead and Coho Smolt Population Estimates and 95% Confidence Intervals for 2019

	Steelhead		Coho	
Stream[a,b]	**Estimate**	**95% CI**	**Estimate**	**95% CI**
Clear Fork Sandy River	60	23%	1,341	9%
Zigzag River	159	37%	901	19%
Still Creek	1,101	23%	7,375	8%
Little Sandy River	1,046	125%	1,177	90%
Bull Run River (without Little Sandy)	16,576	55%	1,633	78%
Gordon Creek	1,322	77%	2,121	17%
Beaver Creek	211	37%	1,175	17%

[a]Confidence intervals are expressed as percentages of the associated estimates.

[b]Streams are presented in order from highest-elevation Clear Fork Sandy to lowest-elevation Beaver Creek.

Of all streams monitored in 2019, steelhead smolt production per unit of stream length and per unit of surface area was highest in the Bull Run River, as summarized in Table 6. Gordon Creek had the second highest estimates for both per unit length and area production, but estimates were an order of magnitude lower than the Bull Run's. The Zigzag River had the lowest steelhead smolt production per unit of length and surface area.

Table 6. Steelhead and Coho Smolts per Mile and Smolts per 1,000 ft^2 for 2019

	Steelhead		Coho	
Streams[a]	**Smolts/mile**	**Smolts/1,000 ft^2**	**Smolts/mile**	**Smolts/1,000 ft^2**
Clear Fork Sandy River	12.24	0.10	273.67	2.26
Zigzag River	8.64	0.04	63.90	0.26
Still Creek	73.89	0.42	1010.27	4.15
Little Sandy River	177.29	0.53	199.49	0.60
Bull Run River (without Little Sandy)	1,997.11	4.28	196.75	0.42
Gordon Creek	178.65	0.85	294.58	1.40
Beaver Creek	29.48	0.26	152.60	1.33

[a]Streams are presented in order from highest-elevation Clear Fork Sandy to lowest-elevation Beaver Creek.

Of all streams monitored in 2019, both Coho smolt production per unit of stream length and Coho smolt production per unit of surface area were highest in Still Creek. The Gordon Creek had the second-highest production per unit length and surface area. The Zigzag River had the lowest Coho smolt production per unit stream length and per unit surface area.

Some streams have shown significant changes in fish populations over their monitoring record (Figures 5 and 6). Steelhead have increased significantly in the Salmon River and the Bull Run River. Coho have increased significantly in Lost Creek, Zigzag River, Still Creek, and Little Sandy River. A trend in numbers with a *p*-value of 0.1 or less was considered significant because of the high amount of variability seen in population estimates across years.

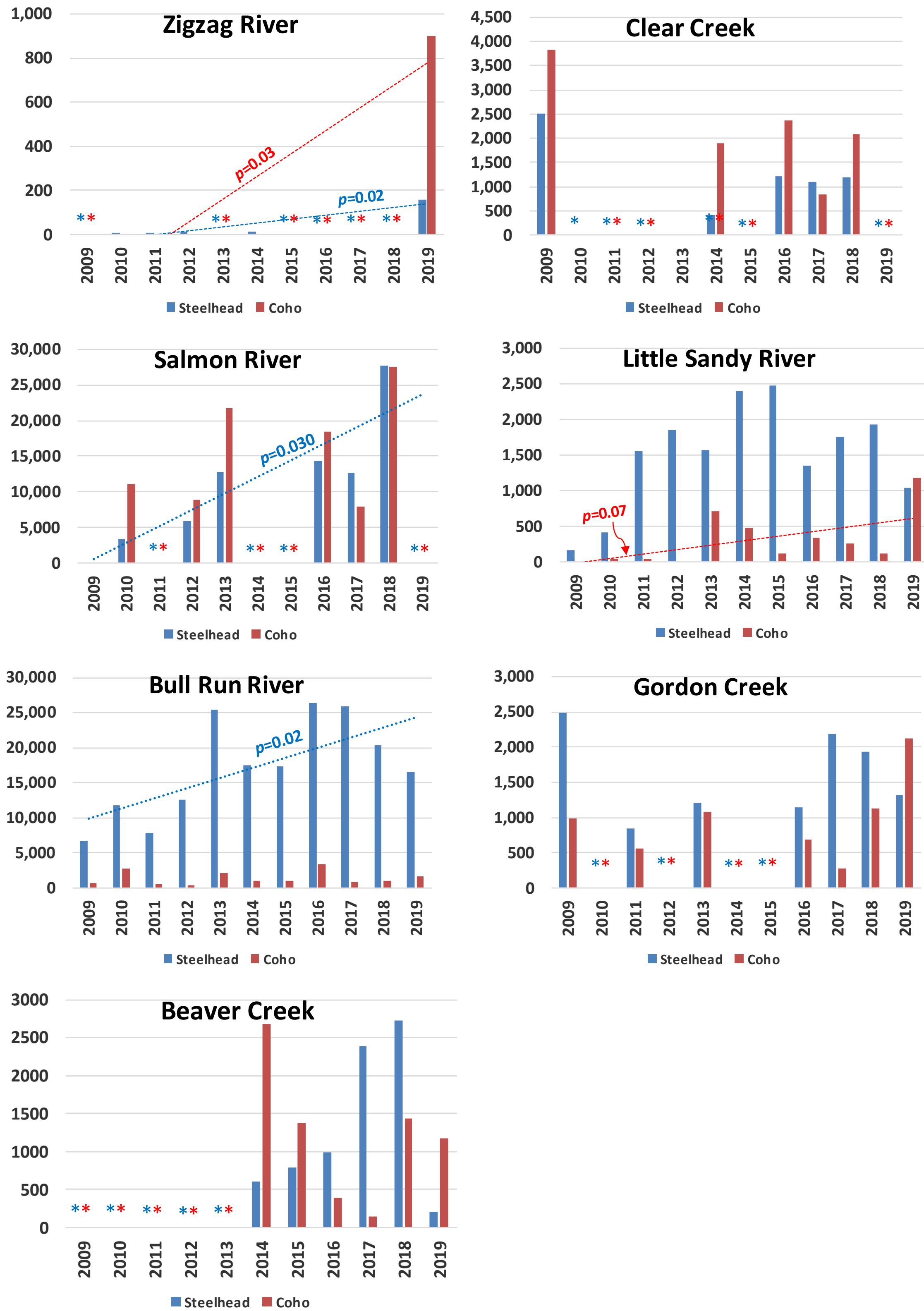

Figure 5. Steelhead and Coho Smolt Population Estimates over Time for Individual Subbasins
Statistically significant changes over time are indicated with a trendline and associated *p*-value. Red lines indicate Coho trends; blue lines indicate steelhead trends. Years with no population estimate are indicated with an asterisk to distinguish them from years with an estimate of zero.

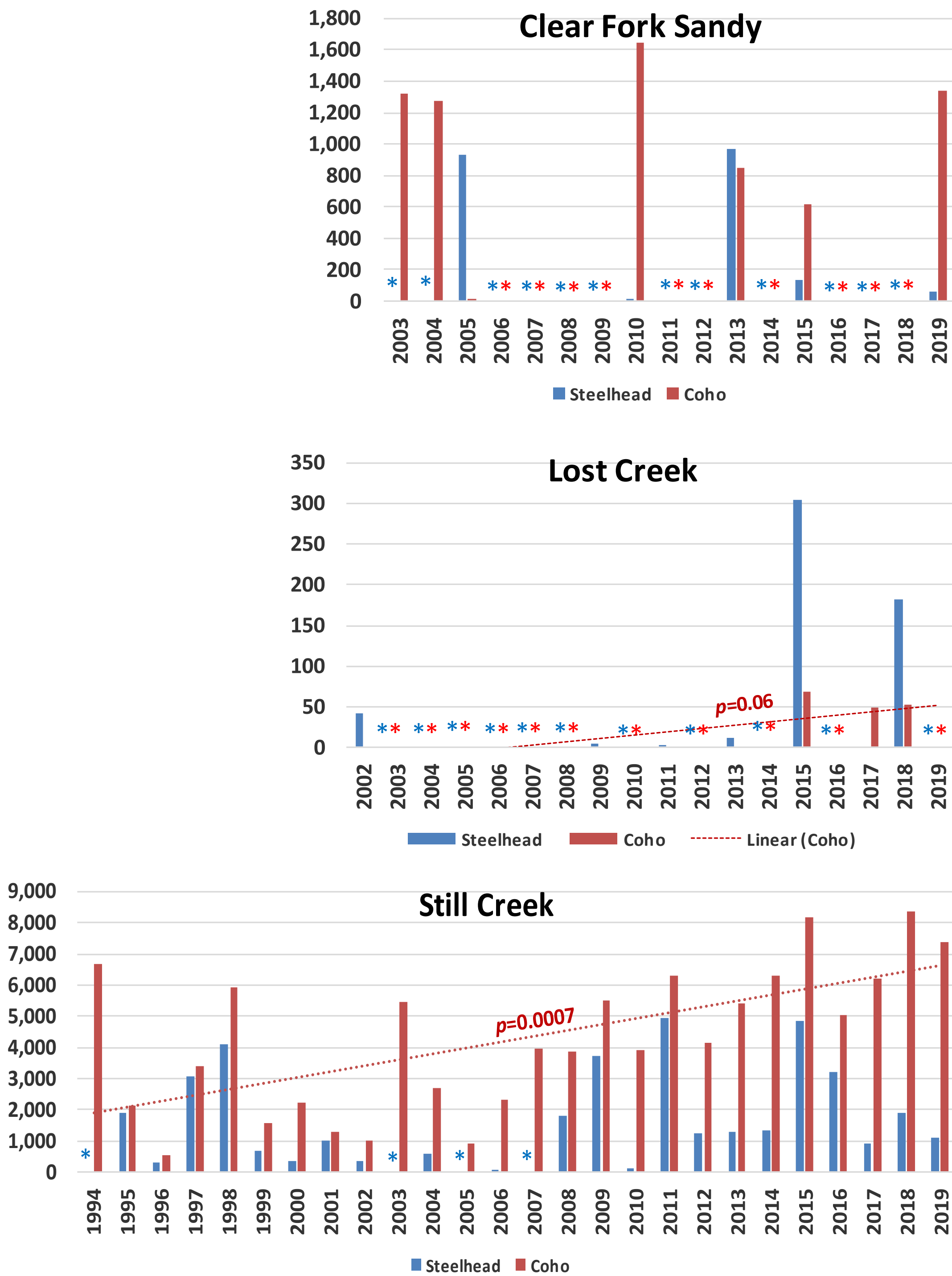

Figure 6. Steelhead and Coho Smolt Population Estimates over Time for Individual Subbasins with Extended Records

Figures are right margin-justified to align trapping years. Statistically significant changes over time are indicated with a trendline and associated *p*-value. Red lines indicate Coho trends; blue lines indicate steelhead trends. Years with no population estimate are indicated with an asterisk to distinguish them from years with an estimate of zero.

4.1.3 Sandy River Basin Index Area Population Estimates

At least four smolt population estimates were compiled from past trapping efforts in each subbasin. The smolt population estimates were used to create gap estimates. The subbasin smolt population estimate statistics are summarized in Table 7 for steelhead and Table 8 for Coho. The average relative contributions of each of the streams monitored in the Sandy River Basin Index Area are illustrated for steelhead and Coho in Figures 7 and 8, respectively.

Table 7. Statistics for Steelhead Subbasin Smolt Trap Population Estimates Compiled from the Sandy River Basin Index Area, 2009–2019

	Clear Fork Sandy	Lost Creek	Clear Creek	Zigzag River	Still Creek	Salmon River	Cedar Creek	Little Sandy	Bull Run	Gordon Creek	Beaver Creek[a]
n	5	7	5	5	23	6	4	9	11	7	6
Average	420	78	1,283	38	1,755	12,805	409	1,773	17,092	1,590	1,287
St. Dev.[a]	486	119	761	68	1,499	8,505	277	463	7,000	612	1,028

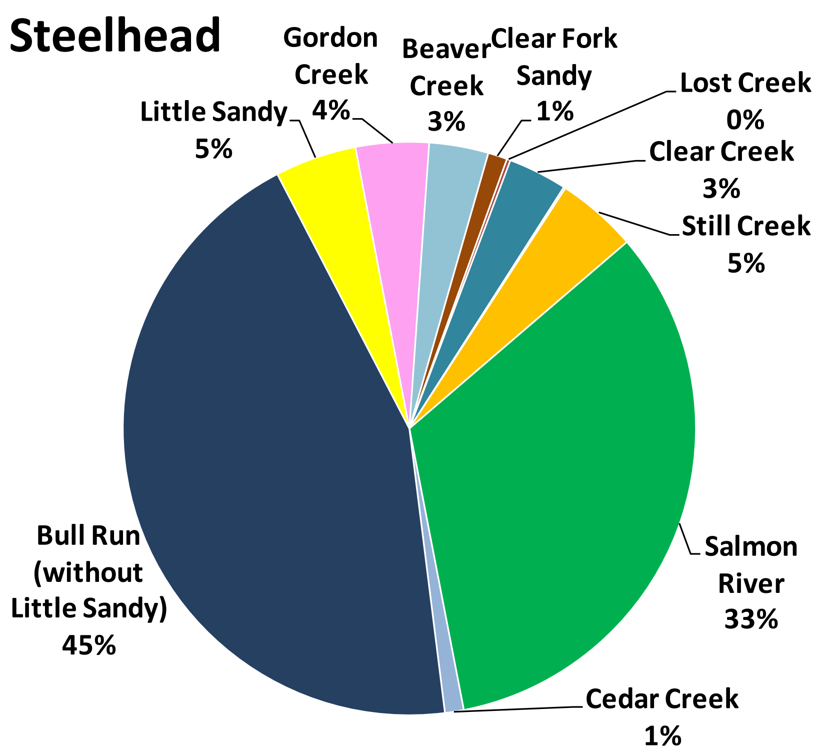

Figure 7. Average Relative Contributions of Monitored Streams to Steelhead Smolt Production in the Sandy River Basin Index Area, 2009–2019

Table 8. Statistics for Coho Subbasin Smolt Trap Population Estimates Compiled from the Sandy River Basin Index Area, 2009–2019

	Clear Fork Sandy	Lost Creek	Clear Creek	Zigzag River	Still Creek	Salmon River	Cedar Creek	Little Sandy	Bull Run	Gordon Creek	Beaver Creek
n	6	7	5	4	25	6	4	10	10	6	5
Average	1,009	24	2,208	180	4,261	15,902	1,673	325	1,340	979	1,199
St. Dev.[a]	591	31	1,079	0	2,329	7,911	781	374	961	591	901

[a]Standard Deviation (St. Dev.) describes the spread of individual subbasin estimates around their average.

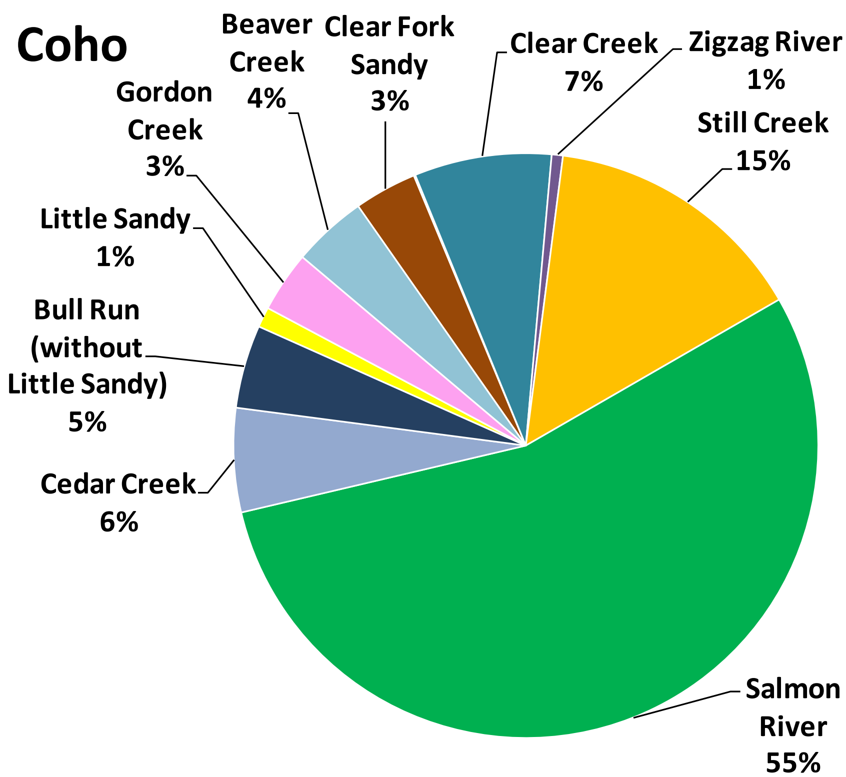

Figure 8. Average Relative Contributions of Monitored Streams to Coho Smolt Production in the Sandy River Basin Index Area, 2009–2019

The subbasin steelhead and Coho smolt population estimates and demonstrative gap estimates, as well as their 95 percent confidence intervals, are summarized in Tables 9 and 10, respectively, for the 11 years of the Sandy River Basin Smolt Monitoring Plan period (2009–2019). Expanded estimates were used for the 2011 subbasin population estimates and for Still Creek and the Salmon River in 2012, when trapping started late enough in the season to miss a significant portion of the smolt emigration. Averages of existing subbasin smolt population estimates (from Tables 7 and 8) were tentatively used as the gap estimates for this exercise.

Table 9. Subbasin Steelhead Smolt Population Estimates and Gap Estimates Since the Inception of the Sandy River Basin Smolt Monitoring Plan[a]

	Clear Fork Sandy	Lost Creek	Clear Creek	Zigzag River	Still Creek	Salmon River	Cedar Creek	Little Sandy	Bull Run	Gordon Creek	Beaver Creek
2009	420	5	2,514	38	3,709	12,805		160	6,637	2,483	1,287
	227%	na	83%	na	87%	130%		153%	96%	97%	25%
2010	4	78	1,283	5	138	3,419		416	11,701	1,590	1,287
	na	300%	116%	na	102%	77%		56%	149%	75%	25%
2011	420	1	1,283	1	4,958	12,805		1,552	7,750	839	1,287
	227%	na	116%	na	15%	130%		51%	33%	63%	25%
2012	420	78	1,283	13	1,236	5,819		1,856	12,495	1,590	1,287
	227%	300%	116%	na	39%	20%		67%	59%	75%	25%
2013	967	12	1,283	38	1,293	12,755	169	1,569	25,399	1,210	1,287
	51%	55%	116%	na	38%	47%	56%	40%	36%	122%	25%
2014	420	78	418	14	1,341	12,805	791	2,395	17,490	1,590	603
	227%	300%	38%	na	42%	130%	68%	39%	43%	75%	53%
2015	136	304	1,283	38	4,834	12,805	409	2,483	17,341	1,590	785
	73%	63%	116%	345%	38%	130%	133%	36%	24%	75%	34%
2016	420	78	1,201	38	3,192	14,443	426	1,357	26,392	1,150	994
	227%	300%	8%	345%	7%	48%	72%	62%	31%	39%	86%
2017	420	0	1,094	38	905	12,689	248	1,762	25,825	2,185	2,391
	227%	0%	33%	345%	19%	27%	58%	35%	60%	74%	55%
2018	420	182	1,189	38	1,914	27,707	409	1,936	20,402	1,939	2,735
	227%	65%	27%	345%	18%	42%	133%	39%	37%	93%	43%
2019	60	78	1,283	159	1,101	12,805	409	1,046	16,576	1,322	211
	23%	300%	116%	37%	23%	130%	0%	125%	55%	77%	37%

[a]Shaded cells indicate gap estimates using the best information available.

Table 10. Subbasin Coho Smolt Population Estimates and Gap Estimates since the Inception of the Sandy River Basin Smolt Monitoring Plan[a]

	Clear Fork Sandy	Lost Creek	Clear Creek	Zigzag River	Still Creek	Salmon River	Cedar Creek	Little Sandy	Bull Run	Gordon Creek	Beaver Creek
2009	1,009	0	3,838	180	5,528	15,902		0	661	994	1,199
	115%	0%	24%	0%	21%	98%		0%	109%	41%	92%
2010	1,646	24	2,208	0	3,911	11,077		37	2,708	979	1,199
	51%	249%	96%	0%	12%	53%		50%	68%	118%	92%
2011	1,009	0	2,208	0	6,325	15,902		39	483	557	1,199
	115%	0%	96%	0%	9%	98%		166%	61%	70%	92%
2012	1,009	24	2,208	0	4,144	8,838		0	314	979	1,199
	115%	249%	96%	0%	28%	14%		0%	141%	118%	92%
2013	853	0	2,208	180	5,435	21,721	2,589	706	2,010	1,080	1,199
	29%	0%	96%	0%	12%	18%	44%	35%	57%	50%	92%
2014	1,009	24	1,902	0	6,322	15,902	1,208	473	1,009	979	2,680
	115%	0%	20%	0%	8%	98%	14%	85%	200%	118%	41%
2015	618	68	2,208	180	8,159	15,902	1,673	116	937	979	1,380
	59%	111%	96%	0%	8%	98%	91%	103%	58%	118%	14%
2016	1,009	24	2,366	180	5,043	18,399	2,028	332	3,289	694	385
	115%	249%	37%	0%	27%	13%	20%	32%	48%	35%	57%
2017	1,009	48	841	180	6,191	7,859	868	253	733	272	141
	115%	101%	15%	0%	10%	9%	58%	52%	99%	63%	74%
2018	1,009	53	2,091	180	8,380	27,518	1,673	114	966	1,132	1,433
	115%	59%	16%	0%	9%	17%	91%	57%	69%	68%	17%
2019	1,341	24	2,208	901	7,375	15,902	1,673	1,177	1,633	2,121	1,175
	9%	249%	96%	19%	8%	98%	91%	90%	78%	17%	17%

[a]Shaded cells indicate gap estimates using the best information available.

Preliminary steelhead and Coho smolt population estimates for the entire combined index area of the Sandy River Basin are summarized in Table 11 and Figure 9 with their associated 95 percent confidence intervals.

Table 11. Sandy River Basin Index Area Steelhead and Coho Smolt Population Estimates and 95% Confidence Intervals [a]

Year	Steelhead Estimate	Steelhead 95% CI	Coho Estimate	Coho 95% CI
2009	30,058	61.4%	29,311	53.5%
2010	19,920	89.1%	23,788	28.4%
2011	30,896	55.0%	27,721	56.8%
2012	26,076	30.4%	18,714	18.1%
2013	45,982	24.2%	37,981	13.0%
2014	37,945	48.5%	31,507	50.1%
2015	42,008	41.5%	32,220	49.0%
2016	49,691	21.8%	33,749	10.4%
2017	47,557	33.6%	18,395	9.6%
2018	58,871	23.8%	44,549	11.5%
2019	35,050	54.5%	35,530	44.5%

[a]Confidence intervals are expressed as percentages of the associated estimates.

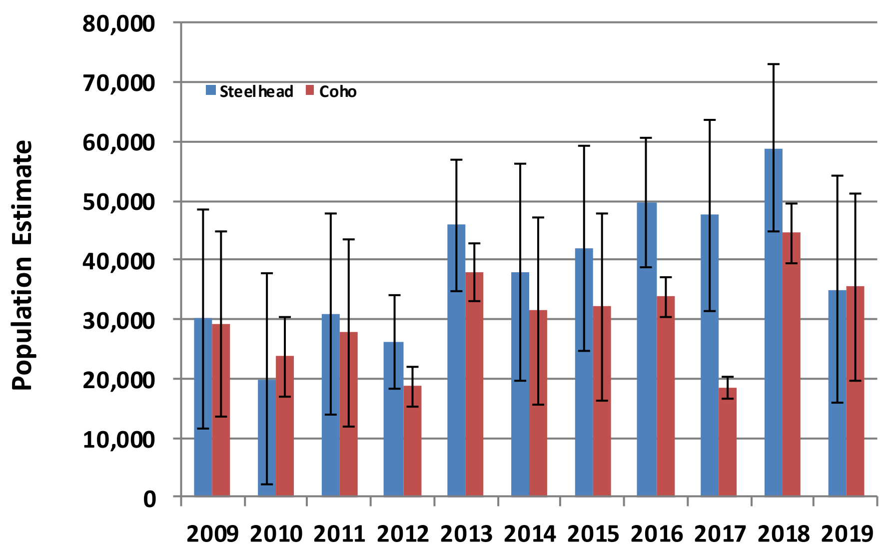

Figure 9. Sandy River Basin Index Area Steelhead and Coho Smolt Population Estimates and 95% Confidence Intervals

Estimates of freshwater productivity (smolts per adult) for steelhead are presented in Table 12. Estimates of freshwater productivity (smolts per adult) for Coho are presented in Table 13. The number of steelhead and Coho smolts are plotted against the number of steelhead and Coho spawners in the parent generation in Figures 10 and 11, respectively. Also plotted in Figures 10 and 11 are spawner/recruit curves fitted to the Sandy River Basin steelhead and Coho data using the Beverton–Holt model. A spawner/recruit curve describes how the number of recruits (offspring) produced per spawner (parent) changes depending on the number of spawners there are, according to a given model. The Beverton–Holt model used in this analysis assumes that the number of recruits is dependent on the density of spawners. The Beverton–Holt equation follows:

$$R = \frac{\propto S}{(1+{}^{S}/_{K})} \qquad \textbf{(Equation 4)}$$

where R is the number of recruits (smolts), S is the number of spawners, α is a parameter related to the productivity (recruits per spawner) of the population at its maximum (low numbers of spawners), and α and K together describe the maximum production (total number of possible recruits). As the number of spawners becomes very large, the number of recruits (smolts) begins to level off near α/K. Two Beverton–Holt spawner/recruit curves were fitted to steelhead data, one including all years of steelhead spawner data since 2010. and the other excluding spawner data from 2011 and 2012. Visibility was unusually poor throughout the steelhead spawning survey season those years, and the resulting steelhead numbers are suspected to be underestimated (Eric Brown-ODFW, pers. comm., 2013).

The number of smolts resulting from each parental generation for each species was determined by using age distribution information derived from the reading of scale samples (see Methods) and smolt fork length distribution data from each smolt trap year. Steelhead smolts from a particular parental year class emigrated at age 1, age 2, age 3, or age 4 in proportions that varied by stream. Coho smolts are assumed to have emigrated at ages 1, 2, and 3.[3]

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[3]According to aging convention for steelhead, an age-1 smolt is the offspring of adults that spawned the previous spring, approximately 12 months before. For Coho, an age-1 smolt is the offspring of adults that spawned the previous fall, approximately 5–6 months before (ODFW 2014).

Table 12. Estimates of Freshwater Productivity for Steelhead in the Sandy River Basin Index Area, 2010–2017

Steelhead Spawners		Steelhead Smolts		Freshwater Productivity
Year	Estimate	Year	Estimate	Smolts Per Adult
2010	2,100	2011–13	28,290	13
2011	527	2012–14	41,530	79
2012	391	2013–15	29,924	77
2013	3,767	2014–16	34,329	9
2014	3,344	2015–17	46,720	14
2015	5,189	2016–18	47,251	9
2016	5,831	2017–19	58,174	10
2017	2,127	2018-20	37,572	18

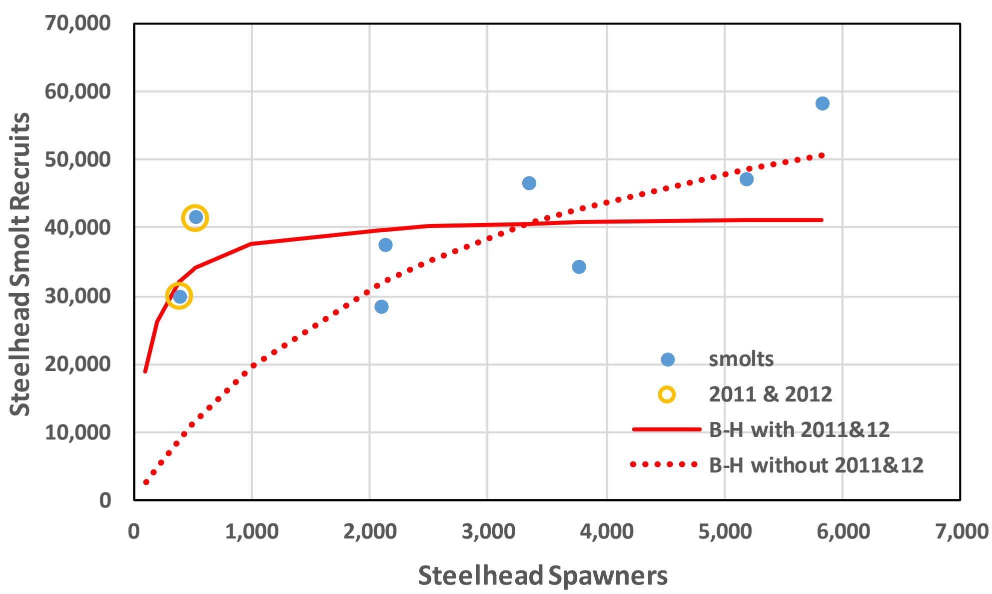

Figure 10. Steelhead Spawners Compared to Resulting Steelhead Smolts in the Sandy River Basin Index Area, Spawner Years 2007–2017

Table 13. Estimates of Freshwater Productivity for Coho Salmon in the Sandy River Basin Index Area, 2010–2017

Coho Spawners		Coho Smolts		Freshwater Productivity
Year	Estimate	Year	Estimate	Smolts Per Adult
2007	753	2009–10	27,891	37
2008	1,277	2010–11	25,063	20
2009	1,667	2011–12	27,104	16
2010	795	2012–13	20,023	25
2011	3,619	2013–14	36,929	10
2012	1162	2014–15	29,188	25
2013	596	2015–16	30,358	51
2014	5,572	2016–17	33,184	6
2015	401	2017–18	18,496	46
2016	743	2018–19	44,010	59
2017	2,025	2019-20	34,474	17

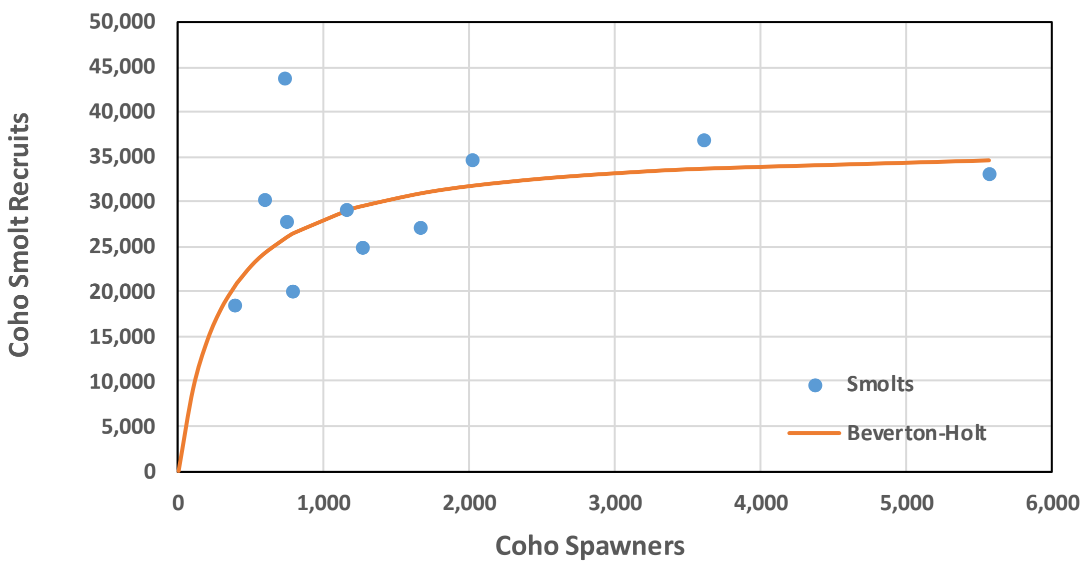

Figure 11. Coho Spawners Compared to Resulting Coho Smolts in the Sandy River Basin Index Area, Spawner Years 2007–2017

4.1.4 Recolonization of the Little Sandy River

Recolonization of the Little Sandy River by steelhead after the removal of Little Sandy Dam in 2008 appears to have been immediate and sustained (Figure 12). The first year that steelhead smolts were expected to result from the first steelhead adults spawning in the newly reopened portion of the stream was 2011. The Little Sandy 2011 steelhead smolt population was comparable in terms of smolts per unit length and area of stream to other streams of similar size that were never blocked to steelhead, like Gordon Creek or Still Creek. The steelhead smolts observed emigrating from the Little Sandy River in 2009 and 2010—with estimated populations of 160 and 416 fish, respectively—were evidently primarily fish that had migrated upstream from the lower river past the site of the dam after its removal.

The Little Sandy River produced the largest number of Coho smolts in 2019 since the dam was removed. This was the tenth year that Coho smolts could be expected in the Little Sandy trap, originating from adults that spawned upstream of the trap site after dam removal in 2008. This was the first year that the number of Coho fry caught in the Little Sandy trap in a given year has not served as an effective predictor of the Coho smolt estimate the following year.

Spawning by Chinook Salmon adults has also been documented to varying degrees in the Little Sandy River since the dam was removed in 2008. This is reflected in the variable presence of Chinook fry in the Little Sandy smolt trap.

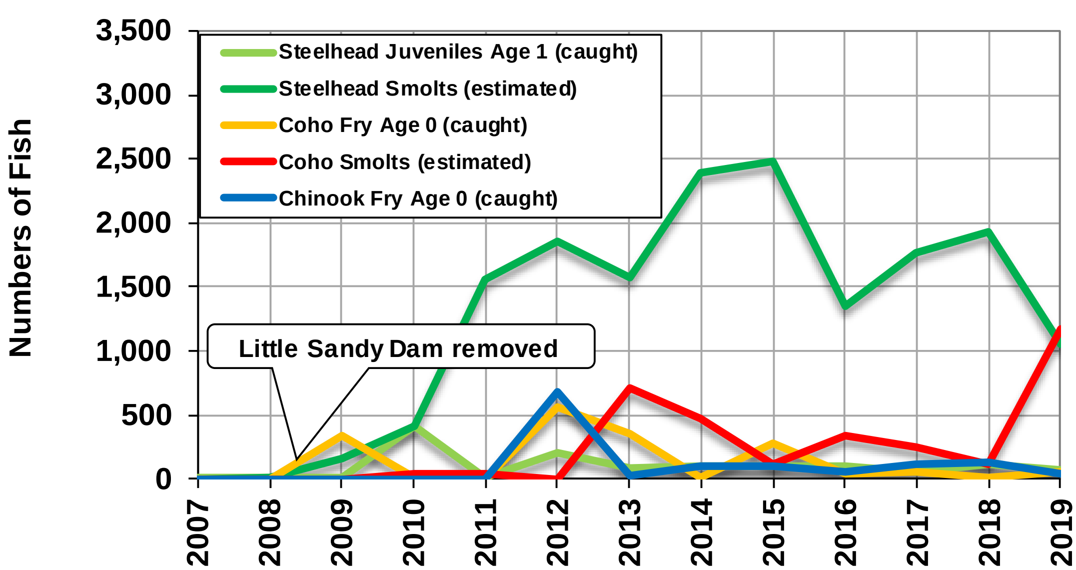

Figure 12. Recolonization of the Little Sandy River by Steelhead, Coho, and Chinook after the Removal of the Little Sandy Dam

4.2 Fork Lengths

Steelhead and Coho average fork lengths varied across monitored streams in 2019, as summarized in Tables 14 and 15, respectively. There were significant differences between the mean fork lengths of both steelhead and Coho smolts among monitored streams (ANOVA, α=0.05, p<<0.001 for both tests). Steelhead smolts emigrating from the Bull Run River were significantly longer than those emigrating from other monitored streams. Little Sandy and Gordon Creek steelhead smolts were the shortest. Beaver Creek Coho smolts were significantly longer on average than those from any other stream. Clear Fork Sandy Coho smolts were the shortest.

Table 14. Steelhead Weighted Mean Fork Lengths, Weighted Standard Deviation, and Range of Fork Lengths of Steelhead Smolts Captured in Sandy River Basin Smolt Traps in 2019

		Weighted			
Streams[a]	**n[b]**	**Mean Fork Length (mm)**	**St. Dev. (mm)**	**Minimum (mm)**	**Maximum (mm)**
Clear Fork Sandy	36	160	18	131	194
Zigzag River	53	162	12	130	187
Still Creek	199	157	15	132	202
Little Sandy	43	153	17	118	187
Bull Run (without Little Sandy)	799	177	20	103	256
Gordon Creek	123	153	22	108	220
Beaver Creek	60	156	26	104	215

[a]Streams are presented in order from highest-elevation Clear Fork Sandy to lowest-elevation Beaver Creek.
[b]n= Number of fish for which fork lengths were determined

Figure 13 shows frequency distributions for steelhead smolt fork lengths. The results of the pair-wise comparisons are summarized below Figure 13.

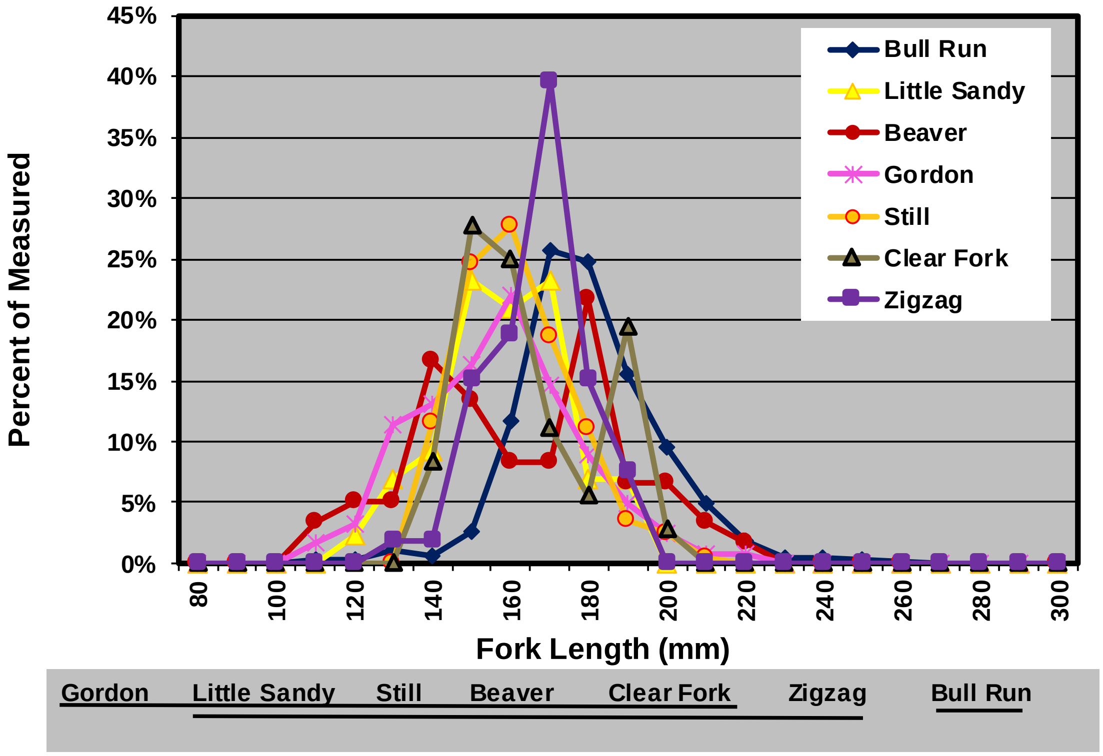

Figure 13. Steelhead Smolt Fork Length Frequency Distributions for Sandy River Basin Traps in 2019[a]

[a]Results of pair-wise statistical comparisons are presented from left to right, shortest to longest.

In Figure 13, streams that are grouped together by being mutually underlined are not statistically distinguishable from one another at a 95 percent level of significance (e.g., steelhead smolts from Gordon Creek are significantly shorter than those from the Zigzag River, but neither are statistically distinguishable from the Little Sandy, Still Creek, Beaver Creek, or Clear Fork Sandy at α=0.05). Steelhead smolts from the Bull Run River were significantly longer than steelhead from all other streams).

Smolt age information reveals that different age distributions among streams obscure differences in steelhead growth. Figure 14 compares the weighted mean fork length of age-2 steelhead in all basins and for all years for which adequate age distribution data exists, with 95 percent confidence intervals. Calculations for the weighted mean fork length of age-2 steelhead emigrating in 2019 were made using aging results from 2018 or averages from previous years. Upper-basin steelhead have comparable mean fork lengths to steelhead from lower in the basin (Figure 13), but upper-basin age-2 steelhead tend to be shorter than lower-basin age-2 steelhead. Little Sandy steelhead, which have been relatively small consistently, are an exception. These patterns have been partly due to the fact that, in comparison to steelhead emigrating from lower-basin streams, a higher proportion of the steelhead emigrating from upper-basin streams are age 3. Age-3 fish are larger because they have had more time to grow. A large proportion of Beaver Creek steelhead, in contrast, emigrate at age 1. Beaver Creek's complex steelhead fork length distribution and age distribution may also indicate that fish from other streams are entering and over-wintering in the stream.

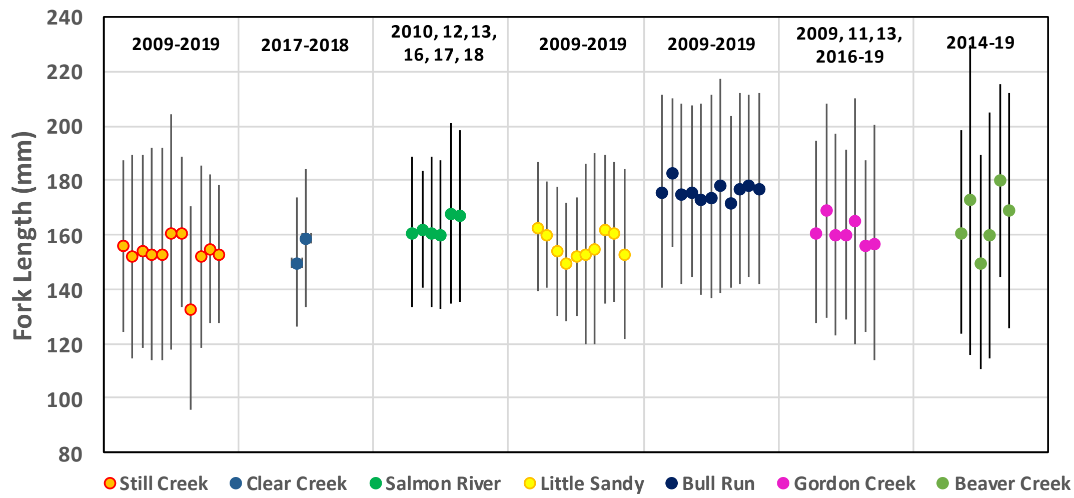

Figure 14. Weighted Mean Fork Lengths of Age-2 Steelhead Smolts for All Sandy River Basin Streams and Years for which Age Distribution Data and Fork Length Data Exist

Table 15. Coho Weighted Mean Fork Lengths, Weighted Standard Deviation, and Range of Fork Lengths of Coho Smolts Captured in Sandy River Basin Smolt Traps in 2019

		Weighted			
Streams[a]	**n[b]**	**Mean Fork Length (mm)**	**St. Dev. (mm)**	**Minimum (mm)**	**Maximum (mm)**
Clear Fork Sandy	555	93	9	70	113
Zigzag River	317	96	8	71	112
Still Creek	1387	94	11	70	129
Little Sandy	71	99	13	79	160
Bull Run (without Little Sandy)	374	119	11	81	155
Gordon Creek	496	101	13	65	166
Beaver Creek	311	125	16	81	164

[a]Streams are presented in order from highest-elevation Clear Fork Sandy to lowest-elevation Beaver Creek.

[b]n= Number of fish for which fork lengths were determined

Figure 15 shows frequency distributions for Coho smolt fork lengths. The results of the pair-wise comparisons are summarized below Figure 15.

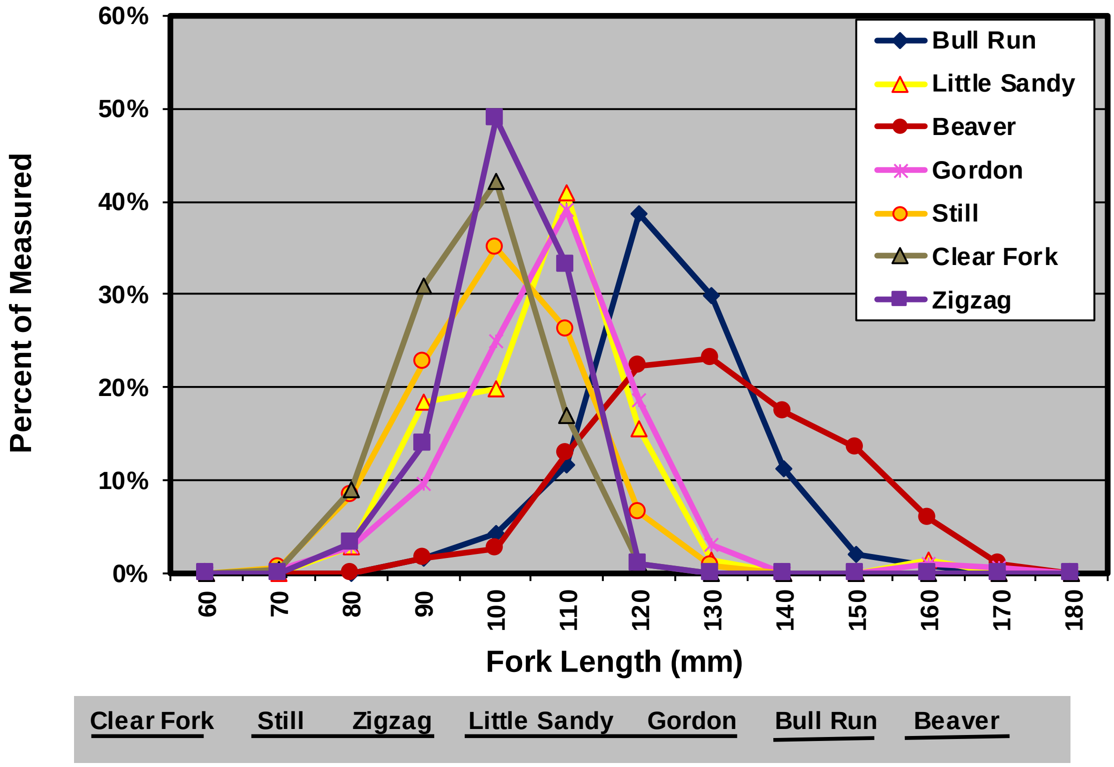

Figure 15. Coho Smolt Fork Length Frequency Distributions for Sandy River Basin Traps in 2019[a]

[a]Results of pair-wise statistical comparisons are presented from left to right, shortest to longest.

In Figure 15, streams that are grouped together by being mutually underlined are not statistically distinguishable from one another at a 95 percent level of significance (e.g., Beaver Creek Coho are significantly longer than Coho from all other streams. Little Sandy Coho are statistically indistinguishable from Coho from Gordon Creek but are significantly longer than Coho smolts from the Zigzag River.)

Smolt age information reveals that very few emigrating Coho smolts in the Sandy River Basin are older than age 2, although most of those appear to emigrate from upper-basin streams. The proportion of age-2 Coho is too small to effect a substantial change to the overall weighted mean fork length of all emigrating Coho.

4.3 Condition Factors

There were significant differences (ANOVA, α=0.05, p<<0.001 for both tests) among the condition factors of steelhead and Coho among streams monitored in 2019. Figures 16 and 17 show the results of Tukey test multiple comparisons of condition factors for these two species across monitored streams. Bull Run steelhead had statistically significant lower condition factors (were thinner) than steelhead from all other streams monitored in 2019. Clear Fork Sandy steelhead had higher condition factors (were fatter) than steelhead from all other streams monitored in 2019 but were statistically indistinguishable from steelhead from the Zigzag River. Beaver Creek Coho had significantly lower condition factors than Coho from all other streams monitored in 2019. Zigzag River Coho had significantly higher condition factors than Coho from all other streams monitored in 2019.

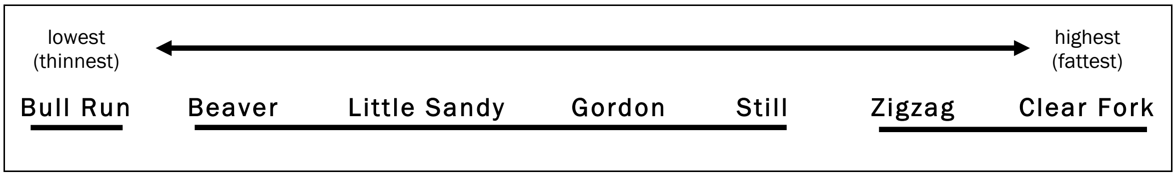

Figure 16. Steelhead Smolt Results of Tukey Test Multiple Comparisons of Steelhead Condition Factors for Sandy River Streams Monitored in 2019

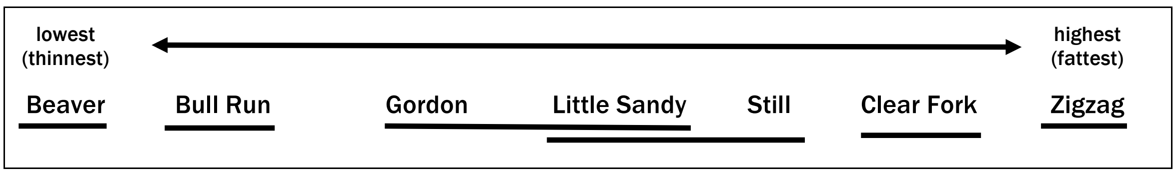

Figure 17. Coho Smolt Results of Tukey Test Multiple Comparisons of Smolt Condition Factors for Sandy River Streams Monitored in 2019

4.4 Emigration Dates

There was no clear pattern in any of the emigration statistics from highest to lowest-elevation streams for either steelhead or Coho (Figures 18 and 19). Gordon Creek steelhead smolts and Little Sandy Coho smolts, in general, emigrated earliest in 2019, although the Beaver Creek emigration finished earliest for both species. Zigzag River steelhead and Clear Fork Sandy Coho emigrated later than from other streams. The weighted mean and median emigration dates for the trapping period are summarized along with the estimated peak emigration date(s) for the population and the dates of first and last capture in Tables 16 and 17 for steelhead and Coho, respectively.

The majority of Beaver Creek Coho smolts emigrated over a very short period of time. More than 50% of all Coho smolts are estimated to have emigrated from Beaver Creek over just three days.

In general, steelhead smolts emigrated earlier than Coho smolts. The Little Sandy was the only exception to this tendency, although steelhead did complete their emigration before Coho in that stream.

Table 16. Steelhead Smolt Weighted Mean Date of Emigration, Associated Standard Deviation, Weighted Median Date of Emigration, Estimated Peak Emigration Date, and Earliest and Latest Capture Dates in Sandy River Streams Monitored in 2019

	Weighted					
Streams[a]	Mean Emigration (Trapping)	St. Dev.	Median Emigration (Trapping)	Peak Emigration	Earliest Date	Latest Date
Clear Fork	10-May	8	8-May	4, 5, 7, 8, 10-May	26-Apr	31-May
Zigzag River	14-May	9	13-May	7-May	28-Apr	3-Jun
Still Creek	23-Apr	16	25-Apr	7-May	27-Mar	1-Jun
Little Sandy	2-May	13	6-May	8-May	3-Apr	26-May
Bull Run	8-May	11	11-May	11-May	25-Mar	31-May
Gordon Creek	17-Apr	20	21-Apr	1, 3-May	12-Mar	25-May
Beaver Creek	28-Apr	7	29-Apr	5-May	10-Apr	10-May

[a]Streams are presented in order from highest-elevation Clear Fork Sandy to lowest-elevation Beaver Creek.

Table 17. Coho Smolt Weighted Mean Date of Emigration, Associated Standard Deviation, Weighted Median Date of Emigration, Estimated Peak Emigration Date, and Earliest and Latest Capture Dates in Sandy River Streams Monitored in 2019

	Weighted					
Streams[a]	Mean Emigration (Trapping)	St. Dev.	Median Emigration (Trapping)	Peak Emigration	Earliest Date	Latest Date
Clear Fork	25-May	9	27-May	28-May	21-Apr	12-Jun
Zigzag River	20-May	14	23-May	28-May	21-Apr	21-Jun
Still Creek	11-May	20	12-May	26-May	26-Mar	21-Jun
Little Sandy	28-Apr	18	1-May	18-Apr	19-Mar	30-May
Bull Run	15-May	16	20-May	27-May	22-Mar	31-May
Gordon Creek	28-Apr	20	4-May	5-May	12-Mar	1-Jun
Beaver Creek	2-May	7	4-May	5-May	13-Mar	23-May

[a]Streams are presented in order from highest-elevation Clear Fork Sandy to lowest-elevation Beaver Creek.

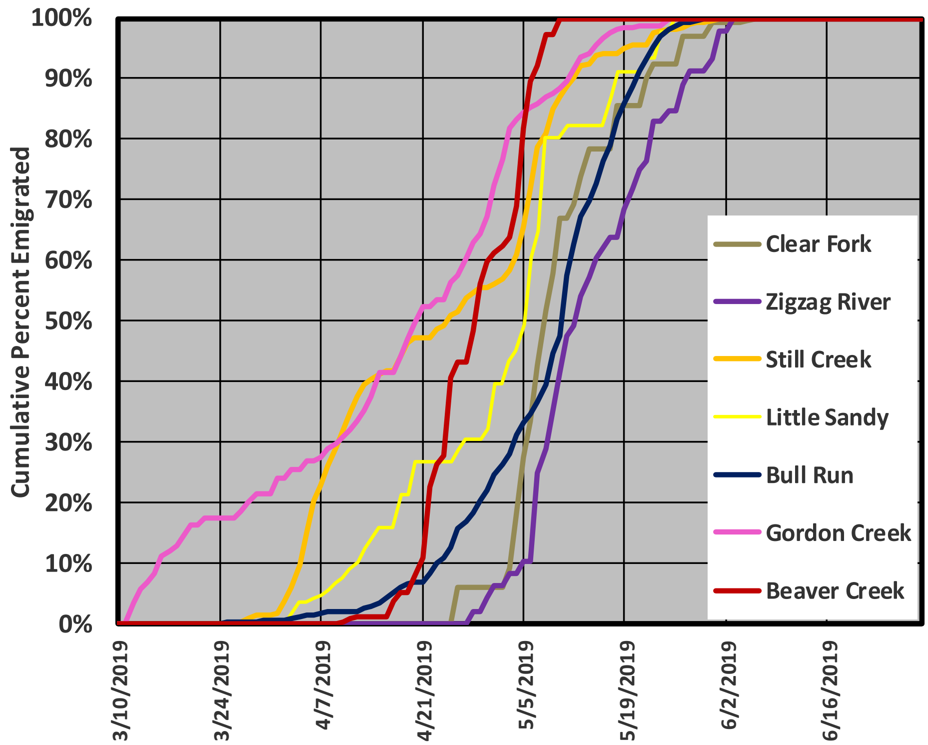

Figure 18. Steelhead Smolt Cumulative Percentage of Total Emigration from Sandy River Streams Monitored in 2019. Steepest Portions of Each Curve Indicate Peak Capture Periods

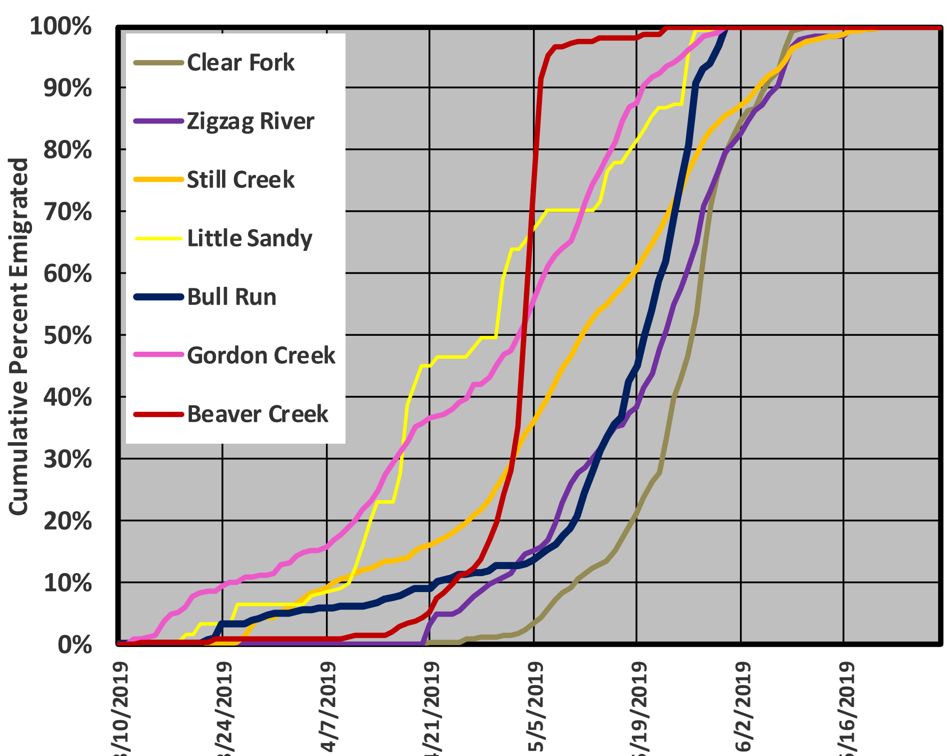

Figure 19. Coho Smolt Cumulative Percentage of Total Emigration from Sandy River Streams Monitored in 2019. Steepest Portions of Each Curve Indicate Peak Capture Periods

4.5 Age Distribution

Both steelhead and Coho smolts are, on average, slightly older at time of emigration from upper-basin streams than smolts from lower-basin streams. Steelhead and Coho smolts from the Little Sandy, however, are, on average, older than expected, given Little Sandy's mid-elevation. Tables 18 and 19 summarize the weighted mean age and age distribution for each stream in the Sandy River Basin Index Area for which adequate age data exist. Age data are averaged across all years of aging data. Coho smolts were systematically sampled in 2018, but ages were not determined for most of those sampled individuals due to contractual limitations. Those scales will be analyzed at a future time.

Table 18. Steelhead Smolt Weighted Mean Age and Age Distribution for Sandy River Streams, 2009–2018

Stream	Weighted Average Age	Age 1	Age 2	Age 3	Age 4
Still Creek	2.34	4.8%	57.9%	35.6%	1.7%
Clear Fork	2.41	0.0%	58.5%	41.5%	0.0%
Clear Creek	2.11	4.7%	80.0%	15.0%	0.3%
Salmon River	2.15	4.2%	76.8%	18.4%	0.6%
Cedar Creek	1.57	43.2%	56.3%	0.4%	0.0%
Little Sandy	2.25	2.3%	71.0%	26.8%	0.0%
Bull Run	2.10	4.6%	81.6%	13.6%	0.2%
Gordon Creek	1.96	21.4%	61.4%	17.1%	0.0%
Beaver Creek	1.44	58.8%	37.9%	3.3%	0.0%

Table 19. Coho Smolt Weighted Mean Age and Age Distribution for Sandy River Streams, 2009–2018

Stream	Weighted Average Age	Age 1	Age 2	Age 3	Age 4
Still Creek	2.03	0.3%	96.1%	3.6%	0.0%
Clear Fork	2.00	0.0%	100.0%	0.0%	0.0%
Clear Creek	2.00	2.3%	95.5%	2.2%	0.0%
Salmon River	2.00	0.0%	99.5%	0.5%	0.0%
Little Sandy	2.04	0.1%	95.4%	4.5%	0.0%
Cedar Creek	2.00	0.0%	100.0%	0.0%	0.0%
Bull Run	1.99	0.6%	99.4%	0.0%	0.0%
Gordon Creek	1.97	3.2%	96.8%	0.0%	0.0%
Beaver Creek	2.00	1.9%	96.7%	1.4%	0.0%

5. Discussion

5.1 Smolt Population Estimation

Most steelhead and Coho tributary smolt population estimates were within the range of estimates during the previous ten years of the Sandy River Basin Smolt Monitoring Program. The Zigzag River, the Little Sandy River, and Gordon Creek produced a record number of Coho smolts, and the Zigzag River produced a record number of steelhead smolts. The Bull Run River continued to produce large numbers of steelhead but produced fewer than in the previous six years. Beaver Creek had a record low steelhead estimate after having a record high estimate in 2018.

The moderate numbers of steelhead and Coho smolts emigrating from most streams in 2019 corresponded to moderate adult returns of both species two years previous. The relatively high production of Coho by Still Creek, the Little Sandy River, and Gordon Creek may be related to extensive fish habitat restoration efforts in those streams in recent years.

The description of smolt production by various streams in the Sandy River Basin could be complicated by movement of fish between subbasins either before or during the time of smolt emigration. Six and two hatchery (adipose-clipped) steelhead smolts were captured in the Bull Run and Gordon Creek traps, respectively. Two and twenty-seven hatchery Coho smolts were captured in the Bull Run and Beaver Creek traps, respectively. These fish would have entered the stream of capture after being released, swum upstream beyond the trap, and then been captured on their way back downstream. Although these fish were not included in the respective population estimates, their presence and the captures of some hatchery smolts in previous years highlight the possibility of similar behavior in wild fish.

When making inferences about the effect of fish habitat conditions on smolt production, studies generally assume that the majority of fish emigrating from monitored streams had their origin in those streams. This assumption is, in part, borne out by observed significant differences in characteristics such as fork lengths and condition factors. A large degree of movement among all streams would tend to equalize these population characteristics among streams. Of a total of 289 steelhead marked in tributaries upstream of Bull Run using paint marks, none were recaptured in the Bull Run, Gordon Creek, or Beaver Creek traps, lending further credence, especially when combined with previous years' observations, to the assumption that such movement between streams is at least not occurring to a significant degree during the spring smolt emigration.

Large numbers of hatchery steelhead also have been observed straying into the Bull Run River in 2014 and 2015. It is possible that the movements of hatchery steelhead in 2014, 2015, and 2018 do not reflect the movements of wild fish. Without further study, however, it cannot be discounted that such movement could occur to some degree and that the differences between the physical characteristics observed between smolts from different streams would have been even larger without it. It is possible that movement into tributaries may involve younger fish, such as age-1 steelhead displaced from their natal streams by intraspecific competition.

A genetic analysis of 1,560 tissue samples collected from steelhead smolts caught in nine smolt traps across the Sandy River Basin in 2017 (Bohling 2019) showed no sibling relationships between steelhead caught in the Bull Run River and any other stream other than the Little Sandy River (which is an upstream tributary to the Bull Run). This result argues against the movement of large numbers of juvenile steelhead across large distances in the Sandy River Basin, although some evidence of movement was observed between streams nearer one another (Still Creek and Clear Creek). Movement may also be occurring from the adjacent Sandy River into the Bull Run, for example, to seek refuge from the glacially turbid conditions of the main stem river.

Unequal trap avoidance by different groups of fish is a perennial concern with studies such as this that rely on mark–recapture methodologies. Trap avoidance could have affected the estimation of smolt population sizes in the Sandy River in 2019. If marked individuals become "trap-shy" (i.e., are caught a second time at a rate lower than fish passing the trap for the first time), this results in an inflated population estimate. Steelhead marked at the upstream Little Sandy trap were recaptured at higher rates at the Bull Run trap than steelhead marked at the Bull Run trap in 2019 (11.9 percent compared with 6.8 percent efficiency, respectively, averaged over the season). If this difference reflects "trap-shy" behavior on the part of steelhead that encountered the Bull Run trap rather than reflecting error in the efficiency estimate, it could result in an inflation of the Bull Run estimate. Recaptured fish had a shorter average fork length than marked fish at the Bull Run trap in 2019 (166.7 mm vs. 175.9 mm, respectively). It is possible that the difference indicates a bias towards smaller fish that are less able to avoid the trap. This difference, however, varies greatly from year to year in the Bull Run Watershed.

Large fish of a given species are probably also stronger swimmers than small fish and may have a greater ability to avoid capture when they recognize a trap in their downstream path. Were this effect to occur equally during the initial capture and subsequent recapture of fish, the result would be an underestimated population size.

Were it to happen during both phases of capture but more strongly during the recapture phase, the result would vary depending on the strength of the effect but could cause an inflated estimate. Consequences of this effect are discussed more fully in Strobel 2010.

The initial estimates of steelhead productivity (smolts per adult) were hampered in 2014 and 2015 by difficulties encountered in generating adult steelhead spawner estimates in previous years. No estimates of the number of steelhead spawners in the Sandy River Basin were generated in 2008 or 2009. The steelhead spawner estimates in 2011 and 2012 were probably biased toward the low end due to poor survey conditions (Eric Brown, ODFW, pers. comm., 2013). Confidence in the Sandy River steelhead spawner estimates from 2013 and beyond is higher. Steelhead productivity estimates are also complicated by the fact that an unknown proportion of steelhead smolts may be summer steelhead. For instance, roughly 10 percent of steelhead smolts emigrating from Bull Run in 2012, 2013, and 2014 were summer steelhead (Smith et al. 2015). The percent of steelhead smolts that were summer run in 2017 ranged from 2% and 3.2% in Beaver Creek and Cedar Creek, respectively, to 6.7% and 9.4% in the Salmon River and the Bull Run River (Bohling 2019). Although there is some likelihood that summer steelhead redds are being counted during winter steelhead spawner surveys, the extent to which this is happening is unclear.

Steelhead and Coho smolt populations for the final Sandy River Basin Index Area, the trends in smolt numbers over time, and Sandy River Basin freshwater productivity (smolts per adult) will be calculated in 2029, after 20 years of annual smolt monitoring. The preliminary calculations made in 2019 and those to be made in future years will improve with the collection of additional data.

Linear trend will lose its value over time as a measure of improvement in smolt numbers in streams where increases are attributable to restored fish passage or isolated restoration efforts. The Little Sandy showed no statistically significant increase for steelhead for the period 2009–2019 using linear regression, even though steelhead smolt production was near zero before 2010. Linear regression evaluates change over the entire time period analyzed. If that change is punctuated in time (for example, from the restoration of fish passage), the linear change observed will become less significant over time. Pre- and post-treatment comparisons are a better method of evaluating stream improvements punctuated in time. However, linear regression will continue to be a useful tool for evaluating the benefits of continuing restoration efforts or population declines due to degrading environmental conditions.

5.2 Fork Lengths

The observed differences in fork length distribution for steelhead and Coho smolts among Sandy River Basin streams monitored in 2019 mirror the differences observed in other years and may be due to one or both of two factors: (1) how rapidly fish are able to grow in each stream (which is related to stream productivity), and (2) how long they have had to grow. Steelhead and Coho weighted mean fork lengths have shown a correlation with water temperature (Strobel 2012). Steelhead smolts also vary in age from 1 to 4 years (Table 18). Their fork lengths, therefore, can reflect varying growth conditions over multiple years, as well as variations from stream to stream in the average length of time spent growing. Coho smolts also vary in age, although to a much lesser degree (Table 19). Scale samples are collected annually from steelhead and Coho smolts for determining the proportions of emigrating smolts of various ages. The continued determination of ages from these scale samples will provide an improved ability to distinguish between the effects of growth and age.

Beaver Creek and Clear Fork Sandy steelhead smolts showed distinct bimodal fork length distributions in 2019. This pattern, unusual among streams in the Sandy River Basin, is not unusual for Beaver Creek, which has consistently shown a bimodal or even trimodal steelhead fork length distribution. This phenomenon could be a result of Beaver Creek steelhead being of diverse histories, including fish reared in Beaver Creek and other fish overwintering in Beaver Creek from elsewhere in the Sandy River Basin or even from outside the basin (Bohling 2019). Clear Fork Sandy steelhead smolts may also represent two distinct groups of fish, possibly from the broad, open lower reaches and from the confined, shaded upper reaches of Clear Fork Sandy, or from within the tributary and from the mainstem of the Sandy River.

5.3 Condition Factors

In 2019, average condition factors for both steelhead and Coho smolts were generally negatively related to average fork length at a 95% level of statistical confidence for two-year-old steelhead (p=0.03, R^2=0.63) and Coho (p=0.005, R^2=0.82). It is unlikely that lower condition factors in fish reflect, in general, poor rearing conditions throughout the year. If lower condition factors reflected poor rearing conditions, then the low condition factors would tend to correlate with low fork lengths overall, which is not the case. A general negative relationship between condition factor and fork length observed frequently in the past for both Coho and steelhead could arise from warmer winter temperatures in low-elevation streams in the months prior to capture. Higher metabolic rates and possibly even growth in generally inactive overwintering fish associated with warmer water temperatures could result in greater use of fat stores. It is also possible that the decline in condition factor with increasing fork length could be an artifact of the fact that smolts in all streams tend to show a similar relationship, and there are observed differences in average fork length among streams. The observed relationship among streams was similar to the relationship within streams in 2019 (similar negative slopes). The difference could not be distinguished statistically (Tukey multiple-comparisons test between slopes).

The statistically significant decline in condition factor with increasing fork length observed consistently among fish from a single stream is an indication of a change in body shape as smolts grow, a change that has been observed visually in the field. Large smolts appear to be more slender than small smolts. The contribution of some excess water potentially transferred with each measured fish to the weighing scale tray, which would affect the weights of smaller fish more than larger fish, might also contribute to the negative relationship.

5.4 Emigration Dates

Unlike in many previous years, in 2019 neither steelhead nor Coho smolts showed a tendency to emigrate earlier from low-elevation streams than from higher-elevation streams. Both species emigrated earlier from Gordon Creek than from other streams, as was observed in 2018. The reason for the unusually early push of steelhead from Gordon Creek in 2018 and 2019 is unknown.

5.5 Age Distribution

The weighted average age of smolts is probably related to stream elevation by way of water temperature. Higher-elevation streams tend to have colder water temperatures, which slow the metabolic rates of fish. In an environment with plentiful food, growth rates are slower in colder streams. It is likely that the portion of fish that fail to reach a sufficient size by the time of smolt emigration have a survival incentive to remain an additional year to grow larger. Conversely, in warmer, low-elevation streams, fish may grow large enough one year early to confer a survival advantage to individuals that avoid an additional year of risk in the stream environment before seeking the rewards of an ocean migration.

Little Sandy smolt age distributions tend to resemble those of fish from higher-elevation streams than lower-elevation streams. This tendency corresponds with their generally shorter length-at-age.

6. Findings, Conclusions, and Recommendations

- Population estimates or approximations could be generated for steelhead and Coho smolts in seven streams in 2019.
- Steelhead and Coho smolt estimates in 2019 were generally within the range of previous years' estimates. Zigzag River had a record-high steelhead estimate. Zigzag River, Little Sandy, and Gordon Creek had record-high Coho estimates.
- Estimates of steelhead and Coho smolt production were generated for the entire Sandy River Basin Index Area for years 2009–2019. More accurate estimates will be attempted once additional years of smolt monitoring data are available.
- Estimates of freshwater productivity (smolts per adult) were generated for steelhead for parental years 2010–2017 and for Coho for parental years 2007–2017.
- Steelhead and Coho smolt fork lengths showed significant differences among monitored streams in the Sandy River Basin in 2019. High-elevation streams tended to produce shorter fish of a given age than low-elevation streams, with Little Sandy and Gordon Creek being exceptions, producing shorter smolts than expected based on their relative elevation.
- Steelhead and Coho smolts from different streams in the Sandy River Basin showed significant differences in the average condition factor in 2019. In general, streams with longer smolts of both species showed lower condition factors, which could be a data artifact.
- Steelhead and Coho smolts did not appear to emigrate earlier in general from low-elevation streams than from high-elevation streams in 2019. Little Sandy and Gordon Creek steelhead began migrating early relative to steelhead from other streams. The majority of Beaver Creek smolts of both species emigrated over a

short period of time (over 50% in three days). Steelhead emigrated, on average, earlier than Coho in most streams.

- A larger proportion of both steelhead and Coho smolts emigrating from upper-basin streams were of older ages than smolts emigrating from lower-basin streams.

Figure 20. Screw of the Bull Run Trap Recovered 17 Miles Downstream in the Sandy River after the Trap was Lost in Unseasonably High Flows in Early April, 2019

7. Acknowledgments

The Sandy River Partners would like to acknowledge the efforts and financial support that made the Sandy River Basin Smolt Monitoring Project possible. Smolt monitoring efforts were funded by the involved agencies (the Portland Water Bureau, U.S. Forest Service, and Oregon Department of Fish and Wildlife). Special thanks to the dedicated field crews that installed, maintained, and removed the numerous traps and checked them daily in all weather and flow conditions. Crew personnel included Steve Schaaf, Jon Mueller, and Trevor Diemer from PWB and Catherine Dillon, Marisa Monroe, Nicholas Floyd, Caitlin Scott, Mikenzie Hart, and Greg Wanner from USFS. Additionally, students from the Timberlake Job Corps contributed countless invaluable volunteer hours to help with the USFS smolt traps.

Ten years' worth of smolt scale samples were aged by the ODFW Fish Life History Analysis Project in Corvallis, Oregon, for this project. We are extremely grateful for their efforts. Thanks also to Eric Brown of the ODFW Oregon Adult Salmonid Inventory and Sampling Project (OASIS) for supplying adult steelhead and Coho spawner estimates.

8. Works Cited

Bjorkstedt, Erik P. 2005. DARR 2.0: Updated Software for Estimating Abundance from Stratified Mark-Recapture Data. NOAA/NMFS technical memorandum. NOAA-TM-NMFS-SWFSC-368.

Bjorkstedt, Erik P. 2010. DARR 2.0.2: DARR for R code. National Oceanic and Atmospheric Administration. http://swfsc.noaa.gov/textblock.aspx?Division=FED&id=3346.

Bohling, JH. 2019. Genetic Characteristics of Juvenile Steelhead (Oncorhynchus mykiss) Collected from the Bull Run River and the Surrounding Sandy River Basin, OR. AFTC Final Report 353.

Hutchinson, Matthew W., Jessica L. Vogt, and Alex Neerman. Winter Steelhead of the Clackamas and Sandy Rivers: Spawning Ground Surveys 2006-2007. Oregon Department of Fish and Wildlife, Salem, Oregon. 2007.

Portland Water Bureau. Bull Run Water Supply Habitat Conservation Plan for the Issuance of a Permit to Allow Incidental Take of Threatened and Endangered Species. Final Draft. Portland Oregon. 2008.

Scace, Justin G., Benjamin H. Letcher, and John Noreika. "An Efficient Smolt Trap for Sandy and Debris-Laden Streams." *North American Journal of Fisheries Management,* no. 27 (2007): 1276-86. doi: 10.1577/M07-036.1.

Smith, Christian, Jennifer Von Bargen, and Kieslana Wing, 2015. Genetic Assignment to Run of Steelhead Smolts Captured in the Bull Run River. USFWS Abernathy Fish Technology Center. Abernathy, Washington.

Strobel, Burke. Ecosystem Responses to a Large-Scale Salmon Carcass Enrichment Project. Interim report. Mt. Hood National Forest. Clackamas River Ranger District. Estacada, Oregon. 2004.

Strobel, Burke. 2014. Sandy River Basin Smolt Monitoring, 2013. Portland Water Bureau. Portland, Oregon.

Strobel, Burke. 2010. Sandy River Basin Smolt Monitoring, 2009. Portland Water Bureau. Portland, Oregon.

Suring, Erik J., Eric T. Brown, and Kelly M.S. Moore. 2006. Lower Columbia River Coho Status Report 2002 – 2004: Population Abundance, Distribution, Run Timing, and Hatchery Influence; Report Number OPSW-ODFW-2006-6. Oregon Department of Fish and Wildlife. Salem, Oregon.

Volkhardt, Gregory C., Steven L. Johnson, Bruce A. Miller, Thomas E. Nickelson, and Davd E. Seiler. 2007. Rotary Screw Traps and Inclined Plane Screen Traps. Pages 235-66 in D. H. Johnson et al. *Salmonid Field Protocols Handbook: Techniques for Assessing Status and Trends in Salmon and Trout Populations.* American Fisheries Society. Bethesda, Maryland.

Exhibit A. All Species and Life Stages Captured at Smolt Traps in the Sandy River Basin in 2019

	Clear Fork Sandy	Zigzag River	Still Creek	Little Sandy River	Bull Run River	Gordon Creek	Beaver Creek
Bluegill	0	0	0	0	0	0	19
Catfish	0	0	0	0	0	0	25
Chinook Fry	2,045	451	137	39	467	3,927	404
Chinook Smolts (Wild)	4	1	24	0	5	0	0
Chinook Smolts (Hatchery)	0	0	0	0	71	0	0
Chiselmouth	0	0	0	0	0	0	5
Coho Fry	64	17	105	59	91	2,062	5
Coho Smolts (Wild)	744	320	2,421	71	390	507	364
Coho Smolts (Hatchery)	0	0	0	0	2	0	27
Cutthroat Juveniles	5	0	0	1	0	1	0
Cutthroat Smolts	15	10	8	1	12	18	0
Cutthroat Adults	4	1	2	2	3	5	0
Longnose Dace	1	0	135	65	964	879	53
Speckled Dace	0	0	0	0	5	14	729
Banded Killifish	0	0	0	0	0	0	1
Pacific Lamprey Adult	0	0	0	1	1	12	16
Lamprey Ammocoete	0	0	9	2	3	418	134
Northern Pikeminnow	0	0	0	0	2	1	133
Oriental Weatherfish	0	0	0	0	0	0	1
Peamouth	0	0	0	0	0	0	86
Pumpkinseed	0	0	0	0	0	0	23
Rainbow Trout	9	2	4	2	13	1	0
Redside Shiner	0	0	0	0	0	0	155

	Clear Fork Sandy	Zigzag River	Still Creek	Little Sandy River	Bull Run River	Gordon Creek	Beaver Creek
Sucker	0	6	5	0	75	33	39
Sculpin	0	0	0	4	25	61	294
Steelhead Fry	0	1	0	18	1	571	0
Steelhead Juvenile	407	191	228	69	12	153	1
Steelhead Smolts (Wild)	36	53	202	44	801	123	60
Steelhead Smolts (Hatchery)	0	0	0	0	6	2	0
Steelhead Adult	1	0	2	0	0	1	0
Stickleback	0	0	0	0	0	0	9
Whitefish Adult	1	0	2	0	0	2	0

[a]Chinook, Coho, and steelhead fry were too numerous to identify individually in most streams. Salmonid fry were subsampled. Unidentified fry were assigned based on the relative proportions of subsampled fry.

Appendix I

Bull Run HCP Research Report

Western Toad Monitoring for Reservoir Operations Measure R-3

June 2020

John Deshler
City of Portland Water Bureau

Contents

Figures

1. Summary

The City of Portland Water Bureau (PWB) was in full compliance in 2019 with its Habitat Conservation Plan obligations for reservoir operations Measure R-3, Reed Canarygrass Removal. The reed canarygrass was cut and raked off the areas along the north bank of the upper end of Bull Run Reservoir 1 on April 10.

Measure R-3 is intended to benefit western toads (*Bufo boreas*) and northern red-legged frogs (*Rana aurora*), and the HCP measure has a simple approach. It was assumed that removal of reed canarygrass in known areas of amphibian breeding along the shore at the upper end of Bull Run Reservoir 1 would result in improved breeding habitat. Based on years of monitoring, it has been determined that has not been the case.

Evaluating the effectiveness of PWB's efforts to improve toad and frog breeding habitat at the three areas was not part of the original measure. However, in 2016, PWB chose to begin monitoring water temperature and toad breeding site selection to determine whether the measure was having the desired outcomes for toads. This appendix summarizes the results for all previous years of monitoring.

In 2019, toads laid eggs, most of which developed into tadpoles, but productivity was very low because tadpole numbers declined exponentially, and no toadlets were found late in the breeding season. Eggs were first laid around May 10 to May 13 and first observed on May 15. Eggs hatched into tadpoles by the time of the survey on May 22.

In 2019, all eggs were laid near Area 2 where the reed canarygrass had not been cut and removed. Areas 1 and 3 were not used.

Based on four years of monitoring, we have determined that toads are primarily breeding at untreated sites that have abundant reed canarygrass and flotsam. This year was the fourth consecutive year that most eggs were laid in the grass.

We believe that unusually warm, dry springtime conditions and predation are likely to be factors in the rapid decline of tadpoles and low productivity during each of the last four breeding seasons that have been closely monitored. Lower springtime flows have resulted in early declines in the water level at Reservoir 1. Low water forces tadpoles into the main body of the reservoir and out of the off-channel area where eggs are laid, and this is likely to impact larval development and emergence. Predation from garter snakes, rough-skinned newts, and fish is also likely to affect productivity. These predators are common at the toad breeding areas. Amphibians are the primary prey of garter snakes, and rough-skinned newts have been observed consuming tadpoles at the breeding sites.

Dispersal out of the area seems to be an unlikely explanation for the decline of tadpoles at the breeding areas given (1) the unique conditions of the upper arm of the reservoir that make it suitable for tadpole development, (2) the challenges of navigating and surviving the surrounding aquatic environment, and (3) a similar potential for temperature stress and predation pressure at any other suitable areas.

For 2020 and future years, we are intending to stop cutting and removing the grass at the toad breeding areas and, instead, observe toad breeding outcomes when more vegetative structure is present at the breeding areas. In addition, PWB plans to conduct additional late-summer surveys for toadlets at the Reservoir 1 shoreline.

2. Introduction

PWB committed through Measure R-3 in its Bull Run Water Supply Habitat Conservation Plan (HCP; Portland Water Bureau 2008) to attempt to improve breeding habitat for western toads (*Bufo boreas*) and northern red-legged frogs (*Rana aurora*) at designated areas along the north bank of the upper end of Bull Run Reservoir 1. To fulfill the HCP commitment, PWB staff annually cut and rake reed canarygrass away from the areas. While the measure is intended to benefit both amphibian species, the focus of the measure has been on toads, because toads are considered to be uncommon in the Bull Run Watershed and breed only at the upper end of Reservoir 1, whereas northern red-legged frogs are common, widespread, breeders.

Measure R-3 is based primarily on the premises that (1) toad eggs need warm water to develop properly, and (2) shade from the tall, non-native, invasive canarygrass could potentially lower the water temperature where eggs are laid. Cutting and raking away the grass is intended to allow sunlight to penetrate and warm the water so that eggs can develop properly.

Beginning in 2016, PWB began investigating whether implementation of the measure was having the desired outcomes for toads, even though evaluating the effectiveness of the measure was not part of the measure. This appendix describes the monitoring objectives and results for 2019, the fourth year.

3. Objectives

The objectives of western toad monitoring for 2019 were to determine:

- whether toads select treated (cut) areas for egg-laying,
- the onset and duration of breeding effort (first and last dates of egg-laying),
- the magnitude of the breeding effort (minimum number of breeding adults, points of oviposition), and
- breeding outcomes (did offspring reach the toadlet stage?).

Prior years of monitoring have shown that cutting and removing the reed canarygrass has not resulted in warmer water.

An overarching goal of monitoring is to determine how management of the Reservoir 1 water level may affect toad breeding. Specifically, PWB wants to learn whether and how the reservoir could continue to be managed to allow toad breeding to persist and succeed at the upper end of the reservoir each spring without interfering with water supply requirements and goals or with the requirements of the HCP.

To achieve these objectives, PWB is engaging in toad monitoring at the areas they are known to breed.

4. Monitoring Methods

Survey Timing, Frequency, and Locations

Toad surveys were conducted in the spring, once a week. The month of May was the focal period because May is (1) when off-channel waters first reach the temperature threshold required to initiate breeding, and (2) when breeding adults and eggs have been observed in prior years.

In 2019, the treated and untreated areas were surveyed, including uncut shoreline habitat between them. At treated areas, reed canarygrass was cut and removed. The focal area was Area 1, where most toad breeding and egg deposition have been observed in prior years. See Figure 1 for the locations of the areas and boundaries of the treated sites.

Breeding Site Selection

A site was considered a breeding site if eggs or breeding pairs in amplexus (mating position) were observed there.

Breeding site selection was examined in the current year and prior years (2016–2018) to determine whether toads are selecting the same areas each year for breeding and to compare the magnitude of breeding effort at each area.

Breeding Onset, Duration, and Magnitude

Toads are known to initiate breeding when the water at their communal breeding sites reaches 14 °C (Marc Hayes, Washington Department of Fish and Wildlife, personal communication). This water temperature threshold is an important indicator of breeding onset and is important for egg and larval development. Therefore, during each field survey day, water depth was measured at a permanent stake at each treatment site, and, if sufficient water was present at the stake, water temperature was collected at 10-cm and 30-cm depths. These data assisted in determining when toads would initiate breeding. Data from recent years in the Bull Run Watershed have confirmed that toads begin breeding when the water at their preferred breeding areas rises to 14 °C in spring (Portland Water Bureau 2016).

The onset of breeding was the first survey when eggs or pairs in amplexus were found. The duration of breeding began with breeding onset and ended with the last date when new points of oviposition were found.

During each survey, adult toads, pairs in amplexus, new points of egg oviposition, and juvenile toads (tadpoles and metamorphs) were counted. Adult male and adult female toads were tallied separately or as "unknown sex" when identification was not possible. The sexes were identified by size (females much larger) and amplexus position (males on top).

The magnitude of breeding effort was assessed qualitatively. The magnitude was based on the minimum number of breeding adults, the estimated quantity of eggs observed, the number of points of oviposition, and the size (area and quantity of eggs) of the points of oviposition.

Breeding Outcomes

Productivity is defined as the number of toadlets produced. Because we used non-invasive observational methods to attempt to detect toadlets, productivity can be described only qualitatively (e.g. "none," "few," or "many"). The qualitative descriptions are relative to the many thousands of toadlets that are detected dispersing from other regional breeding sites, and sometimes historically at Reservoir 1.

The toadlet stage is reached when larval toads absorb their tails and move from the aquatic to the terrestrial environment. Although individual toadlets are small, the toadlets can be highly conspicuous as they disperse in huge numbers from breeding areas into the forest.

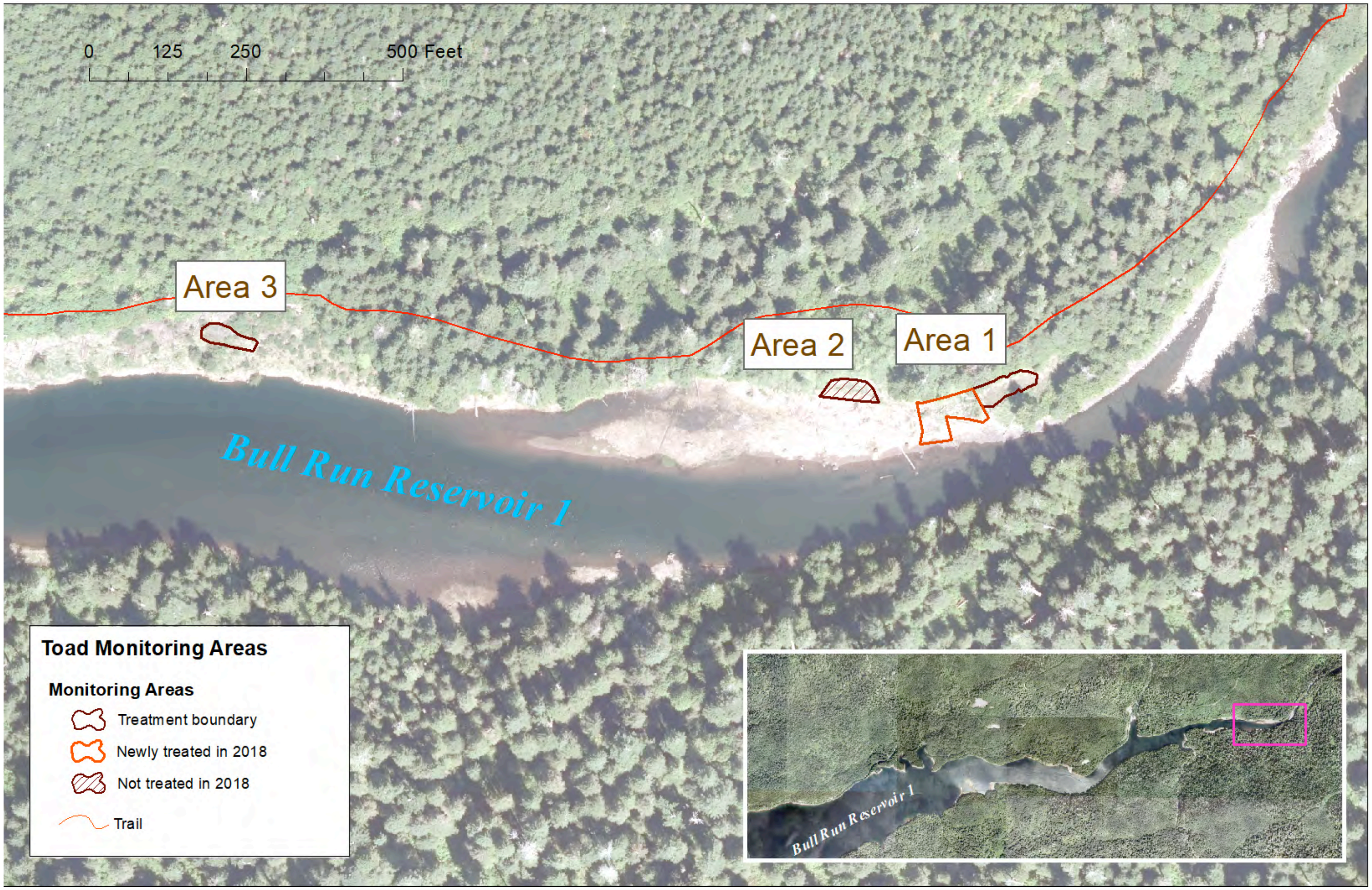

Figure 1. Toad Monitoring and Reed Canarygrass Treatment Areas

5. 2019 Results and Discussion

Survey Timing, Frequency, and Locations

Treatment (grass cutting and removal) occurred on April 10, with a focus on treating the primary breeding area (Area 1).

In 2019, the survey period was May 1 through June 26. The survey period ended when no toads, eggs, or tadpoles were present at the site. Of the nine survey days, five were in May. Surveys began between 8:20 a.m. and 10:30 a.m.

Surveys for toad breeding were focused on Areas 1 and 3, but Area 2 (untreated) was also surveyed because toads bred there.

Water levels began declining in May, and survey effort shifted to any shoreline habitat or small pools near the treated areas where toads, eggs, hatchlings, or tadpoles could be found. By June 12, all sites of oviposition were dry, and only one desiccating pool remained in the grass. By June 19, the entire area of treated and untreated reed canarygrass was dry, and water near the breeding area was transitioning from a lake to a river channel such that the last two surveys were done along the river channel where there was no grass.

Breeding Site Selection

All observations of adults and all eggs were in uncut areas with abundant reed canarygrass and flotsam, especially floating logs, bark, and sticks.

In 2019, toads shifted their breeding to Area 2, where treatment did not occur. Area 2 and untreated habitat adjacent to Area 1 were the only places eggs were laid in 2019. Area 2 had not been used by toads during prior years when it had been treated; it was used only this year when it was uncut and full of flotsam. Furthermore, no toads bred in treated portions of Area 1, a primary breeding area in prior years, where the treatment area was expanded in 2018 and 2019. This is the first year that no toads bred at Area 1. This was also the first year since 2010 that Area 2 had been allowed to fully regrow its grass and become inundated with flotsam.

No toads bred at Area 3.

Breeding Onset, Duration, and Magnitude

Breeding onset is estimated to have occurred between May 10 and 13 during days of very warm weather when water temperatures spiked above 14 ^{o}C. The first point of oviposition was found during the May 15 survey. No adults were in the water on that date, probably due to a drop in ambient and water temperatures. The last new points of oviposition were found one week later, on May 22.

The duration of breeding (egg-laying) was approximately 10 days (May 12 to May 21). Larval toads (tadpoles) were observed from May 22 (hatchlings) to June 19 (a few large tadpoles).

The magnitude of breeding was based on the number of points of oviposition, the estimated number of breeding females, and estimated number of tadpoles. The first point of oviposition included overlapping clusters produced from an estimated eight females. The latter five points were separated and estimated to have been from individual females. An estimated 13 females laid eggs in 2019. Unlike prior years when many adults have been observed, only four adults were observed in the water in 2019, all of them on May 22.

The peak in tadpole observations was June 5, when an estimated 50,000 to 100,000 tadpoles were observed.

The relatively short duration of breeding and the rapid decline in tadpoles may have been influenced by declining water levels (See Figure 2). The Reservoir 1 elevation achieved its spring peak of 1044.5 feet on May 4. Beginning on May 8, immediately prior to egg-laying, the water level declined slowly before leveling off around 1040.0 feet on May 25. By June 26, the last survey day, it had dropped another 10 feet.

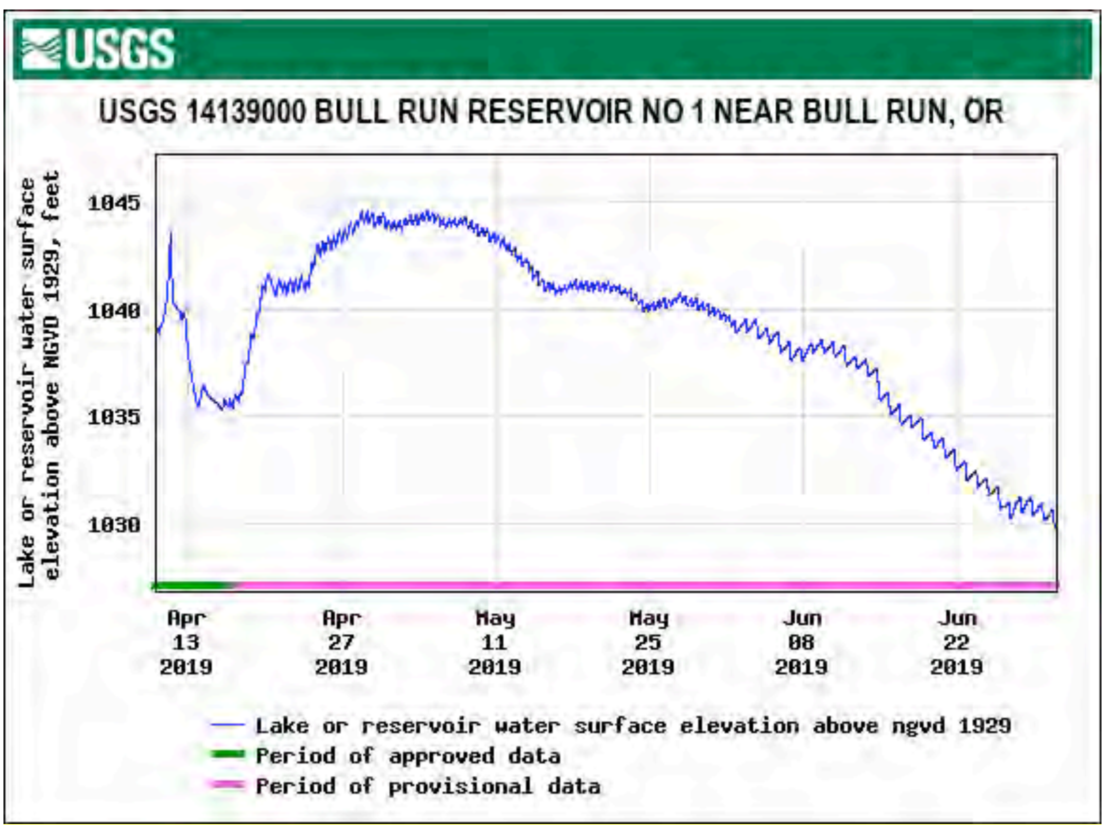

Figure 2. Reservoir 1 Water Level (Elevation) in Spring 2019

The magnitude of the breeding effort was moderate as compared to recent years. During the initial 10-day period of egg-laying, a minimum of 22 adults were observed at Area 1. Although only four points of oviposition were detected during the season, some of the points were relatively broad and contained overlapping or adjacent clusters of eggs that obviously had been laid by multiple females. Eggs were too numerous to count, but at least 100,000 eggs were estimated to have been laid, perhaps many more.

Breeding Outcomes

Breeding success for toads at Reservoir 1 in 2019 was considered extremely low.

Toad breeding during the spring of 2019 was characterized by relatively few breeding females, a brief period of egg-laying, successful hatching of eggs, then a rapid decline of tadpoles, and no toadlets. Because eggs hatched quickly, and the initial drop in the Reservoir 1 level was gradual, no eggs were desiccated. But weekly surveys identified an exponential decline in the number of tadpoles at the breeding area during just one week in June. On June 5, tens of thousands of tadpoles were estimated to have been present; by June 12, only a few dozen were observed scattered along the reservoir shoreline. It did not appear that the decline in tadpoles was associated with a decline in the Reservoir 1 level. From June 5 to June 12, the reservoir gradually fell 1.5 feet. While this decline did substantially reduce the area of near-shore habitat, a relatively broad area of grass remained inundated with water during that period. Ultimately, no tadpoles were observed at the breeding site on June 26.

Avoiding the desiccation of eggs was a desired outcome and a measure of success for the breeding season and for water-level management for toads; however, the rapid decline in tadpoles was not.

The cause of the annual, rapid, exponential decline in tadpoles is unknown. Predation is a plausible explanation. Rough-skinned newts (*Taricha granulosa*) are abundant each year at the breeding area during the toad breeding season, and they are often observed near eggs, hatchlings, and tadpoles. As the 2019 season progressed, garter snakes (*Thamnophis sp.*) became common on the areas, especially in June and July. Garter snakes primarily eat amphibians and fish (Csuti et al. 1997). Garter snakes were regularly seen swimming in the isolated pools where toad tadpoles were aggregated. Trout (*Onchorhynchus sp.*), another potential predator, are common in Reservoir 1. But because trout feed primarily at night, they were seldom observed in the reservoir margins when we were surveying for toads.

Dispersal of tadpoles from their natal area could explain the tadpole decline. However, we find that unlikely because (1) toadlet emergence in the Bull Run Watershed and other toad breeding sites is known to occur *at* the site of egg-laying, where waters are warm and calm and suitable for larval development, and (2) dispersal would require tadpoles to swim out of their natal, warm-water margins, across the deep, flowing, cold-water channel, while avoiding predators and locating different, more suitable, warm-water margins where they could feed and develop. The existence of such warm-water margins is not known.

6. Summary of Results from 2016–2019

Breeding Site Selection

In each of the past four years, the toads on Reservoir 1 have mated and laid eggs primarily in dense, uncut, reed canarygrass between Area 1 and Area 2. The 2019 breeding season was notable because the uncut portion of Area 1 where toads had primarily bred in prior years was avoided after treatment was expanded into it, and toads began using Area 2 where treatment did not occur and where toads had not bred when it was treated.

We are convinced that a pattern in breeding site selection has been established: toads are selecting areas for mating and egg-laying that include dense vegetative structure and mostly avoiding treated areas.

Onset, Duration, and Magnitude of Breeding Effort

Breeding onset in 2019 occurred in May, as in prior years. Breeding onset for the four years of study has fluctuated annually, ranging from May 3 to May 28.

The duration of breeding in 2019 was similar to 2018, but brief relative to 2016. In 2016, egg-laying began about 10 days earlier and finished nearly 10 days later than in 2019. In all years, instances of egg-laying have occurred sporadically, rather than continuously, in May. Most egg-laying has coincided with the first few periods of warm weather and water temperatures above 14 ^{o}C, while a few late breeders have been found in some years, but not in 2019.

The magnitude of breeding was low in 2019 in comparison to some prior years. In 2019, only one pair was observed in amplexus, and an estimated 13 pairs bred. In 2016 and 2018, 17 and 20 pairs were observed in amplexus, respectively, and the density of eggs suggested that many more pairs bred in those years.

A qualitative comparison of egg-laying and breeding adults seems to indicate that the duration and magnitude of breeding have declined from 2016 to 2019. In 2016, the minimum number of breeding adults and points of oviposition were greater than in subsequent years, with 2019 having the lowest number compared to all other years.

Breeding Outcomes

For the combination of all four years of monitoring, productivity (toadlets emerging onto land) is estimated to have been extremely low. In no year were any fully terrestrial toadlets found entering the forest, nor were conditions suitable for toadlet development and emergence.

In 2016, despite observations of many adult toads, abundant eggs, and a long, four-week period of egg-laying, no tadpoles were ever observed. Desiccation destroyed most eggs in that year. In 2017 and 2019, most eggs hatched and developed into tadpoles, but the decline in tadpole numbers was rapid and exponential. Only a few toadlets may have emerged in 2017, an observation based on the presence of tailed toadlets at the water's edge in late July. In 2018, approximately half of all eggs developed into tadpoles, and the other half were desiccated. The decline in tadpoles was rapid in June, however, and no toadlets were observed. In 2019, no toadlets emerged. Predation and declining water levels during the breeding season may be affecting toad productivity.

Water levels at Reservoir 1 were much higher during mid- to late-summer in several of the years that immediately preceded the monitoring period, and these years may have been productive for toads. During the monitoring period (2016–2019), no water was available at the breeding area for larval toads in late July and August, except during 2016 (Figure 3).

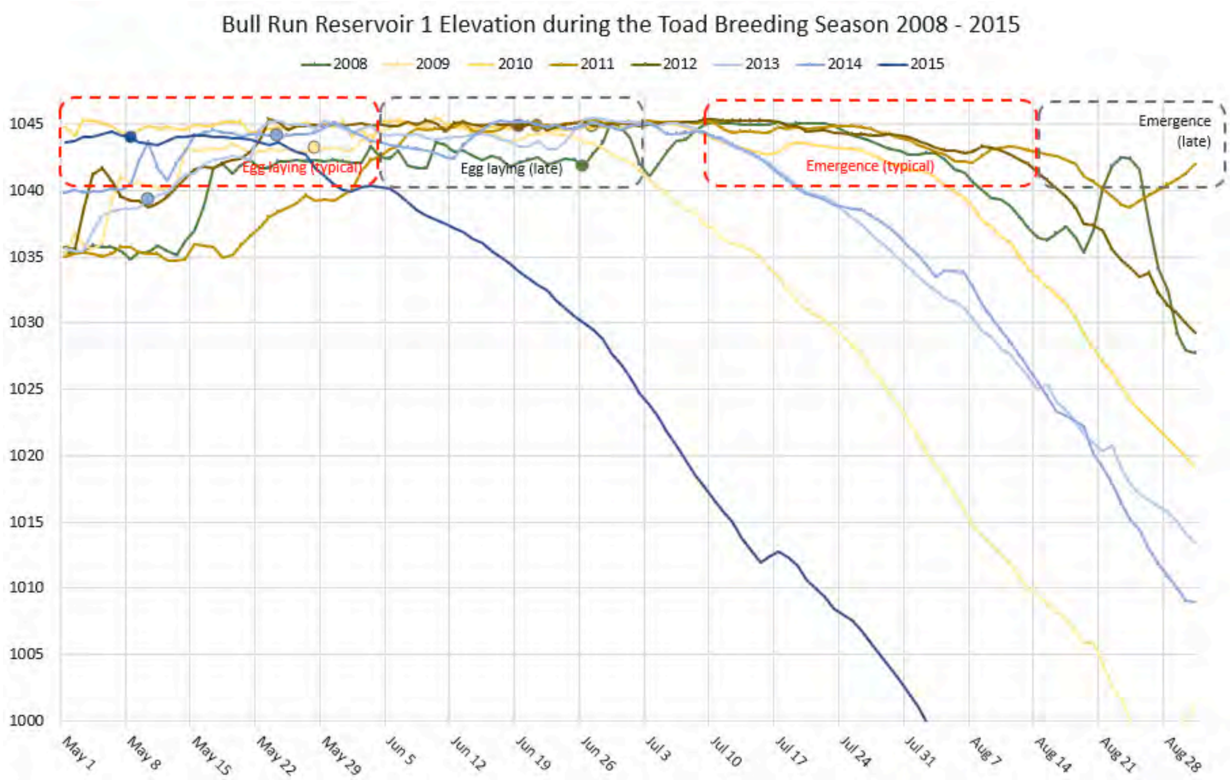

Figure 3. Bull Run Reservoir 1 Water Level during the Toad Breeding Season, 2008–2019. The Estimated Start of Egg-laying in Each Year (Dots) is based on Recent and Historical Surveys and the 14 °C Threshold

In 2016, fluctuating water levels early in the season caused all eggs to desiccate, so adequate late-season water was inconsequential. In contrast, many of the preceding eight years (2008–2015) had some "late water" for toadlet development and possible emergence. Four of the years from 2008 to 2012 (not 2009) may have been particularly good for larval development and toadlet emergence because Reservoir 1 was relatively full even at the start of August (Figure 3). The greatest known toadlet emergence occurred in 2008.

7. Approach for 2020 and Future Years

The four years of monitoring (2016–2019) have shown that Measure R-3 is not achieving its goal of "improving breeding and rearing habitat" for western toads because the current commitment (grass cutting) is not demonstrating an improvement. Adult and larval toads have shown a pattern of avoiding the treated areas, and red-legged frogs attach their eggs to vegetation, including grass. The cut areas are mostly unused. In addition, data collected in prior years have shown that the original goal of a temperature benefit for larval toads (warmer water for development created by reduced shading) was not achieved by cutting the grass (see the HCP 2017 annual report).

For 2020 and future years, PWB is requesting to change the Measure R-3 commitment to better achieve the goal of improving breeding and rearing habitat. The requested change is to (1) stop cutting the grass so that the toads and frogs have the vegetative structure they seek during laying and larval development, and, instead, (2) monitor toad and frog breeding at the site and examine future breeding outcomes. Monitoring will collect data that inform potential future efforts to improve breeding outcomes for toads and frogs at the site. Monitoring requires greater effort and resources than the simple, one-day effort of cutting and removing the grass. But, the extra effort is necessary to try to retain toad breeding at the site. If toad productivity continues to be low, even in years when toads lay eggs that successfully hatch into tadpoles, then PWB will attempt to determine whether predation or some other factor is negatively affecting productivity.

8. Works Cited

Csuti, B., O'Neil, T.A., Shaughnessy, M.M., Gaines, E. P., and J.C. Hak. 2001. *Atlas of Oregon Wildlife.* Oregon State University Press, Corvallis, Oregon. 525 pp.

Portland Water Bureau. 2008. Bull Run Water Supply Habitat Conservation Plan for the Issuance of a Permit to Allow Incidental Take of Threatened and Endangered Species. Portland, Oregon.

Portland Water Bureau. 2017. Bull Run Water Supply Habitat Conservation Plan Annual Compliance Report 2016 – Year 7. Portland, Oregon. 273 pp.

Appendix J

Bull Run HCP Effectiveness Monitoring Report

Correspondence on Measures

June 2020

City of Portland Water Bureau

Correspondence on Measures

Note: Each item refers to two pieces of correspondence: a letter from the Portland Water Bureau (PWB) to the National Marine Fisheries Service (NMFS) and the NMFS response. Letters appearing in previous reports are summarized and appear in gray. If the appendix includes letters relevant to the current compliance year, the letters are summarized and presented in full following the summaries.

Correspondence Summaries from Compliance Reports 2010–2019

Item 1. April 26, 2011, letter from Steve Kucas, PWB, to Ben Meyer, NMFS, proposing to create conservation easements in another subbasin of the Sandy River watershed to replace the benefits of Measure H-22, Boulder 1 Riparian Easement

May 11, 2011, letter from Michael Tehan, NMFS, to Steve Kucas, PWB, authorizing the City to implement conservation easements in Gordon Creek to compensate for Measure H-22

Item 2. July 22, 2011, letter from Steve Kucas, PWB, to Ben Meyer, NMFS, proposing to place large wood pieces in another subbasin of the Sandy River tributary to replace the benefits of Measure H-26, Boulder 0 and 1 LW Placement

August 16, 2011, letter from Ben Meyer for Michael Tehan, NMFS, to Steve Kucas, PWB, authorizing the City to place large wood in Gordon Creek to compensate for Measure H-26

Item 3. August 22, 2011, letter from Steve Kucas, PWB, to Ben Meyer, NMFS, requesting authorization to use riparian easements on lower Bull Run or Sandy River parcels in fulfillment of HCP riparian easement targets

September 16, 2011, letter from Michael Tehan, NMFS, to Steve Kucas, PWB, authorizing the City to purchase some parcels of land on the lower Bull Run or Sandy River and create riparian easements to fulfill HCP easement targets

Item 4. February 14, 2012, letter from Steve Kucas, PWB, to Ben Meyer, NMFS, requesting authorization to increase the number of large wood structures in Trout Creek reach 1A in lieu of adding wood in Trout Creek reach 2A for Measure H-7

March 15, 2012, letter from Michael Tehan, NMFS, to Steve Kucas, PWB, authorizing the City to place additional large wood structures in Trout Creek reach 1A in lieu of placing them in Trout Creek 2A

Item 5. December 9, 2011 letter from Steve Kucas, PWB, to Ben Meyer, NMFS, requesting authorization to obtain conservation easements in the Sandy River reach 2 instead of reach 1, establish easements wider than 100 feet wide in the lower Sandy River, and establish conservation easements on lands owned by The Nature Conservancy

January 5, 2012, letter from Michael Tehan, NMFS, to Steve Kucas, PWB, authorizing the City obtain conservation easements in the Sandy River reach 2 in lieu of reach 1, obtain conservation easements in sites wider than 100 feet pending NMFS review and giving priority to parcels on side-channels, and establish conservation easements on lands owned by The Nature Conservancy

Item 6. September 18, 2012, letter from Steve Kucas, PWB, to Ben Meyer, NMFS, requesting authorization to obtain conservation easements along the main stem of the Sandy River in lieu of Gordon Creek and establish a long-term 200-foot-wide easement on the Camp Collins property

September 25, 2012, letter from Michael Tehan, NMFS, to Steve Kucas, PWB, authorizing the City to obtain conservation easements along the main stem of the Sandy River in lieu of Gordon Creek and establish a long-term 200-foot-wide easement on the Camp Collins property

Item 7. April 2, 2013, letter from Steve Kucas, PWB, to Ben Meyer, NMFS, requesting authorization to discontinue implementation of Measure R-2, Cutthroat Trout Rescue

April 26, 2013, letter from Michael Tehan, NMFS, to Steve Kucas, PWB, authorizing the City to discontinue implementation of Measure R-2, Cutthroat Trout Rescue

Item 8. August 6, 2013, letter from Steve Kucas, PWB, to Marc Liverman, NMFS, requesting authorization to fund fish carcass placement in reaches other than those specified in the Habitat Conservation Plan (HCP) for Measures H-25 and H-29

December 3, 2013, letter from Kim W. Kratz, NMFS, to Steve Kucas, PWB, authorizing the City to fund fish carcass placement in reaches other than those specified in the Habitat Conservation Plan (HCP) for Measures H-25 and H-29

Item 9. November 18, 2014, letter from David G. Shaff, PWB, to Kim Kratz, NMFS, requesting confirmation that the Habitat Conservation Plan (HCP) Implementing Agreement documents the City's commitment to forgo consumptive use of the Little Sandy River and serves as the Little Sandy Flow Agreement for Measure F-4

December 4, 2014, letter from Kim W. Kratz, NMFS, to David G. Shaff, PWB, confirming that the City has documented its commitment to forgo exercise of its rights and claims to the Little Sandy River and that no additional flow agreement is required for Measure F-4

Item 10. March 31, 2015, letter from Steve Kucas, PWB, to Marc Liverman, NMFS, requesting approval to pursue implementing off-channel habitat improvements in the Sandy River, reaches 1 and 2, in lieu of implementing Measure H-9, Sandy 1 Channel Reconstruction

April 14, 2015, letter from Kim W. Kratz, NMFS, to Steve Kucas, PWB, approving the City's proposal to pursue the proposed alternative habitat improvement measures in lieu of implementing Measure H-9

Item 11. July 10, 2013, letter from Steve Kucas, PWB, to Ben Meyer, NMFS, requesting approval to shift the location of some of its conservation easement acreage targets to other locations within the Sandy River Basin that provide equal or greater benefits to fish.

July 12, 2013, letter from Michael P. Tehan, NMFS, to Steve Kucas, PWB, approving the City's request to shift some of its conservation easement acreage targets to other locations within the Sandy River Basin and requesting identification of the specific reaches that would be in the new target area

Item 12. March 9, 2016, letter from Steve Kucas to Marc Liverman, NMFS, requesting acquisition of additional conservation easement acreage targets in reaches Sandy 7 and 8 within the Sandy River Basin that provide good benefits to fish

February 13, 2017, letter from Kim W. Kratz , NMFS, to Steve Kucas, PWB, approving acquisition of conservation easement acreage targets in reaches Sandy 7 and 8

Item 13. September 16, 2019, letter from Steve Kucas, PWB, to Marc Liverman, NMFS, requesting approval to use the most recent version EDT3 in place of the discontinued version EDT2 for evaluating the effectiveness of HCP measures in terms of modeled VSP parameters for Sandy River fish populations

October 17, 2019, email reply from Mischa Connine, NMFS, approving the use of EDT3 as a replacement for the discontinued version EDT2 for evaluating the effectiveness of HCP measures in terms of modeled VSP parameters for Sandy River fish populations