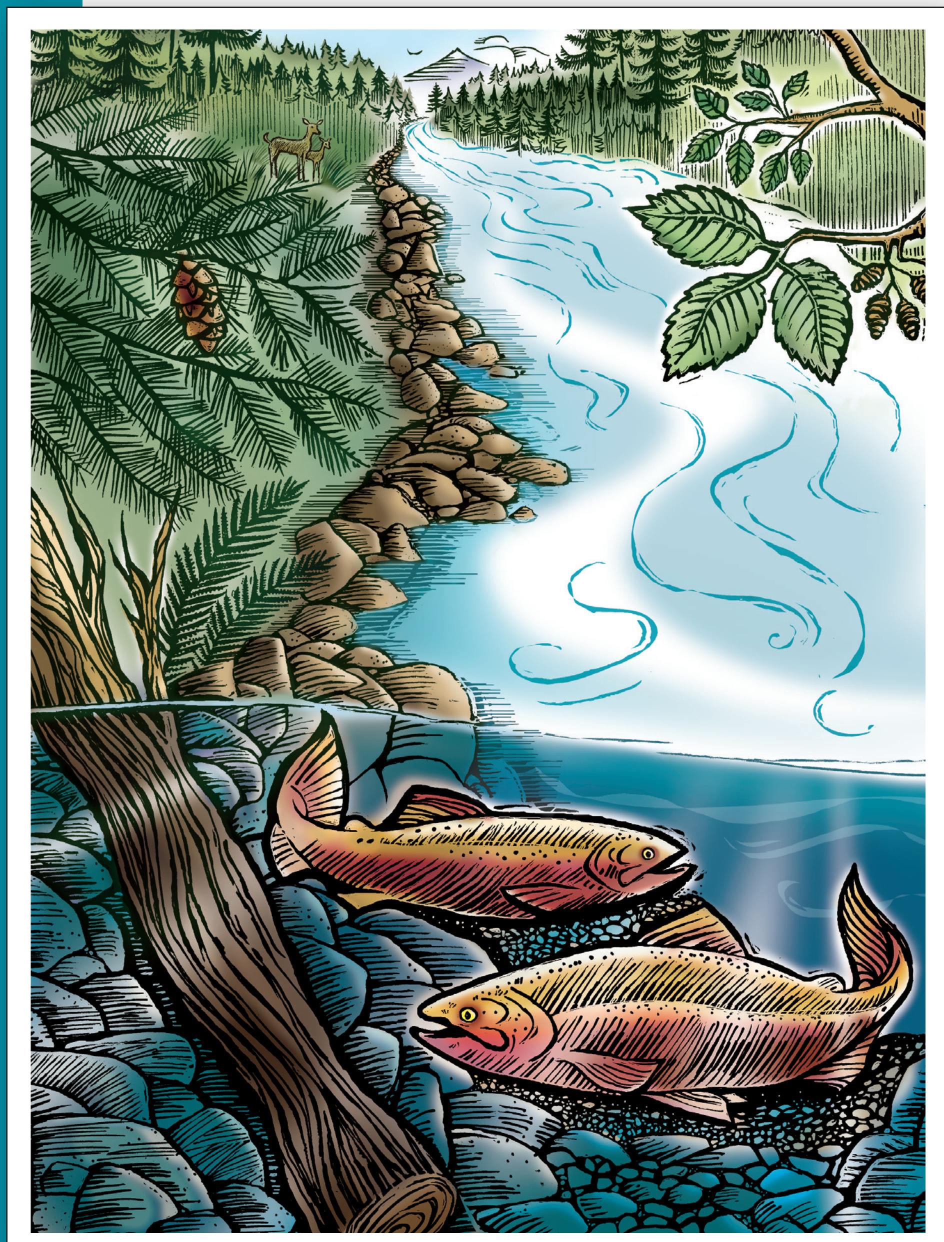
Bull Run Water Supply
Habitat Conservation Plan

Annual Compliance Report 2016—Year 7



Final · May 2017

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.

Stephen T Kucas Jr. — May 30, 2017

Steve Kucas, Environmental Compliance Manager, PWB Resource Protection — Date

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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
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
TMDL	total maximum daily load
USGS	U.S. Geological Survey
7DADM	7-day average of daily maximum temperature

1. Executive Summary

For 2016, the City met the terms and conditions of every HCP conservation measure with the exception of downstream water temperature targets. For 35 days, mostly occurring from mid-September to late October, the temperature of the Bull Run River exceeded the HCP temperature target. The City presented the 2016 water temperature information to the Oregon Department of Environmental Quality, the National Marine Fisheries Service, and the Oregon Department of Fish and Wildlife. Those agencies directed the City to continue to monitor water temperatures in the lower Bull Run River in 2017 and to work with the agencies, starting in the spring, on operational measures to improve performance of the system for temperature control.

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 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's (ODEQ) approved the City's Temperature Management Plan for the Lower Bull Run River (Appendix G 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 2012, the City obtained a Clean Water Act 401 Certification from ODEQ for Portland's Bull Run Reservoir Hydroelectric Project associated with the improvements to the water intake towers at Bull Run Dam 2. A report on water quality monitoring required by the certification is included in this compliance report as Appendix B.

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 H, new in this Year 7 report, summarizes the results of the first year of 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 seventh year of the HCP was 2016, referred to as Year 7 throughout this document. This is the seventh 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 project in one location and increasing the amount 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 G).

The City met the terms and conditions of every HCP conservation measure for 2016 with the exception of downstream water temperature targets. For 35 days, the temperature of the Bull Run River exceeded the HCP temperature target. The City presented the 2016 water temperature information to the Oregon Department of Environmental Quality, the National Marine Fisheries Service, and the Oregon Department of Fish and Wildlife. Those agencies directed the City to continue to monitor water temperatures in the lower Bull Run River in 2017 and to work with them, 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. 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 G 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 seventh 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 F and H. Appendix G summarizes key correspondence between PWB and NMFS on obtaining authorization for changes to measures, including adjustments to the terms of selected measures.

Table 12, beginning on page 54, 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 12 also indicates where the effectiveness monitoring reports (Appendixes A, B, and H) and the research reports (Appendixes C, D, and E) 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. Monitoring Results for Certification According to Section 401 of the Clean Water Act provides results of water quality monitoring in Bull Run Reservoir 2 and lower Bull Run River before and after the modifications to the water intake towers at Bull Run Dam 2 (see Appendix B). Effectiveness monitoring, described in detail in Appendix A, 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 degree of gravel scour in spawning beds suitable for Chinook spawning, 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 and Little Sandy rivers 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.

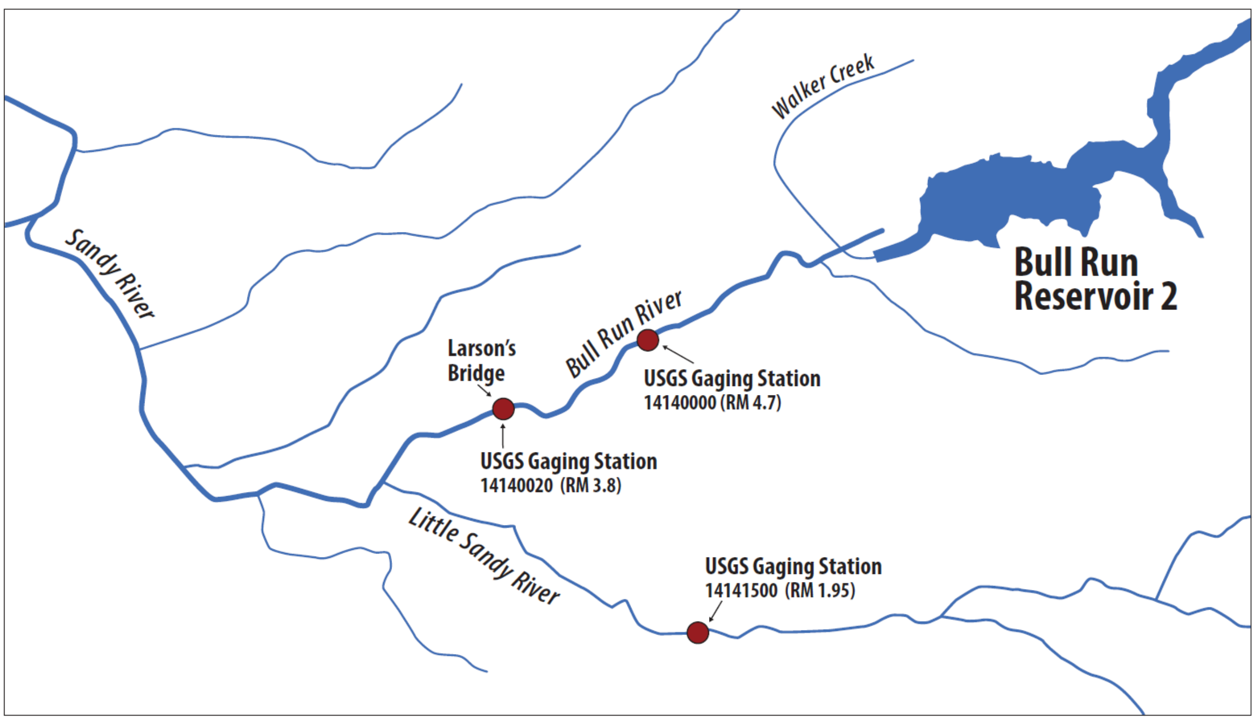

Figure 1. USGS Gaging Stations for Compliance Monitoring

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"/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 F of the HCP for more details on the Chinook survey procedures.

Status of Work for Calendar Year 2016

The City met the minimum instream flow requirements of HCP Measure F-1 in 2016. Guaranteed minimum flows for normal water years were used as the flow targets January through May and July through December in 2016. See Measure F-2 for spring flow requirements for 2016.

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 2016

Flow Target Period		Index Period		Average Inflow (cfs)	Flow Target (cfs)
From	To	From	To	During Index Period	
1-Oct	3-Oct	19-Sep	25-Sep	106	70
4-Oct	10-Oct	26-Sep	2-Oct	85	70
11-Oct	17-Oct	3-Oct	9-Oct	1066	400
18-Oct	24-Oct	10-Oct	16-Oct	2232	400
25-Oct	31-Oct	17-Oct	23-Oct	1807	400
1-Nov	7-Nov	24-Oct	30-Oct	770	308
8-Nov	14-Nov	31-Oct	6-Nov	686	274
15-Nov	21-Nov	7-Nov	13-Nov	396	158
22-Nov	28-Nov	14-Nov	20-Nov	1267	400
29-Nov	30-Nov	21-Nov	27-Nov	991	397

cfs: cubic feet per second

Releases from Bull Run Reservoir 2 were reduced on October 12, October 25, and November 22, 2016, to permit Portland Water Bureau (PWB) fish biologists to safely conduct spawning surveys 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.

Lower Bull Run River flows at USGS Gage No. 14140000 are depicted in Figure 2.

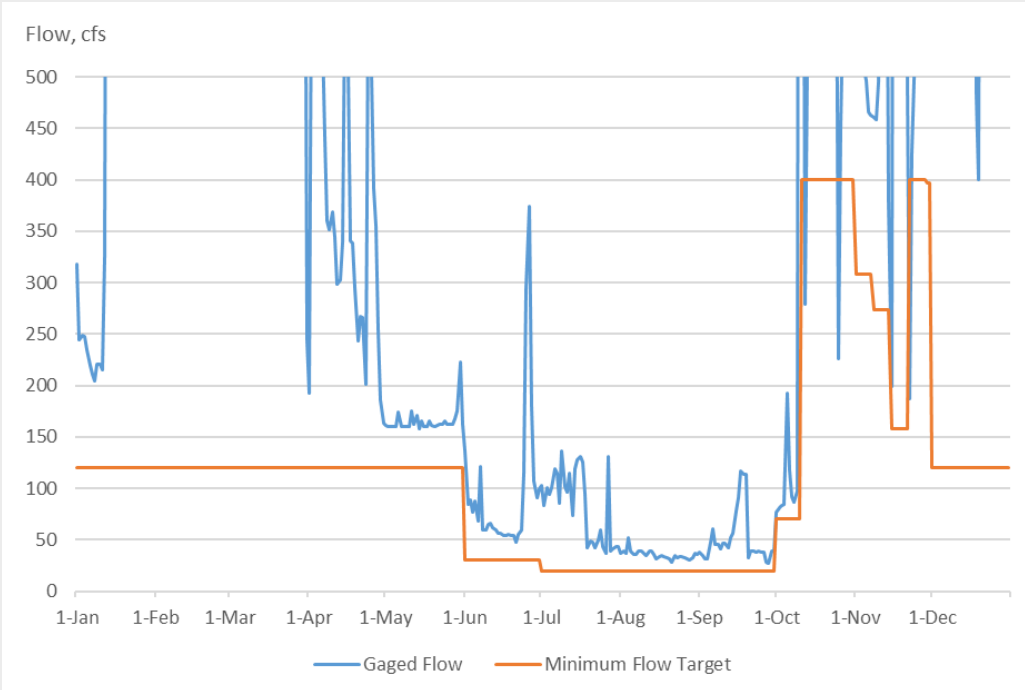

Figure 2. Lower Bull Run River Minimum and Actual Flows[a] in 2016

[a]Flows exceeding 500 cfs are not shown.

Planned Accomplishments for Calendar Year 2017

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 2017 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 Measure 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 per week from August through November. See Appendix F 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 2016

The critical spring trigger was met in 2016. Drawdown initially commenced on May 30, 2016. Downstream flows were decreased below 120 cfs starting June 2. Additional rains in mid-June refilled Bull Run reservoirs. Reservoir drawdown began again on June 30, 2016.

Because critical fall minimum flows were implemented in 2014 and 2015, the option to implement critical fall flows in 2016 was not available. The lowest 10 percent of total reservoir inflow during August and September from 1940 through 2015 was 3.53 billion gallons. Total reservoir inflow during August and September 2016 was 3.8 billion gallons with the effect Bull Run Lake release water removed; therefore, critical fall conditions did not occur in 2016. Lower Bull Run River flows at USGS Gage No. 14140000 are depicted in Figure 2 on page 40.

Planned Accomplishments for Calendar Year 2017

Critical spring and fall triggers will be assessed in 2017. If the critical spring trigger is 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 and Sandy rivers.

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"/hour (0.17'/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 assure 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"/hour.

Status of Work for Calendar Year 2016

The City was in compliance with Measure F-3 in 2016

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"/hour (hr) for 99.86 percent of the time in 2016. Downramping exceedences occurred during 12 hours, or 0.14 percent of total operating hours during the monitoring year.

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

Eleven of the twelve hours of downramping exceedences were excluded from the fluctuation limit as allowed by Measure F-3; for those hours the City analyzed the flow data to determine why the exceedences occurred. One of the twelve hours in 2016 was due to operator error. The City looked at each hour of the downramping exceedences to improve future operations. Accounting for each hour of the allowed downramping exceedences is as follows:

- 1 hour was associated with the failure of a wicket gate shear pin at Portland Hydroelectric Project Powerhouse 1 (PHP1) that required that the unit to be taken off line to allow the replacement of the shear pin. Portland Hydroelectric Project Powerhouse 2 (PHP2) was running at maximum flow with excess water going over the Dam 2 main spillway at that time. The instantaneous loss of flow at PHP1 resulted in a similar drop in the stage at Gage 14140000.
- 1 hour was associated with the tripping of an 86G alarm causing the immediate loss of flow through PHP1 while PHP 2 was running at maximum flow with excess water going over the BR Dam 2 spillway. The instantaneous loss of flow at PHP1 resulted in a similar drop in the stage at Gage 14140000.
- 1 hour was associated with the tripping of a seal water flow alarm at PHP1. PHP2 was running at maximum flow with excess water going over the BR Dam 2 main spillway at that time. The instantaneous loss of flow at PHP1 resulted in a similar drop in the stage at Gage 14140000.
- 4 hours were associated with the mandatory testing and calibration of the new Rotork valve actuators to repairs to the I-G-6 valve.
- 1 hour was associated with operator error when a new operator with limited experience with Howell-Bunger valve operations made a larger adjustment to the I-G-6 valve than the previous Operator, resulting in the exceedance.
- 2 hours were associated with the flow restrictions placed on the Dam 2 North Tunnel of 500cfs due to damage to the cathode protection system in the North Water Tower resulting in debris in the North Tunnel that had to be removed before normal operations could resume. During this restriction period, incoming flows from Reservoir 2 exceeded the ability of PHP2 and the South Howell-Bunger valves ability to pass the flow. This action was taken to assure compliance with Safe Drinking Water Act standards.
- 2 hours were associated with the mandatory maintenance and testing of the PHP2 as it was brought back on line after completion of the yearly scheduled maintenance outage period.

Planned Accomplishments for Calendar Year 2017

Flow downramping will continue to be monitored in 2017.

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 multi-level 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 will also 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 assure 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 2016

Infrastructure changes (the addition of multi-level water intake gates on the north tower at Bull Run Reservoir 2) were completed in 2014, and the multi-level intakes were placed into operation for temperature management. 2016 was the third year of using the multi-level 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 January 20 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 late March. Prior to stratification, the temperature of the bottom of the reservoir increased or decreased with the temperature of the entire reservoir. Very warm spring conditions in 2016 presented challenges for accumulating cold water in the Bull Run reservoirs, with April and May average stream temperatures being close to the warmest on record. Early summer temperatures in the bottom layer of the reservoir were 8.3 °C, which is 1.3 °C warmer than the 7 °C projected during the development of Habitat Conservation Plan.

In addition, the beginning of the temperature management period was marked by dry conditions. This led to an early start of reservoir drawdown on May 30, triggering critical spring conditions, in which instream flows were decreased as early as June 2. Temperature targets for the lower Bull Run River were low (13 °C) at that time, and required large releases from Reservoir 2 of bottom water to meet targets. At that time, the City conferred with ODFW, NMFS, and ODEQ regarding this issue, and the agencies allowed a gradual target increase from 13 °C on June 1 to 16 °C on 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). On June 1 and August 18–20, 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. The City met the target in these periods despite this exception.

In early- to mid-September, the bottom of Reservoir 2 warmed at an accelerated rate, marking the depletion of remaining cold water at the bottom of the reservoir. Starting September 14, lower Bull Run temperatures could no longer be held below the target temperature. For the period of September 14-23, lower Bull Run 7DADM temperature stayed close to the target, but departed farther from the target starting September 24 as Reservoir 2 bottom temperatures rose. Stream temperatures rose again in response to increased minimum flows that began October 1.

Substantial rains in the Bull Run watershed that started October 4 cooled the Bull Run reservoirs, and the lower Bull Run 7DADM temperature declined below 13 °C on October 19. Even though the water temperature targets for the lower Bull Run were exceeded for 35 days from September 14 through October 18, the highest 7DADM temperature during this period was 14.8 °C. The numeric criterion for that time period was 13 °C.

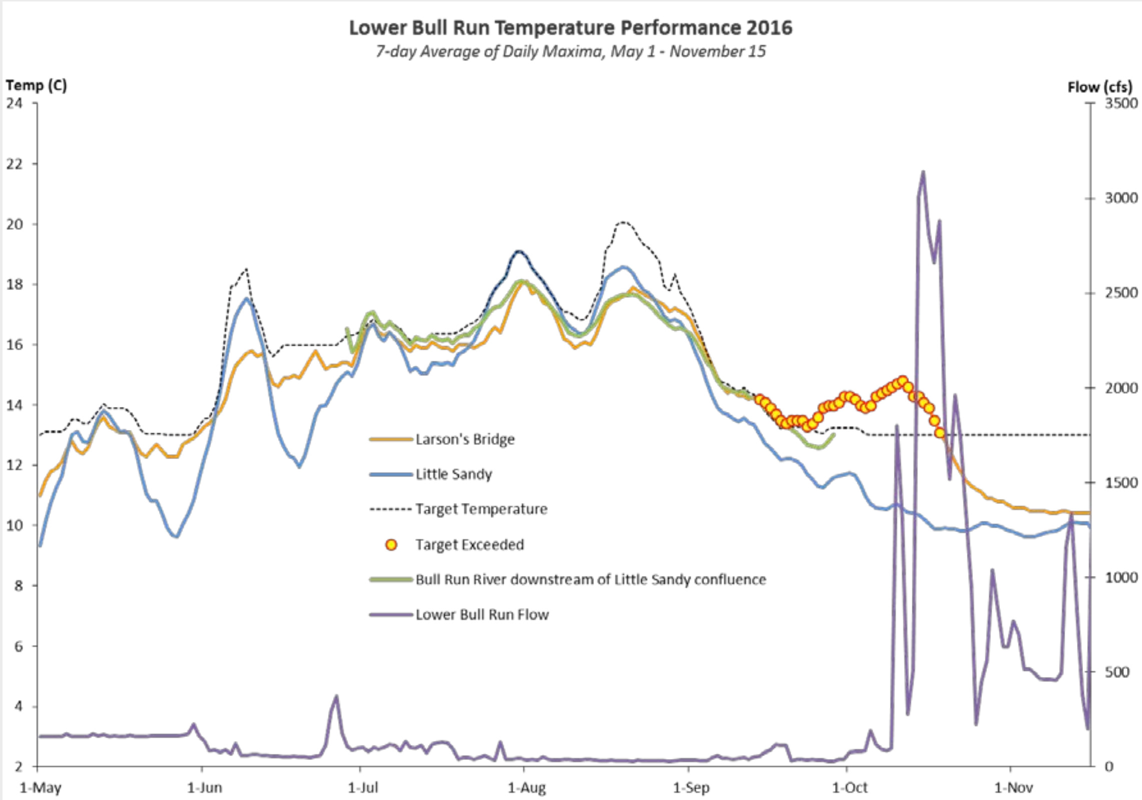

Figure 3. 7-Day Moving Average of Daily Maximum Water Temperature in the Lower Bull Run River at Larson's Bridge (USGS Gage No. 14140020) and at Little Sandy River (USGS Gage No. 14141500) for 2016. Target temperature combines numeric criteria, Little Sandy temperature, and air temperature and calendar 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.

Planned Accomplishments for Calendar Year 2017

The City communicated the water temperature information to ODEQ, NMFS and ODFW throughout 2016. 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 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 fourth year operating the new multi-level intakes at Bull Run Dam 2 will be 2017. The City will incorporate knowledge from the first three years of operating with the new multi-level intakes to improve management tools and operations in 2017.

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 assure 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 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 2016

The Bull Run reservoirs were operated to meet the requirements of Measure R-1 in 2016. Graphs of the daily surface elevations of each reservoir are shown in Figures 4 and 5.

Reservoir 1 was operated within 2 feet of the spillway elevation (1036 feet above mean sea level [MSL]) from January 1 through March 29 with brief storm-causes increases above 1036 feet above MSL. The spillway gates were lowered (closed) on March 29, and Reservoir 1 slowly filled to the top of the spillway gates and held there (1,043–1,045 feet) until Reservoir 1 started drawing down on June 30. Reservoir 1 reached its minimum elevation for 2016 of 997.0 feet on September 24, then refilled to spillway elevation (1,036 feet) on October 16. Other shorter periods of drawdown occurred October through December due to high fish flow releases and preparation for fish flow surveys.

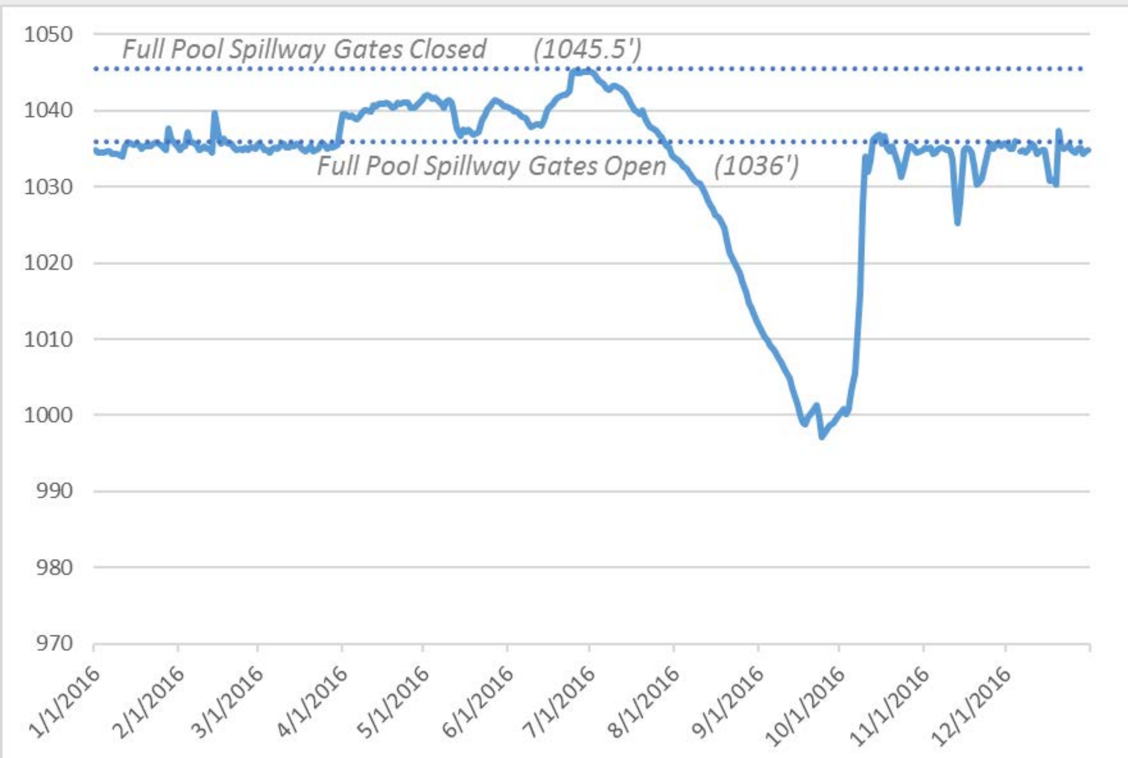

Figure 4. Reservoir 1 Elevations[a] During 2016

[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; one data point from the SCADA system was used to fill in a missing point of USGS data.

Reservoir 2 was operated within 2 feet of spillway elevation (860 feet) until September 21, when the level reached 857.3 feet. Reservoir 2 reached its minimum elevation for 2016 of 849.3 on October 5, then refilled to spillway elevation (860 feet) on October 14.

Reservoir 2 remained above the 858-foot elevation for the remainder of the year, except for brief periods to handle minimum downstream fish flows or to prepare for downstream fish surveys.

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

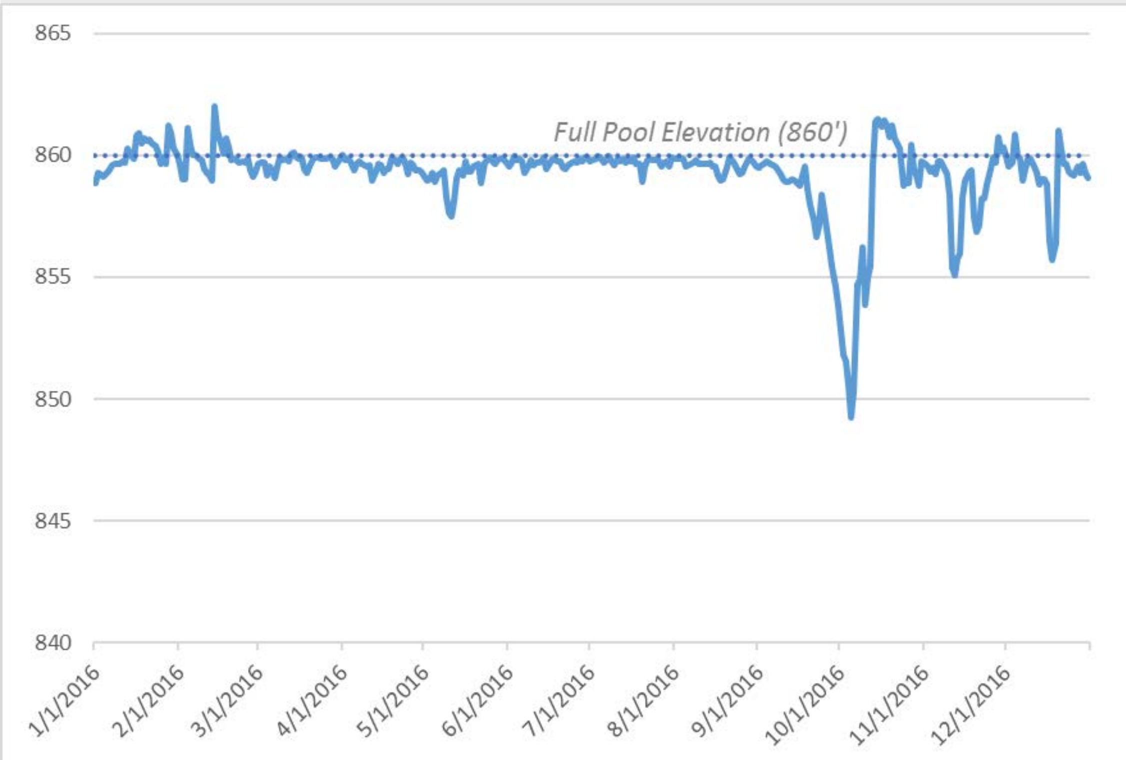

Figure 5. Reservoir 2 Elevations[a] During 2016

[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; several data points from the SCADA system were used to fill in a missing point of USGS data.

Figure 6. Reservoir 1 and Dam 1 During A Drawdown Period

Planned Accomplishments for Calendar Year 2017

Reservoir elevations will be managed in 2017 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

The City has identified three areas along the upper end of Bull Run Reservoir 1 that are important for reproduction and egg incubation for western toads and red-legged frogs to improve breeding and rearing habitat for these species.

Measure Commitments

Measure R-3—Reed Canarygrass Removal: For HCP Years 1-50, the City will cut and rake reed canarygrass away from three 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 prior to the summer season lowering of the spillway gates on Dam 1, which will flood the shallow area of the reservoir. The areas to be cut are approximately 10' x 15', 100' x 100', and 100' x 40'; this total area to be cut is approximately one-third acre.

Status of Work for Calendar Year 2016

The City met the requirements of Measure R-3 by following the first option in the plan described in the HCP Compliance Report for 2015 (see Measure R-3, Planned Accomplishments for 2016). The City cut and removed reed canarygrass from the three areas on April 27 (Figure 7).

Figure 7. Reed Canarygrass Removal, Spring 2016

Two additional steps were also taken in 2016. First, toad breeding was monitored at the three areas from April 5 through June 29. During monitoring, data on water temperature and water level were collected, and the date and locations of breeding onset were determined. Appendix H in this report provides more information on the monitoring effort. Second, reed canarygrass was cut and removed again on September 12 at the three areas, to improve breeding and rearing habitat for toads and frogs for the following year (2017). The late summer cutting was timed to occur prior to the normal recharge of Reservoir 1 in early fall, so that the areas would be flooded soon after the cutting, and reed canarygrass growth would be restricted through the fall and winter months.

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. Once the three areas were cut, the grass was removed with rakes and pitchforks, leaving grass stubble and exposed mineral soil (Figure 8).

Figure 8. Grass Stubble and Mineral Soils after Reed Canarygrass Removal, 2016

Data from monitoring in 2016 will be combined with data collected in future years to more precisely evaluate the periods that toads use the sites for breeding.

Planned Accomplishments for Calendar Year 2017

In 2017, the City plans to follow one of two options to restrict and monitor reed canarygrass growth at the three areas. The first option is to repeat the first step taken in 2016 and in the HCP years prior to 2015: cutting and removing reed canarygrass in late spring, just prior to the period when Reservoir 1 is filled to the top of the spillway gates and held there. The first option will most likely be used if flows in spring and summer are expected to be normal to high. The second option is to repeat the steps taken in 2015, including flooding the three areas early in the spring and cutting the reed canarygrass in late summer. The second option will most likely be used if flows in spring and summer are expected to be lower than normal.

If reservoir levels allow, reed canarygrass may be cut twice in 2017 (as occurred in 2016) regardless of which option is used. The City believes that both options can be effective for restricting reed canarygrass at the three areas during the period when western toads and northern red-legged frogs use the areas for breeding.

In 2017, as in 2016, the City plans to go above and beyond the requirements of Measure R-3 by monitoring toad breeding in relation to water temperature, water depth, reservoir level, and time of year (dates of egg laying). Using the information gained through monitoring, the City may be able to manage the level of Bull Run Reservoir 1 to benefit toads, while continuing to meet water supply requirements and goals, and the requirements of the HCP.

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 mimic 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 F of the HCP describes how the City will assess the effectiveness of the placed spawning gravel.

Status of Work for Calendar Year 2016

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 2016, 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 late January 2016 (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 1,260 cfs to approximately 1,280 cfs. No gravel was placed in pools.

Figure 9. Placing Gravel in the Bull Run River in 2016

Gravel placement did not result in accumulations great enough to hinder the movement of fish at any of the three sites. A high flow (5,720 cfs) on February 15, 2016, redistributed most of the placed gravel.

Planned Accomplishments for Calendar Year 2017

Spawning gravel will be placed in the lower Bull Run River in January 2017. 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 2016

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 2016. The City also managed invasive species on lower Bull Run River riparian land.

Planned Accomplishments for Calendar Year 2017

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 2016

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

Planned Accomplishments for Calendar Year 2017

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 and Sandy rivers:

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 2016

The City complied with all of the commitments in Measure O&M-2 in 2015.

Planned Accomplishments for Calendar Year 2017

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

The City will obtain 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 7). 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 7. Easement Acre Targets and Acres Obtained for HCP Implementation, Year 7 (2016)

Measure Code	Reaches	HCP Years	Easement Acre Targets	Acres Obtained by Year 2010–2015	Acres Obtained by Year 2016	Total Acres Obtained
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						
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	2	0	2
	Grand Total		**373**	**246**	**0**	**246**

[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 G, Item 3).

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 2016

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 met with NMFS in 2015 to provide an update on the status of the easement program. The City is ahead of schedule for acquiring conservation easements in the Sandy River Basin. Currently, the City has finalized easements for 246 acres (Table 7). The City did not acquire new conservation easements in 2016. The City identified a potential new easement of 30 acres on reach Sandy 7 in the Upper Sandy. This property was appraised in 2016 and is anticipated to close in 2017.

For all easements or acquired riparian buffer areas, canopy cover will be estimated both prior to work on site and after planting to determine progress towards canopy cover goals. Canopy cover estimates have not yet been determined for all acquired easements.

Table 8 summarizes the location, acreage total, and condition of the canopy cover for the easements that the City has obtained to date. Figures 10 and 11 show two recent easement parcels.

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 Camp Collins, Mench, TNC Kingfisher, and TNC Hyman easements exceed the $\geq$ 70 percent criterion stated in the HCP. The City will continue to track the canopy cover for all easements.

Figure 10. Looking Across the Sandy River at the Cornwall Easement (North Side)

Table 8. Location, Amount, and Estimate of Canopy Cover for Easements, HCP Year 7 (2016)

Reach/ Property Owner	Year Acquired	Number of Easements	Acres	Initial Canopy Cover Estimate[a]
Gordon 1A & 1B		2	23 Total	
Maunder	2011		3	47%
Bonner	2012		20	33%
Sandy 2		1	145 Total	
TNC Kingfisher	2014		25	71%
TNC Cornwall	2014		13	64%
TNC Diack	2014		35	53%
TNC Hyman	2014		2	82%
TNC Partridge	2014		16	40%
Camp Collins	2013	1	54	85%
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%
Sandy 8		1	2 Total	
Mench	2011		2	92%

Abbreviation: TNC is The Nature Conservancy

[a]Canopy cover data are collected within the first year of easement acquisition and every 5 years after that. Follow-up monitoring results will be available by April 1, 2017 for the Maunder, Rayne, and Mench easements and will be reported in the HCP Compliance Report for 2018.

Planned Accomplishments for Calendar Year 2017

The City will continue to pursue easements to meet specific HCP targets. The City will provide updates to NMFS to report progress towards meeting habitat goals.

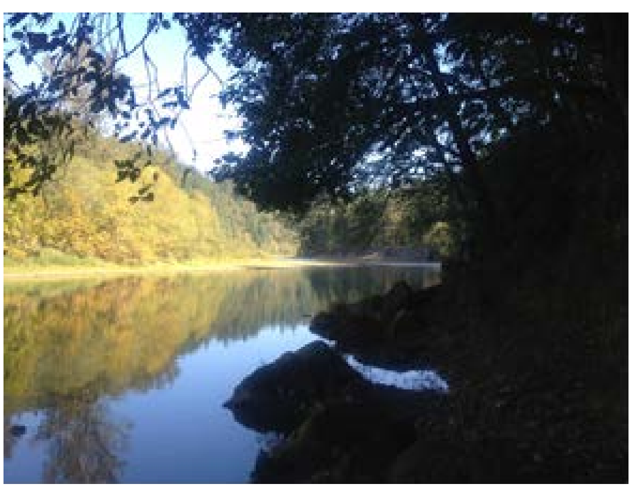

Figure 11. Looking Across the Sandy River at the Camp Collins Easement (North Side)

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 river front 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 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 2016

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 sellers for $150,000 pending environmental review.
- The environmental site assessment indicated lead contamination from more than 30 years of illegal shooting activity on the parcel.
- City staff develop 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 sellers 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 sellers are still reluctant to proceed with a sale based on the additional resources brought by the Sandy River Basin Partners.

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

Planned Accomplishments for Calendar Year 2017

The City will discuss the impacts of not being able to implement Measures H-23 and H-24 with NMFS. The City believes that the habitat benefits projected for these measures could be made up by the implementation of other conservation easement acquisitions.

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 2016

In a previous year, the City reviewed all certificated surface water rights within the Cedar Creek drainage. The City's examination resulted in three water rights to be considered for acquisition/leasing to meet the habitat goals of Measure F-5. The three water rights were located at Brownell Springs. The City had the rights appraised by a consultant, WestWater Research. (2015. Valuation of Brownell Springs Water Rights. Final Report, Prepared for Portland Water Bureau.)

In the fall of 2016, the City of Portland met with the City of Sandy to discuss the possibility of Portland leasing its Brownell Springs water rights to return water to upper Cedar Creek from June to September. The City of Sandy discussed the possibility of Portland leasing the Brownell Springs water rights at their City Council meeting in November 2016. The Sandy City Council declined to enter into an agreement with the City of Portland. The City has found no willing sellers of certified surface water rights in the Cedar Creek drainage.

Planned Accomplishments for Calendar Year 2017

The City has found no willing sellers of certified surface water rights within the Cedar Creek drainage. The City will not be able to implement this measure. The City will work with NMFS to discuss the benefits of this measure to determine whether the City can compensate with other HCP measures.

4.1.2.3 Large Wood Placement

Measures H-4 and H-17—Large Wood Placement

Location: Sandy River, Cedar Creek

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 will increase habitat complexity, providing benefits such as pools and cover for migrating, spawning, and rearing fish in the Sandy River reach 2 and Cedar Creek, reaches 2 and 3.

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

A general large wood measure description is provided in the following subsection so that duplicate text is not repeated. The specific measures for the Sandy River Basin reaches differ only by the number of logs to be placed. In future HCP compliance reports, the specific measure commitments will be included to track City compliance.

Measure Commitments

Within HCP Years 6–10, the City will work with willing landowners to place a minimum of 600 key logs into Cedar Creek. Within HCP Years 6–10, the City will work with willing landowners to place a minimum of 300 key logs into the Sandy River in a way that restores flow to at least 2,100 lineal feet of side channel. 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 reaches, Sandy 2 and Cedar 2 and 3. 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 only be used when wood movement cannot be tolerated. Anchoring will only be used 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 2016

Under the terms of HCP measure H-4, Sandy 1 and 2 Log Jams, the City is obligated to place 300 key logs in the Sandy River in a way that activates at least 2,100 feet of side channel at bankfull flows. HCP Measure H-9 will not be implemented and habitat goals were added to measure H-4 (see Appendix G, Item 5). Additional side-channel habitat and the placement of large wood were increased for measure H-4.

Under the terms of HCP measure H-17, Cedar 2 and 3 LW Placement, the City is obligated to place 600 key logs in Cedar Creek. The HCP also stipulates that large wood placements will be maintained for 15 years. The City is obligated to conduct compliance monitoring of these placements and their functional integrity.

Figure 12. Typical Large Wood Placement

H-4 Sandy 1 and 2 Log Jams

Preparations for H-4 were continued in 2016. All design-related analyses and modeling were completed and the design set was brought to a 90 percent level of completion before the end of the year. Permitting was initiated and agreements were negotiated with landowners to allow work on their properties. The City is planning to place log jams at two sites along the Sandy River, excavate portions of one historic side channel and one floodplain tributary channel, and place individual large wood pieces. The City continued accumulating construction materials for this measure. Even though Measure H-4 indicated placing a minimum of 300 key logs, the City is planning to place more large wood to meet HCP habitat goals.

H-17 Cedar 2 and 3 LW Placement

Measure H-17 was implemented in 2016. Landowner permissions were obtained for three properties only, so the number of placed logs had to be reduced to 467 pieces arranged in 55 structures. Large wood pieces included tree stems with and without root wads. Stems with root wads were at least 30 feet long, with an average diameter at approximately breast height of 18 to 24 inches. Root wad diameter was at least 4.5 feet. Stems without root wads were at least 40 feet long with an average diameter of 18 to 24 inches at the large end. Logs were placed using a heavy-lift helicopter and structures were designed to withstand a 100-year flood.

Planned Accomplishments for Calendar Year 2017

H-4 Sandy 1 and 2 Log Jams

The City plans to implement this measure in the summer of 2017. The City will continue acquiring construction materials for this measure in the spring of 2017.

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 otherwise 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 7–66–7–69 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 7–69–7–74 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 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 2016

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 2016.

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 2017

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 has 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 have the potential to be affected by work in Bull Run Reservoir 2 are listed in Table 9 with the language from the Oregon Administrative Rule that describes the standard.

Table 9. 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	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 dissolved oxygen.
pH	Algal blooms may cause spikes in pH values.
Temperature	Changes in withdrawal depth may result in temperature changes downstream.

Prior to the Dam 2 Tower improvements (from 2009 to 2013), PWB gathered monitoring data to provide baseline information. Monitoring data from 2016 were compared to the baseline data. Reservoir monitoring for 401 certification conditions in 2016 showed results were within anticipated ranges, with the exception of low dissolved oxygen levels at the base of Reservoir 2 that persisted for approximately six weeks, from August 9 through September 20, 2016. The period of low dissolved oxygen levels at the base of Reservoir 2 does not represent a significant change to water quality. Appendix B of this report describes the monitoring efforts and results in detail.

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.

For the first monitoring year, the City conducted baseline monitoring to serve as a benchmark for effectiveness monitoring of large wood and log jam placement.

4.2.1 Large Wood and Log Jam Placement

Measures H-3, H-4, and H-17—Large Wood Placement

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

Benefits: 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 will increase habitat complexity, providing benefits such as pools and cover for migrating, spawning, and rearing fish in Gordon Creek reaches 1A and lB, Trout Creek reach 1A, Cedar Creek reaches 2 and 3, and Sandy River reach 2.

Measure Commitments

The measure commitments for HCP Measures H-4, H-5, H-6, and H-17 are described in Section 4.1.2.3, which starts on page 40 of this report.

[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.

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 created for reaches 1A and 1B of Gordon Creek are to achieve 80 percent of the predicted increase in pool and pool tail habitat within 15 years of implementation. Additional habitat objectives for reaches 2 and 3 of Cedar Creek are to achieve 80 percent of the predicted increase in beaver ponds and pools within 15 years of implementation. Reach 2 of the Sandy River and reach 1A of Trout Creek have 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 2016

The City fully complied with the effectiveness monitoring as required by the HCP for Measures H-4, H-5 and H-6 (which have been completed), and H-17 (which was completed after effectiveness monitoring occurred in 2017). The specific monitoring accomplishments are referenced by measure name (e.g., Gordon 1A and 1B LW Placement) in Appendix A of this report.

Planned Accomplishments for Calendar Year 2017

The collection of baseline data for effectiveness monitoring will be conducted in 2017 in the Sandy River reach 2, for Measure H-4 (to be implemented in 2017). Post-treatment data collection for effectiveness monitoring will be conducted in 2017 in Cedar Creek for Measure H-17. Baseline and post-treatment habitat surveys will follow protocols identical to those used in 2016.

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 2016. 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 2016 was within the range of previous years (2010-2015) at all locations and flows, but was less than in 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.

Figure 13. PWB Staff Evaluating Spawning Gravel in the Lower Bull Run River

4.3.1.2 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 ten-year, seven-day average flood. No additional TDG data were collected in 2016 because the appropriate flow conditions for monitoring did not occur.

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 D of this report.

4.3.1.3 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 2016, but high flows prevented scheduled surveys from being conducted on two occasions. The peak adult Chinook count, minimum escapement[2] estimate, and cumulative redd count in 2015 were within the range of previous years' estimates, 2005-2014.

A detailed description of the Bull Run Adult Chinook Population Research protocol is available in Appendix F of the HCP. Protocols followed on two occasions in late August and early September 2015 differed from those described in HCP Appendix F because of the operation of a weir near the mouth of the Bull Run River by ODFW to collect returning adult hatchery Chinook salmon. These protocol changes and the results of the current year's survey are available in Appendix E of this report.

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

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 (JOM) 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 eight streams, one more than planned, in 2016: Clear Creek, Still Creek, Salmon River, Cedar Creek, Bull Run River, Little Sandy River, Gordon Creek, and Beaver Creek. Population estimates were calculated for steelhead and coho smolts in all eight streams and fork length distributions, condition factors, and emigration patterns were analyzed. The average ages of smolts from the Bull Run River, Little Sandy River, and Beaver Creek from 2015 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 2014.

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 than coho smolts, on average, in all streams. Steelhead from all streams emigrated at approximately the same time, while coho emigrated earlier from low-elevation than from higher-elevation streams.

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 lower 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 F of the HCP. The results of this research are presented in Appendix F 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 for Calendar Year 2016

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

Through June 2018, the City committed to fund one project for building funding capacity for the Sandy River Basin Partners, two projects to do scale analysis, one culvert replacement project in the Salmon River Basin, and eight restoration projects for the upper Sandy River, the Salmon River, or Still Creek, which are priority restoration subbasins for the partners.

The City has committed a total of $881,626 of Habitat Fund dollars through June 2018 to projects implemented by Sandy River Basin Partners. Table 10 shows the past projects that have been funded through the HCP Habitat Fund.

Table 10. 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	Partially fund design and construction of habitat

Table 10. Past Projects Funded through the HCP Habitat Fund				
Number	**Project Partner**	**Amount**	**Duration**	**Purpose**
			2011	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.
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.
Subtotal for Past Projects		$733,228		

Planned Accomplishments for Calendar Year 2017

The City has approved one project from Sandy River Basin Partners to be implemented between July 2017 and June 30, 2018. The City will provide funding to The Freshwater Trust to support construction of habitat restoration projects on the Salmon River and

Still Creek. Table 11 shows the project planned to be funded through the HCP Habitat Fund.

Table 11. Planned Projects to Be Funded through the HCP Habitat Fund

Number	Project Partner	Amount	Duration	Purpose
Not yet assigned	Freshwater Trust	$148,398	July 2017 through June 2018	Restoration work on the Salmon River and Still Creek.
Subtotal for Planned Projects		$148,398		

Table 12. 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 2016 (HCP Year 7), 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**	**HCP 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 2016.
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 2016.
F-3	**Flow Downramping**	Maintain downramping rate at or below 2”/hour	Record hourly flows at USGS Gage No. 14140000	2010–59	Ongoing measure. Measure was in full compliance in 2016.
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 G, Item 9).
T-1	**Pre-infrastructure Temperature Management**	<u>Pre-infrastructure objective:</u> 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	HCP 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 2016.
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 2016.
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 2016. Appendix H, new in this Year 7 report, summarizes 2016 monitoring conducted to determine whether the measure is having the desired outcomes for toads.

Bull Run Measures–Compliance

#	Measure	Measurable Habitat Objective	Compliance Monitoring	HCP Years	Status
H-1	**Spawning Gravel Placement**	Supply spawning gravel in amounts equivalent to natural accumulation	Survey the lower Bull Run River (RM 1.5–RM 6.0) annually in Years 2–11 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 F of the HCP	2010–59	Ongoing measure. Measure was in full compliance for 2016.
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 2016.
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 2016.
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 2016.

Offsite Measures–Compliance

#	Measure	Measurable Habitat Objective	Compliance Monitoring	HCP 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	HCP 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	HCP 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.
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	Measure has been partially completed—PWB anticipates full compliance by 2024.
H-19	**Salmon 1 Riparian Easement and Improvement**	Establish riparian forest of ≥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	PWB anticipates full compliance.
H-20	**Salmon 2 Riparian Easement and Improvement**	Establish riparian forest of ≥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 ≥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	

Offsite Measures–Compliance

#	Measure	Measurable Habitat Objective	Compliance Monitoring	HCP Years	Status
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).
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	HCP 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.
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.

Offsite Measures–Compliance

#	Measure	Measurable Habitat Objective	Compliance Monitoring	HCP Years	Status
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.
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**	**HCP Years**	**Status**
H-4	**Sandy 1 and 2 Log Jams**	Place 10 engineered log jams in reaches Sandy 1 and 2	Same as above	2015–19	Design for this measure has been finished. Implementation is planned for 2017.
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, August 16, 2011 (see Appendix F, Item 2 in the 2011 report) and March 15, 2012 (see Appendix G, Item 4 in the 2012 report).

Offsite Measures–Compliance

#	Measure	Measurable Habitat Objective	Compliance Monitoring	HCP 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.
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 Sandy 1 and 2 LW Placement 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	HCP 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 Redesign**	Maintain one-third mile of floodplain habitat for steelhead, coho, and spring Chinook Place 25 pieces of LW in reaches Zigzag 1A and 1B	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	
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 2016.
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 2016.
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 2016.

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 will continue through 2019, or as determined by ODEQ. See Appendix B.

Offsite Measures—Effectiveness

#	Measure	Measurable Habitat Objective	Effectiveness Monitoring	HCP 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 A.
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 A.
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**	**HCP 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 1 and 2 Log Jam Placements**	Achieve 80% of predicted increase in pieces of LW within 15 years of implementation	Conduct habitat surveys per monitoring protocol	2015–19	Measure was in full compliance in 2016. Effectiveness monitoring was initiated in 2015 and will continue through 2030.
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 was in full compliance in 2016. Effectiveness monitoring was initiated in 2014 and will continue through 2029.

Offsite Measures—Effectiveness					
#	**Measure**	**Measurable Habitat Objective**	**Effectiveness Monitoring**	**HCP Years**	**Status**
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).
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	
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 2016.

Research

Topic	Research Protocol & Analysis	Results Reporting	HCP Years	Status and Report Location
Spawning Gravel Placement	Change in gravel from baseline each year, trends over time, using t-tests & linear regression	HCP Years 6 and 12	2010–59	Measure was in full compliance in 2016. 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 2016.
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 2016. See Appendix D.
BR Adult Chinook Population	Survey, sampling, linear regression	Include with annual compliance report	2010–59	Measure was in full compliance in 2016. See Appendix E.
Sandy River Basin Smolt Monitoring	Mark recapture study, various analyses methods	Include with annual compliance report	2010–59	Measure was in full compliance in 2016. See Appendix F.

Appendixes

A. Effectiveness Monitoring for Offsite In-Channel Conservation Measures

B. Monitoring Results for Certification According to Section 401 of the Clean Water Act

C. Lower Bull Run River Spawning Gravel Research

D. Total Dissolved Gases in the Bull Run River

E. Lower Bull Run River Adult Chinook Population

F. Sandy River Basin Smolt Monitoring

G. Correspondence on Measures

H. Western Toad Monitoring for Reservoir Operations

Appendix A

Bull Run HCP Effectiveness Monitoring Report

Effectiveness Monitoring for Offsite In-Channel Conservation Measures

April 2017

Burke Strobel
City of Portland Water Bureau

Contents

Tables

1. Summary

The City of Portland Water Bureau (PWB) was in full compliance with its Habitat Conservation Plan obligations in 2016 with regard to effectiveness monitoring for offsite in-channel conservation measures. Fish habitat surveys were conducted for four offsite measures—H-4, Sandy 1 and 2 Log Jams; H-5, Gordon 1A and 1B Large Wood Placement; H-6, Trout 1A Large Wood Placement; and H-17, Cedar Creek Large Wood Placement.

This appendix summarizes the results of the 2016 surveys. The data collected in 2016 for H-4, Sandy 1 and 2 Log Jams and H-17, Cedar Creek Large Wood Placement, contribute to information about baseline conditions, with which the post-treatment conditions of each stream will be compared. This was the second year of baseline monitoring in the Sandy River. It was also the second year of post-treatment monitoring in Gordon Creek and Trout Creek. H-5, Gordon 1A and 1B Large Wood Placement and H-6 Trout 1A Large Wood Placement were implemented in September 2012.

2. Introduction

PWB committed through its Bull Run Water Supply Habitat Conservation Plan (HCP; Portland Water Bureau 2008) to implement a number of in-channel fish habitat enhancement measures at offsite locations. Offsite locations are those not in the Bull Run watershed, but at 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.

Associated with each offsite in-channel measure are one or more measurable habitat objectives. 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.

In 2016, baseline data and post-treatment data were collected in streams. Baseline data were collected in the Sandy River and Cedar Creek. Post-treatment data were collected for Gordon Creek and Trout Creek in 2016.

This appendix describes the effectiveness monitoring protocols and results to-date for the in-channel measures to be conducted in the Sandy River, Cedar Creek, Gordon Creek, and Trout Creek. 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 ranked by the predicted net change in the attributes' respective metrics listed in Table 1. The net attribute changes in Table 1 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 time scales that are longer than the time scales for the offsite in-channel measures. The benefits of other measures are not part of the scope of this research.

The anticipated benefits from H-4, Sandy 1 and 2 Log Jams and H-6, Trout 1A Large Wood Placement have been changed from what was originally reported in the HCP. The scope of Measure H-4 has been changed to include the restoration work in Sandy 2 and to include the expected fish production benefits originally attributed to HCP measure H-9, Sandy 1 Channel Reconstruction. The original measure planned for Sandy 1 and 2 anticipated increasing large wood in Sandy 2 by 70 percent. The current measure scope calls for increasing large wood by 39 percent, but also anticipates creating off-channel habitat and improving riparian function. Riparian function is not evaluated by the City's Effectiveness Monitoring Program. The scope of Measure H-6 has been changed to include the restoration work in Trout 1A and to include the wood pieces intended for placement in Trout 2A by HCP measure H-7 Trout 2A Large Wood Placement. HCP measure H-7 was cancelled in 2012 because of the lack of landowner permissions.

The net changes predicted in Table 1 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 to statistically 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 1. Attributes and Measurable Habitat Objectives in Reaches Affected by In-Channel Measures and Surveyed in 2016[a,b]

Attribute	Measurable Habitat Objective (80% of Net Change in Metric) 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	100%	Cedar 2
Large Woody Debris	Number of pieces per channel width	67%	Cedar 3
Beaver Ponds	Percentage of reach (by surface area) that comprises beaver ponds	39%	
Pool Habitat	Percentage of reach (by surface area) that comprises pool habitat	25%	
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 tail-outs	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 tail-outs	326%	
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

[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.

4. Key Questions and Hypothesis

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

Question: 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 significantly change (summarized in Table 1). 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 2. 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 2. Paired Treatment and Control Reaches in Streams Surveyed in 2015

Watershed	Treated Reaches	Control Reaches
Lower Sandy River[a]	Sandy 2	Sandy 2
Middle Sandy River	Cedar 2	Cedar 4
	Cedar 3	Cedar 4
Lower Sandy River	Gordon 1A	Gordon 2A
	Gordon 1B	Gordon 2A
Lower Sandy River	Trout 1A	Trout 3A
	Trout 2A	Trout 3A

[a]The upstream-most one mile of Sandy 2 serves as the control reach for the rest of Sandy 2.

5.2 Spatial Scale

The measureable habitat objectives (in Table 1) 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 three pre-treatment surveys and five post-treatment surveys are conducted. Pre-treatment surveys will be 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 1 foot 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)
  - 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

[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.

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 monuments survey reaches at specific intervals to allow for standardization of lengths between years, unless natural landmarks are identified to serve a similar purpose.

6. Analysis

6.1 Data Storage

Monitoring data collected during the HCP is maintained by PWB in a 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):

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

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. 2016 Results

Tables 3, 4, 5, and 6 summarize the results for offsite in-stream measure effectiveness monitoring surveys conducted in 2016 in the Sandy River, Cedar Creek, Gordon Creek, and Trout Creek, respectively. The tables also compare survey results with the values for the current condition of the same habitat attributes in the EDT database.

Table 3. Comparison of Values for Various Habitat Attributes[a] in the Sandy River Derived from the EDT Database and 2016 Survey Results

	Treatment Reach		Control Reach	
	Sandy 2 Reach		Sandy 2 Upper Reach	
Attribute	EDT Current	2016 Survey	EDT Current	2016 Survey
Large Wood (pieces/CW)[b]	6.5	7.9	6.5	1.1
Backwater Pools	2.4%	0.5%	2.4%	0.0%
Beaver Ponds	0.0%	0.1%	0.0%	0.0%
Pools	13.9%	29.3%	13.9%	36.7%
Pool Tails	2.8%	5.9%	2.8%	0.7%
Small-Cobble Riffles	34.8%	9.4%	34.8%	0.0%
Large-Cobble Riffles	34.8%	33.3%	34.8%	45.2%
Glides	11.1%	21.5%	11.1%	17.4%
Off-Channel Habitat	3.0%	0.0%	3.0%	0.0%

Table 3. Comparison of Values for Various Habitat Attributes[a] in the Sandy River Derived from the EDT Database and 2016 Survey Results

	Treatment Reach		Control Reach	
	Sandy 2 Reach		Sandy 2 Upper Reach	
Attribute	**EDT Current**	**2016 Survey**	**EDT Current**	**2016 Survey**
Percent Fines	14.5%	21.5%	14.5%	6.0%
Embeddedness	37.5%	38.8%	37.5%	32.0%

[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 4. Comparison of Values for Various Habitat Attributes[a] in Cedar Creek Derived from the EDT Database and 2016 Survey Results

	Treatment Reaches				Control Reach	
	Cedar 2 Reach		Cedar 3 Reach		Cedar 4 Reach	
Attribute	**EDT Current**	**2016 Survey**	**EDT Current**	**2016 Survey**	**EDT Current**	**2016 Survey**
Large Wood (pieces/CW)[b]	1.5	1.6	1.5	1.3	3.0	3.2
Backwater Pools	14.0%	0.0%	7.0%	0.1%	2.0%	0.0%
Beaver Ponds	1.0%	0.9%	6.0%	0.0%	0.0%	0.0%
Pools	14.0%	23.1%	21.0%	29.8%	19.0%	12.5%
Pool Tails	3.0%	4.6%	4.0%	2.1%	3.0%	0.7%
Small-Cobble Riffles	25.0%	15.3%	24.0%	10.4%	28.0%	3.2%
Large-Cobble Riffles	35.0%	56.1%	33.0%	56.3%	50.0%	83.6%
Glides	0.0%	0.0%	6.0%	1.2%	4.0%	0.0%
Off-Channel Habitat	8.0%	0.0%	15.0%	0.0%	0.0%	0.0%
Percent Fines	14.5%	0.8%	8.5%	20.0%	8.5%	2.2%
Embeddedness	0.0%	20.4%	0.0%	23.0%	0.0%	28.0%

[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 5. Comparison of Values for Various Habitat Attributes[a] in Gordon Creek Derived from the EDT Database and 2016 Survey Results

	Treatment Reaches				Control Reach	
	Gordon 1A Reach		Gordon 1B Reach		Gordon 2A Reach	
Attribute	EDT Current	2016 Survey	EDT Current	2016 Survey	EDT Current	2016 Survey
Large Wood (pieces/CW)[b]	1.5	2.5	1.5	3.7	1.5	4.0
Backwater Pools	0.0%	0.2%	0.0%	0.1%	0.0%	0.0%
Beaver Ponds	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Pools	14.0%	38.4%	6.5%	29.8%	3.2%	21.0%
Pool Tails	3.5%	2.0%	1.3%	0.4%	3.2%	0.5%
Small-Cobble Riffles	52.3%	20.6%	58.4%	3.4%	40.6%	0.9%
Large-Cobble Riffles	30.2%	32.0%	33.8%	66.3%	52.9%	77.6%
Glides	0.0%	6.9%	0.0%	0.0%	0.0%	0.0%
Off-Channel Habitat	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%
Percent Fines	24.0%	11.5%	8.5%	9.6%	8.5%	2.6%
Embeddedness	0.0%	27.5%	0.0%	29.5%	0.0%	19.6%

[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 2016 Survey Results

	Treatment Reaches				Control Reach	
	Trout 1A Reach		Trout 2A Reach		Trout 3A Reach	
Attribute	EDT Current	2016 Survey	EDT Current	2016 Survey	EDT Current	2016 Survey
Large Wood (pieces/CW)[b]	1.5	1.6	1.5	1.6	1.5	2.4
Backwater Pools	10.3%	0.0%	0.0%	0.0%	0.0%	0.0%
Beaver Ponds	0.0%	51.8%	0.0%	0.0%	0.0%	0.0%
Pools	4.1%	2.6%	0.0%	8.1%	3.9%	14.3%
Pool Tails	1.0%	0.4%	0.0%	0.0%	0.0%	0.5%
Small-Cobble Riffles	41.2%	13.2%	58.0%	0.0%	54.9%	0.0%
Large-Cobble Riffles	43.3%	7.0%	42.0%	91.9%	41.2%	85.2%
Glides	0.0%	25.1%	0.0%	0.0%	0.0%	0.0%
Off-Channel Habitat	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%

Table 6. Comparison of Values for Various Habitat Attributes[a] in Trout Creek Derived from the EDT Database and 2016 Survey Results

	Treatment Reaches				Control Reach	
	Trout 1A Reach		Trout 2A Reach		Trout 3A Reach	
Attribute	EDT Current	2016 Survey	EDT Current	2016 Survey	EDT Current	2016 Survey
Percent Fines	14.5%	15.0%	8.5%	0.0%	8.5%	5.0%
Embeddedness	0.0%	36.4%	0.0%	10.0%	0.0%	20.0%

[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 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 measureable 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 is given in respective order in parentheses in the Reach column, separated by a comma.

Table 7. Baseline Averages, Post-Treatment Targets, and Post-Treatment Averages for Habitat Attributes with Measurable Habitat Objectives in Streams Surveyed in 2016[a,b]

Attribute	Baseline Average	Standard Deviation	Post-Treatment Target	Post-Treatment Average[c]	Reach
Large Woody Debris (pieces/CW)	7.41	0.65	9.0	NA	Sandy 2 (n=1,0)
Off-Channel Habitat	0.03%	0.00%	3.04%	NA	
Large Woody Debris (pieces/CW)	2.04	0.34	3.00	NA	Cedar 2 (n=2,0)
Large Woody Debris (pieces/CW)	2.10	0.82	2.50	NA	Cedar 3 (n=2,0)
Beaver Ponds	0.00%	0.00%	7.89%	NA	
Pool Habitat	27.12%	2.35%	26.31%	NA	
Large Woody Debris (pieces/CW)	2.32	0.44	10.00	2.77	Gordon 1A (n=4)
Backwater Pools	0.48%	0.78%	5.10%	0.11%	

Table 7. Baseline Averages, Post-Treatment Targets, and Post-Treatment Averages for Habitat Attributes with Measurable Habitat Objectives in Streams Surveyed in 2016[a,b]

Attribute	Baseline Average	Standard Deviation	Post-Treatment Target	Post-Treatment Average[c]	Reach
Pool Habitat	36.27%	7.44%	30.00%	35.95%	Gordon 1B (n=4)
Pool-Tail Habitat	1.03%	0.64%	5.10%	1.89%	
Small-Cobble Riffles	8.20%	4.96%	34.80%	15.85%	
Large-Cobble Riffles	43.63%	7.72%	25.00%	36.01%	
Fine Sediment	12.64%	4.55%	18.00%	15.28%	
Large Woody Debris (pieces/CW)	3.67	0.53	10.00	4.60	
Backwater Pools	0.07%	0.08%	4.70%	0.07%	
Pool Habitat	26.06%	8.51%	20.20%	23.20%	Trout 1A (n=3)
Pool-Tail Habitat	0.37%	0.32%	5.50%	0.62%	
Small-Cobble Riffles	2.26%	1.76%	35.00%	3.81%	
Large Woody Debris (pieces/CW)	1.11	1.00	1.60	2.06	
Large Woody Debris (pieces/CW)	5.47	1.21	1.70	4.34	Trout 2A (n=3)

[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 takes the place of a post-treatment average if the project has not yet been implemented.

9. Discussion

The results presented in Tables 3, 4, 5, 6, and 7 of this report contribute to the baseline average of values and begins a record of post-treatment values for the respective monitored habitat attributes. 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 this stream in 2016 are post-treatment measurements. Further post-treatment data will be collected in Gordon Creek and Trout Creek in 2019, 2022, and 2025. The bureau will begin collecting post-treatment data on Cedar Creek in 2017. One more year of baseline data will be collected on the Sandy River.

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

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Appendix B

Bull Run HCP Monitoring Report

Monitoring Results for Certification According to Section 401 of the Clean Water Act

February 2017

Kristin Anderson
City of Portland Water Bureau

Contents

1. Summary

The City modified its Bull Run Dam 2 water intake towers per the commitments described in the Bull Run Water Supply Habitat Conservation Plan (HCP) Measure T-2. As part of the conditions from the Federal Energy Regulatory Commission that oversees the associated Portland Hydroelectric Project, the City must monitor and report on the impacts of the Dam 2 Tower project to the Oregon Department of Environmental Quality (DEQ). DEQ has issued a Section 401 certification under the Clean Water Act. The certification requirements describe the conditions the City must meet (Oregon Department of Environmental Quality 2012). The 401 conditions require the City to report on five water-quality parameters: 1) nuisance phytoplankton growth, 2) the creation of taste, odors, and toxic conditions, 3) dissolved oxygen levels, 4) pH levels, and 5) temperature.

This report is produced annually, as part of the HCP compliance report. Baseline water quality sampling occurred from 2009 to 2013. Baseline conditions are those that existed before construction and operation of the Dam 2 tower. The City will be monitoring the five water quality parameters for five years, 2014–2018. Initial monitoring started after the completion of the Dam 2 Tower project. The monitoring data will be compared to pre-construction and operation conditions (baseline conditions) to document changes in water quality due to the modifications to the Dam 2 tower, or Dam 2 operations.

This report includes results from the 2016 water quality monitoring efforts (see Exhibit A). For nuisance phytoplankton growth and taste, odors, and toxic conditions, the City tracked nutrient conditions and did not observe any increasing trends compared to baseline conditions. Observations of dissolved oxygen and pH were within the range observed in baseline conditions, with the exception of some measurements of dissolved oxygen at the base of the reservoir. The results section of this appendix includes a discussion of water quality criteria for reservoirs as described in the Oregon Administrative Rules and how Bull Run Reservoir 2 results comply with these criteria.

2. Introduction

As part of the HCP, the City of Portland is implementing its Temperature Management Plan for the Lower Bull Run River to fulfill requirements of the Clean Water Act (City of Portland 2008). The Temperature Management Plan describes the background, scientific basis for, baseline conditions, and implementation plan for HCP Measure T-2. The intent of HCP Measure T-2—Post-infrastructure Temperature Management—is to better control the temperature of water that PWB releases from the reservoir for fish in the lower Bull Run River. The measure requires that PWB design, permit, and complete a project to modify water intake towers at Dam 2 to allow taking water from the reservoir at different levels. For the Dam 2 Tower Improvement Project, the north intake tower was modified to have multi-level gates for taking water from Reservoir 2.

Conducting this project affects the operation of the Portland Hydroelectric Project (PHP) Powerhouse 2. Because of the proposed modifications to the Dam 2 infrastructure, the City completed a non-capacity license amendment process with the Federal Energy Regulatory Commission (FERC). As part of that licensing process, the Oregon Department of Environmental Quality (ODEQ) reviewed the impacts of the Dam 2 Tower project on certain water-quality parameters that have the potential to be affected by the operation of the modified north intake tower. ODEQ approved a 401 certification for the Dam 2 Tower Project and issued certification conditions to the City in 2012.

Section 401 of the CWA requires certification that the discharge water from a proposed action, such as work on the intake towers, will comply with water-quality standards in Oregon. The five water-quality parameters identified in the 401 certification that have the potential to be affected by work in Bull Run Reservoir 2 are listed in Table 1 with the Oregon Administrative Rule (OAR) number and the OAR description of the potential impact.

Table 1. Water Quality Parameters to Monitor for CWA Section 401 Certification

Water Quality Parameter	Oregon Administrative Rule	Potential Impact
Nuisance Phytoplankton Growth	OAR 340-041-0019	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	OAR 340-041-007(12)	Taste and odor or toxic conditions can occur from nuisance algal blooms.
Dissolved Oxygen	OAR 340-041-0016	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 dissolved oxygen.
pH	OAR 340-041-0021	Algal blooms may cause spikes in pH values.
Temperature	OAR 340-041-0028	Changes in withdrawal depth may result in temperature changes downstream.

The initial monitoring from 2009 to 2013 provided baseline results. The monitoring results in subsequent years are compared with the baseline data.

3. Monitoring Design

Monitoring for the five parameters was conducted as specified in Table 2 (on page 5) when conditions were safe to do so.

3.1 Parameters

3.1.1 Nuisance Phytoplankton Growth and the Creation of Taste, Odors, and Toxic Conditions

The purpose of this monitoring is to determine whether operation of the new intake structure will contribute to the formation of nuisance or toxic algal blooms in Reservoir 2. In 2016, the City completed monthly sampling of nutrient concentrations in Bull Run Reservoir 2. Nutrient samples were analyzed for nitrate ($NO_3^{=}$), nitrite (NO_2^{-}), total nitrogen (N), reactive phosphorus ($PO_4^{=}$), and total phosphorus (P). See Section 3.2 for a description of the sampling methods for these parameters.

3.1.2 Dissolved Oxygen

Dissolved oxygen was monitored upstream and downstream of Bull Run Dam 2 in 2016. This monitoring fulfills two objectives:

- To determine whether operation of the new intake structure contributes to changes in dissolved oxygen concentrations within the reservoir
- To determine whether operation of the new intake structure provides the level of oxygen saturation established by Oregon DEQ in the Clean Water Act Section 401 Certification Conditions (Oregon Department of Environmental Quality 2012).

Monitoring for reservoir dissolved oxygen concentrations consisted of biweekly dissolved oxygen measurements in Bull Run Reservoir 2. Monitoring for lower Bull Run River flow consisted of biweekly dissolved oxygen measurements in the lower Bull Run River downstream of Reservoir 2. A station for this monitoring has been established at the bridge over the Bull Run River immediately below Headworks (Headworks Bridge). See Section 3.2 for a description of the sampling methods for this parameter.

3.1.3 pH Levels

Compliance with the pH parameter was monitored through biweekly pH measurements in Bull Run Reservoir 2. See Section 3.2 for a description of the sampling methods for this parameter.

3.1.4 Temperature

Compliance with the temperature parameter was monitored upstream and downstream of Bull Run Dam 2. This monitoring fulfills two objectives:

- Provide information on how operation of the new intake affects stratification in Reservoir 2
- Determine how the daily maximum temperature in the lower Bull Run River is affected by operation of the new intake tower

Monitoring for stratification consisted of biweekly temperature measurements in Bull Run Reservoir 2. Monitoring the daily maximum temperature measurements at Larson's Bridge in the lower Bull Run River was already being conducted as part of compliance for HCP Measure T-1 Pre-Infrastructure Temperature Management. For HCP Measure T-2, Post-Infrastructure Temperature Management, the bureau continues to report on temperatures in the lower Bull Run River at Larson's Bridge for the period required for 401 Certification.

3.2 Sampling

Reservoir water sampling was conducted from a boat at the deepest part of Reservoir 2, denoted as Station 60-1. Grab samples for nutrients were collected with a Kemmerer sampler at discrete depths beginning at three meters above the reservoir bottom, continuing up at intervals in the water column and ending with a sample at a depth of one meter.

Measurements of dissolved oxygen, pH, and temperature were collected *in situ* in a vertical profile using a multiparameter probe that logs the data as they are collected. During the baseline monitoring period, a weight was suspended three meters below the sampling device to determine reservoir depth. Investigators interpreted that the action of the weight hitting the bottom of the reservoir caused some sediment to be stirred up, resulting in lower-than-expected dissolved oxygen concentrations. Late in 2013, reservoir sampling for dissolved oxygen included using a depth finder to determine reservoir depth. Samples at the Headworks Bridge for downstream dissolved oxygen measurements were collected by a multiparameter probe lowered from the bridge into the river.

Temperature measurements at Larson's Bridge were made by the U.S. Geological Survey (USGS) using a temperature probe placed in the river. Data were stored at 15-minute intervals on a data logger on-site and telemetered hourly via satellite to the USGS data center, from which they were made available on the Internet. The 15-minute data are considered provisional and are used by the USGS to determine daily mean, minimum, and maximum temperatures, which are published annually as approved data.

Table 2 summarizes the sampling methods, locations, and baseline sampling periods by parameter.

Table 2. Sampling Methods, Locations, and Baseline Periods for Section 401 Water Quality Parameters

Water Quality Parameter	Sampling Method	Sampling Location	Baseline Sampling Period
Nuisance Phytoplankton Growth	Monthly nutrient samples at specific depths	Reservoir 2 Station 60-1	January 2009 – December 2013
Creation of Taste, Odors, Toxic Conditions	Monthly nutrient samples at specific depths	Reservoir 2 Station 60-1	January 2009 – December 2013
Dissolved Oxygen	Biweekly *in situ* vertical profiles	Reservoir 2 Station 60-1	January 2009 – December 2013
	Biweekly multiparameter probe lowered from bridge	Headworks Bridge	August 2012 – December 2013
pH	Biweekly *in situ* vertical profiles	Reservoir 2 Station 60-1	January 2009 – December 2013
Temperature	Biweekly *in situ* vertical profiles	Reservoir 2 Station 60-1	January 2009 – December 2013
	15-minute monitoring with on-site data logger	USGS Station 14140020 at Larson's Bridge	N/A[a]

[a]Temperature data are continually collected at this location.

3.3 Map of Sampling Sites

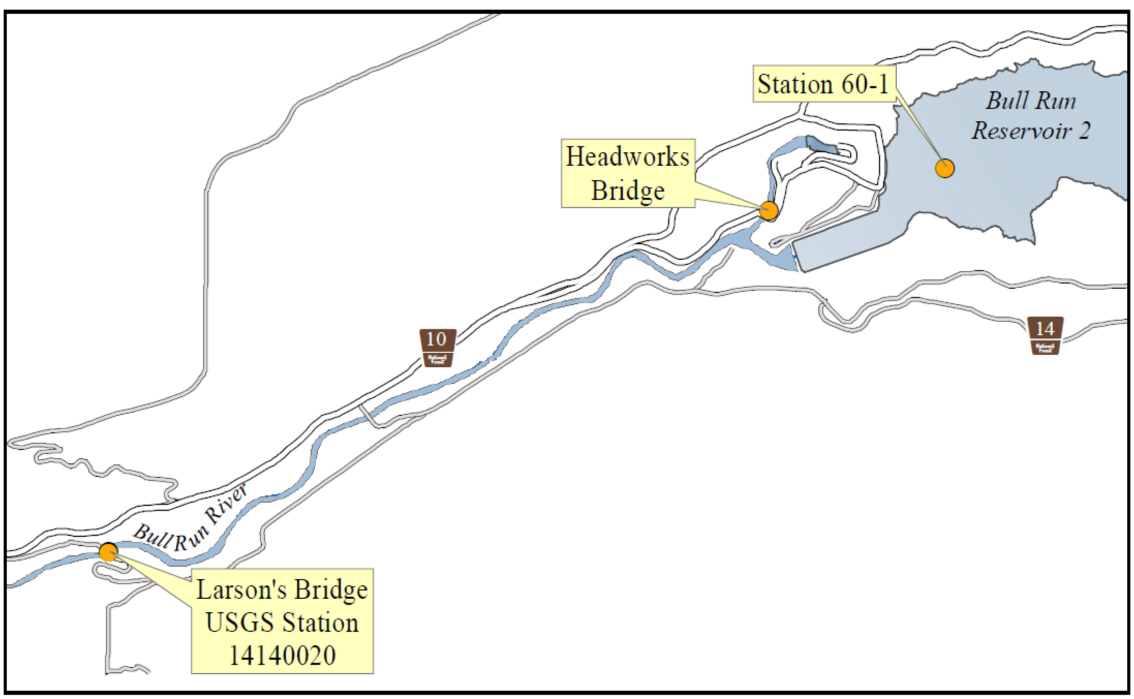

Figure 1. Sampling Sites for Monitoring

4. Analysis

Data for each parameter were analyzed by PWB staff. Reservoir nutrient concentrations were calculated at each sample depth for each nutrient. Reservoir dissolved oxygen concentration and saturation levels, temperatures, and pH levels for the entire reservoir profile were recorded. In the lower Bull Run River, dissolved oxygen concentration and saturation levels and temperatures were recorded for readings taken at Headworks Bridge. Temperature data at Larson's Bridge are available online at the USGS website, http://waterdata.usgs.gov/or/nwis/dv/?site_no=14140020&agency_cd=USGS&referred_module=sw.

5. Results

Data from 2016 were compared to the 2009–2013 baseline results (see Table 2 for the baseline sampling periods). As anticipated with the infrastructure change, stronger stratification occurred in the reservoir, creating more defined zones of water temperature and other water quality parameters within the vertical profile of Reservoir 2. However, nearly all water quality parameters monitored for the Section 401 certification still were within the ranges observed during the baseline monitoring period, with the exception of 9 dissolved oxygen measurements that were below the lowest value observed during the baseline period. Thermal stratification occurs each year in the reservoir, with a defined epilimnion, metalimnion, and hypolimnion.[1] Dissolved oxygen measurements outside of the baseline range are limited to the hypolimnion and in 2016 and were observed for six weeks during the monitoring period. In all observations from 2014 through 2016 in which dissolved oxygen at the base of the reservoir was lower than baseline conditions, 95% or more of the reservoir still had favorable conditions for cold-water fish.

Exhibit A includes raw data from the 2016 monitoring effort in Reservoir 2 and at the Headworks Bridge site. Temperature data for the lower Bull Run River from USGS Station 14140020 at Larson's Bridge are available from the USGS at the following website: http://waterdata.usgs.gov/or/nwis/dv/?site_no=14140020&agency_cd=USGS&referred_module=sw.

5.1.1 Nuisance Phytoplankton Growth and the Creation of Taste, Odors, and Toxic Conditions

For nuisance phytoplankton growth and the potential creation of taste, odors, and toxic conditions, the City tracked nutrient concentrations to determine whether there were increasing trends compared to baseline condition levels. In 2016, nutrient results showed

[1] The epilimnion is the uppermost, warm layer of a water body; the metalimnion (also referred to as the thermocline) is the middle layer defined by its rapidly decreasing temperature with depth; and the hypolimnion is the bottom, cold layer of a water body. These layers typically develop in the spring and persist through early to mid-fall.

no observable increasing trends. Reactive phosphorus ranged from <0.003 – 0.004 milligrams per liter (mg/L), and total phosphorus was <0.01 mg/L. Nitrite was <0.005 mg/L, nitrate ranged from <0.01 – 0.066 mg/L, and total nitrogen from <0.05 – 0.14 mg/L.

Table A-1 shows nutrient monitoring results for 2016. Samples were often collected and analyzed at a frequency greater than the required frequency.

5.1.2 Dissolved Oxygen

Dissolved oxygen concentrations downstream of Dam 2 were at or above values observed in the baseline monitoring period. Sampling in 2016 showed dissolved oxygen saturation values of 99.5 - 108 percent at the Headworks Bridge. Baseline sampling in 2012–2013 showed dissolved oxygen saturation values of 94.5 – 103 percent at the Headworks Bridge. Table A-2 shows results of dissolved oxygen monitoring at the Headworks Bridge.

In the 2013 compliance report, the lowest values of dissolved oxygen that were observed in Bull Run Reservoir 2 were questionable due to the monitoring practice. Yet with a change in method to using a depth finder rather than a weight to determine the reservoir depth, low dissolved oxygen values were still observed at the base of the reservoir. This changes the interpretation of the lowest dissolved oxygen values observed from 2009 to 2013; it now appears that low dissolved oxygen values occur naturally without sediment disturbance.

The monitoring results from 2016 show, overall, high levels of dissolved oxygen. Of 817 total observations of dissolved oxygen in Reservoir 2 in 2016, 19 observations showed dissolved oxygen concentrations lower than 6 mg/L. Dissolved oxygen concentrations lower than 6 mg/L were observed in the bottom 2-10 meters of the reservoir from August 9 through September 20. These values ranged from 3.9-5.9 mg/L. The lowest values of dissolved oxygen (3.9-4.8 mg/L) were observed August 23 and September 6. The lowest observed value during the baseline monitoring period from 2009-2013 was 5.2 mg/L.[2] Dissolved oxygen concentrations below 5.2 mg/L were observed in the bottom 2-7 meters of the reservoir from August 9 through September 20.[3] Table A-3 includes dissolved oxygen results from Reservoir 2.

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[2] One observed value of 2.5 mg/L during the baseline monitoring period was later discarded due to lack of confidence in the results.

[3] One observation on August 23 taken 10 m off the bottom of the reservoir had a dissolved oxygen value of 5.0 mg/L. This measurement was taken out of sequence with the rest of the profile and this value is not in line with the rest of the profile, indicating that the dissolved oxygen probe may not have stabilized.

5.1.3 pH Levels

The range of pH observed in 2016 is within the range observed in the baseline monitoring period. Results ranged from pH 5.9 – 7.4. It is notable that many instances of pH less than 6.5 were observed, in both the baseline monitoring period and 2016. The lowest observed value during the baseline monitoring period from 2009–2013 was 5.8. Table A-3 includes results for pH observed in Reservoir 2 during the 2016 monitoring period.

5.1.4 Temperature

Table A-3 also includes temperature measurements taken during profiling of Reservoir 2 during the 2016 monitoring period. As expected, thermal stratification was observed to change seasonally. Figure A-1 shows the thermal stratification throughout 2016.

6. Conclusions

With the exception of low dissolved oxygen levels at the base of Reservoir 2 that persisted for approximately six weeks, monitoring in 2016 showed results within ranges observed in the baseline conditions. Continued monitoring will provide results that can be compared with the baseline conditions to look for changes relative to pre-project conditions.[4]

7. Works Cited

City of Portland. 2008. Bull Run Water Supply Habitat Conservation Plan For the Issuance of A Permit to Allow Incidental Take of Threatened and Endangered Species. Appendix G. Temperature Management Plan for the Lower Bull Run River. Portland, Oregon. Available at www.portlandoregon.gov/water/46157.

Oregon Department of Environmental Quality. 2012. Clean Water Act Section 401 Certification Conditions for the City of Portland's Bull Run Reservoir Hydroelectric Project (FERC No. 2821), Sandy River Basin, Clackamas County, Oregon. Available online at www.oregon.gov/deq/wq/wqpermits/Pages/Section-401-Hydropower.aspx.

[4] This is true for all parameters except temperatures in the lower Bull Run River, which will be monitored under HCP Measure T-2, Post-Infrastructure Temperature Management.

Figure A-1. Bull Run Reservoir 2 temperature profiles 2016.

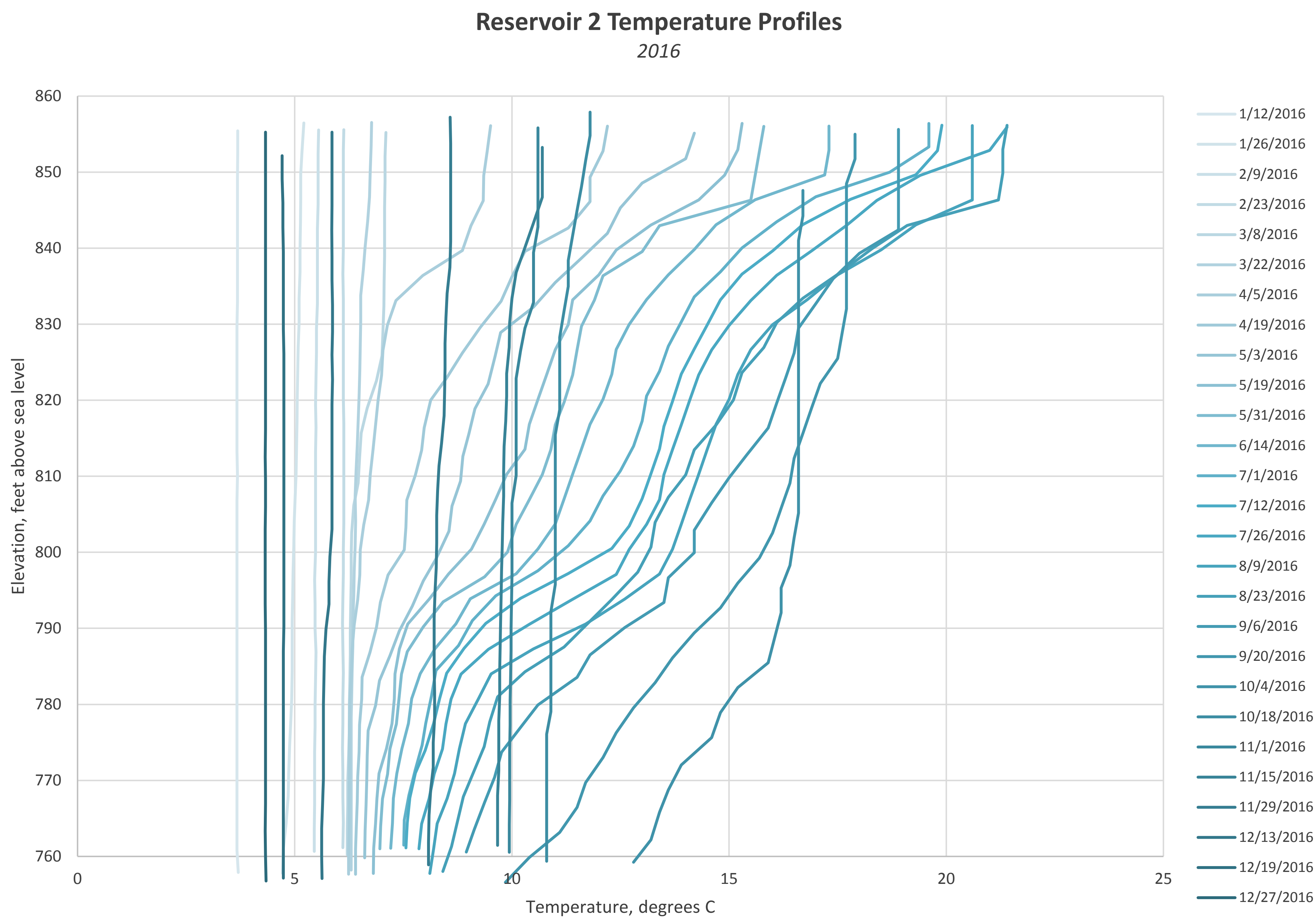

Table A-1. Reservoir 2 Nutrient Monitoring at Station 60-1 for Reactive Phosphorus, Total Phosphorus,

Sample Depth M	Elevation ft MSL	PO_4 mg/L	Total P mg/L	NO_2 mg/L	NO_3 mg/L	Total N mg/L
1/12/2016						
1	856.2	<0.003	<0.01	<0.005	0.040	0.08
6	840.3	<0.003	<0.01	<0.005	0.040	0.07
15	810.8	<0.003	<0.01	<0.005	0.040	0.07
22	787.8	<0.003	<0.01	<0.005	0.040	0.07
30	761.6	<0.003	<0.01	<0.005	0.040	0.08
1/26/2016						
1	855.7	<0.003	<0.01	<0.005	0.037	0.07
6	839.1	<0.003	<0.01	<0.005	0.038	0.07
15	809.5	<0.003	<0.01	<0.005	0.037	0.07
22	786.8	<0.003	<0.01	<0.005	0.038	0.07
31	757	<0.003	<0.01	<0.005	0.039	0.07
2/9/2016						
1	855.5	<0.003	<0.01	<0.005	0.029	0.06
6	839.5	<0.003	<0.01	<0.005	0.029	0.06
15	809.5	0.003	<0.01	<0.005	0.028	0.06
22	786.8	<0.003	<0.01	<0.005	0.028	0.06
30	760.6	<0.003	<0.01	<0.005	0.028	0.06
2/23/2016						
1	856	<0.003	<0.01	<0.005	0.020	0.06
6	840.4	<0.003	<0.01	<0.005	0.021	0.07
15	810.8	<0.003	<0.01	<0.005	0.020	0.07
22	787.8	0.004	<0.01	<0.005	0.022	0.06
30	761.6	<0.003	<0.01	<0.005	0.024	0.06
3/8/2016						
1	854.6	<0.003	<0.01	<0.005	<0.010	0.06
6	838.3	<0.003	<0.01	<0.005	<0.010	0.06
14	811.8	<0.003	<0.01	<0.005	<0.010	0.05
22	785.8	FE[b]	FE	FE	FE	FE
30	759.6	<0.003	<0.01	<0.005	<0.010	<0.05
3/22/2016						
1	856.6	<0.003	<0.01	<0.005	<0.010	0.05
6	840.3	<0.003	<0.01	<0.005	<0.010	<0.05
15	810.8	<0.003	<0.01	<0.005	<0.010	<0.05
22	787.8	<0.003	<0.01	<0.005	<0.010	<0.05
31	758.3	<0.003	<0.01	<0.005	<0.010	<0.05
4/5/2016						
1	856.7	<0.003	<0.01	<0.005	<0.010	0.06
6	840.3	<0.003	<0.01	<0.005	<0.010	<0.05
15	810.8	<0.003	<0.01	<0.005	<0.010	<0.05
22	787.8	<0.003	<0.01	<0.005	<0.010	<0.05
31	758.3	<0.003	<0.01	<0.005	<0.010	<0.05

Table A-1. Reservoir 2 Nutrient Monitoring at Station 60-1 for Reactive Phosphorus, Total Phosphorus,

Sample Depth M	Elevation ft MSL	PO_4 mg/L	Total P mg/L	NO_2 mg/L	NO_3 mg/L	Total N mg/L
4/19/2016						
1	855.7	<0.003	<0.01 PV4[b]	<0.005	<0.010	0.07 PV4
6	839.2	<0.003	<0.01 PV4	<0.005	<0.010	0.06 PV4
14	813.1	<0.003	<0.01 PV4	<0.005	<0.010	<0.05 PV4
22	786.5	<0.003	<0.01 PV4	<0.005	<0.010	<0.05 PV4
30	760.6	<0.003	<0.01 PV4	<0.005	<0.010	<0.05 PV4
5/3/2016						
1	854.6	<0.003	<0.01	<0.005	<0.010	0.05
6	838.1	<0.003	<0.01	<0.005	<0.010	<0.05
14	812.1	<0.003	<0.01	<0.005	<0.010	<0.05
22	785.8	<0.003	<0.01	<0.005	<0.010	<0.05
30	759.3	<0.003	<0.01	<0.005	<0.010	<0.05
5/31/2016						
1	855.6	<0.003	<0.01	<0.005	<0.010	0.06
6	839.1	<0.003	<0.01	<0.005	<0.010	0.06
15	809.8	<0.003	<0.01	<0.005	<0.010	0.05
22	786.5	<0.003	<0.01	<0.005	<0.010	<0.05
30	760.6	<0.003	<0.01	<0.005	<0.010	0.05
6/14/2016						
1	856.6	<0.003	<0.01	<0.005	<0.010	0.06
6	840.3	<0.003	<0.01	<0.005	<0.010	0.07
15	810.8	<0.003	<0.01	<0.005	<0.010	0.06
22	787.8	<0.003	<0.01	<0.005	<0.010	<0.05
30	761.6	<0.003	<0.01	<0.005	<0.010	0.06
6/28/2016						
0	856.8	<0.003	<0.01	<0.005	<0.010	0.06
6	840.5	<0.003	<0.01	<0.005	<0.010	0.06
0	811.2	<0.003	<0.01	<0.005	<0.010	0.06
22	788.5	0.003	<0.01	<0.005	<0.010	0.05
0	762.5	<0.003	<0.01	<0.005	0.012	0.06
7/12/2016						
1	855.6	<0.003	<0.01	<0.005	<0.010	0.07
6	839.1	<0.003	<0.01	<0.005	<0.010	0.07
15	809.8	<0.003	<0.01	<0.005	<0.010	0.06
22	786.8	<0.003	<0.01	<0.005	<0.010	0.06
30	760.6	<0.003	<0.01	<0.005	0.020	0.09
7/26/2016						
1	856.5	<0.003	<0.01	<0.005	<0.010	0.05
6	840.2	<0.003	<0.01	<0.005	<0.010	0.05
22	787.8	<0.003	<0.01	<0.005	0.010	<0.05
30	761.6	<0.003	<0.01	<0.005	0.020	0.05

Table A-1. Reservoir 2 Nutrient Monitoring at Station 60-1 for Reactive Phosphorus, Total Phosphorus,

Sample Depth M	Elevation ft MSL	PO_4 mg/L	Total P mg/L	NO_2 mg/L	NO_3 mg/L	Total N mg/L
8/9/2016						
1	856.7	<0.003	<0.01	<0.005	<0.010	0.07
6	840.3	<0.003	<0.01	<0.005	<0.010	0.06
15	810.8	<0.003	<0.01	<0.005	<0.010	0.06
22	787.8	<0.003	<0.01	<0.005	<0.010	<0.05
30	761.6	<0.003	<0.01	<0.005	<0.010	0.05
8/23/2016						
1	856.4	<0.003	<0.01	<0.005	<0.010	0.07
6	840.3	<0.003	<0.01	<0.005	<0.010	0.06
15	810.5	<0.003	<0.01	<0.005	<0.010	0.05
22	787.8	<0.003	<0.01	<0.005	<0.010	<0.05
30	761.6	<0.003	<0.01	<0.005	<0.010	0.07
9/6/2016						
1	855.6	0.003	<0.01	<0.005	<0.010	0.07
6	839.3	0.003	<0.01	<0.005	<0.010	0.07
15	809.8	0.003	<0.01	<0.005	<0.010	0.06
22	786.5	<0.003	<0.01	<0.005	0.017	0.06
30	760.6	0.003	<0.01	<0.005	0.030	0.08
9/20/2016						
1	856.7	<0.003	<0.01	<0.005	<0.010	0.07
6	840.3	<0.003	<0.01	<0.005	<0.010	0.07
15	810.8	<0.003	<0.01	<0.005	<0.010	0.06
22	787.8	<0.003	<0.01	<0.005	0.021	0.08
29	764.9	<0.003	<0.01	<0.005	0.029	0.09
10/4/2016						
1	847.5	<0.003	<0.01	<0.005	<0.010	0.07
4	837.9	<0.003	<0.01	<0.005	<0.010	0.07
12	811.6	<0.003	<0.01	<0.005	<0.010	0.07
20	785.4	<0.003	<0.01	<0.005	0.022	0.08
27	762.1	<0.003	<0.01	<0.005	<0.010	0.07
10/18/2016						
1	857.5	HT[b]	<0.01	<0.005	0.063	0.13
7	838	HT	<0.01	<0.005	0.064	0.14
15	811.8	HT	<0.01	<0.005	0.065	0.13
23	785.6	HT	<0.01	<0.005	0.066	0.13
31	759	HT	<0.01	<0.005	0.064	0.13
11/1/2016						
1	855.5	<0.003	<0.01	<0.005	0.049	0.11
6	839.1	<0.003	<0.01	<0.005	0.048	0.11
15	809.8	<0.003	<0.01	<0.005	0.051	0.09
22	786.8	<0.003	<0.01	<0.005	0.044	0.09
30	760.3	<0.003	<0.01	<0.005	0.043	0.09

Table A-1. Reservoir 2 Nutrient Monitoring at Station 60-1 for Reactive Phosphorus, Total Phosphorus,

Sample Depth M	Elevation ft MSL	PO_4 mg/L	Total P mg/L	NO_2 mg/L	NO_3 mg/L	Total N mg/L
11/15/2016						
1	852.7	<0.003	<0.01	<0.005	0.034	0.11
5	839.5	<0.003	<0.01	<0.005	0.040	0.10
14	810.1	<0.003	<0.01	<0.005	0.042	0.10
21	787.1	<0.003	<0.01	<0.005	0.041	0.09
29	760.9	<0.003	<0.01	<0.005	0.041	0.09
11/29/2016						
1	856.6	<0.003	<0.01	<0.005	0.042	0.10
6	840.3	<0.003	<0.01	<0.005	0.045	0.08
15	810.8	<0.003	<0.01	<0.005	0.044	0.08
22	787.8	<0.003	<0.01	<0.005	0.045	0.09
31	758.3	<0.003	<0.01	<0.005	0.047	0.08
12/13/2016						
1	855.5	<0.003	<0.01	<0.005	0.048	0.13
6	839.1	<0.003	<0.01	<0.005	0.048	0.09
15	809.8	<0.003	<0.01	<0.005	0.050	0.10
22	786.5	<0.003	<0.01	<0.005	0.049	0.09
31	757.3	<0.003	<0.01	<0.005	0.045	0.10
12/27/2016						
1	854.5	<0.003	<0.01	<0.005	0.046	0.09
6	838.2	<0.003	<0.01	<0.005	0.048	0.08
14	811.8	<0.003	<0.01	<0.005	0.047	0.08
22	785.8	<0.003	<0.01	<0.005	0.044	0.08
30	759.3	<0.003	<0.01	<0.005	0.044	0.09

[a]m is meters, ft MSL is feet above mean sea level, mg/L is milligrams per liter, PO_4 is reactive phosphorus, Total P is total phosphorus, NO_2 is nitrite, NO_3 is nitrate, Total N is total nitrogen

[b]FE denotes a field exception; PV4 denotes inadequate preservation; HT denotes an exceedance of laboratory hold time. Samples are collected bi-weekly rather than monthly to mitigate these types of issues that arise in sampling and analysis.

Table A-2. Headworks Bridge Data for Dissolved Oxygen (DO) and Temperature[a]

Date	Depth m	DO concentration mg/L	DO saturation %	Temperature °C
1/13/2015	0.11	12.9	103.0	5.3
1/27/2015	0.49	12.4	100.0	5.7
2/11/2015	0.09	12.5	104.0	6.6
2/24/2015	0.24	12.1	101.0	7.1
3/10/2015	0.53	11.7	99.9	7.4
3/24/2015	0.06	11.9	102.0	7.7
4/9/2015	0.23	11.5	100	8.3
4/21/2015	0.09	11.4	101	8.8
5/5/2015	0.28	11.0	97.9	9.5
5/19/2015	1.31	10.7	97.1	10.3
6/2/2015	1.42	11.1	103	11.4
6/16/2015	0.67	11.5	99.5	9.1
7/1/2015	1.15	9.9	99	14.1
7/14/2015	1.37	11.3	102.0	10.0
7/28/2015	0.78	11.4	102	9.7
8/11/2015	1.20	11.0	100	10.2
8/25/2015	0.78	11.1	101	10.2
9/10/2015	1.33	11.3	105.0	11.4
9/22/2015	0.99	10.6	101	12.0
10/6/2015	0.85	10.6	102.0	12.8
10/20/2015	0.88	10.9	111.0	15.4
11/3/2015	0.07	10.6	103.0	13.0
11/17/2015	0.07	11.6	104	9.5
12/1/2015	0.69	12.1	101.0	6.8
12/15/2015	0.08	12.3	102.0	6.9
12/29/2015	0.11	12.7	103.0	5.6

[a]m is meters, mg/L is milligrams per liter, °C is degrees Celsius

Table A-3. Reservoir 2 Profile Data at Station 60-1 for Dissolved Oxygen (DO), Temperature, and pH[a]

Sample Depth m	Elevation ft MSL	DO concentration mg/L	DO saturation %	Temperature °C	pH
1/12/2016					
1	856.2	12.5	97.2	3.7	6.8
2	853.3	12.5	97.1	3.7	6.8
3	850.1	12.5	97.0	3.7	6.8
4	846.8	12.4	96.9	3.7	6.8
5	843.6	12.4	96.8	3.7	6.8
6	840.3	12.4	96.8	3.7	6.8
7	837.0	12.4	96.7	3.7	6.8
8	833.8	12.4	96.6	3.7	6.8
9	830.4	12.4	96.6	3.7	6.8
10	827.2	12.4	96.5	3.7	6.8
11	823.9	12.4	96.4	3.7	6.8
12	820.6	12.4	96.3	3.7	6.8
13	817.3	12.4	96.3	3.7	6.8
14	814.1	12.4	96.2	3.7	6.8
15	810.8	12.3	96.1	3.7	6.8
16	807.5	12.3	96.1	3.7	6.8
17	804.2	12.3	95.9	3.7	6.8
18	800.9	12.3	95.9	3.7	6.8
19	797.7	12.3	95.8	3.7	6.8
20	794.4	12.3	95.8	3.7	6.8
21	790.8	12.3	95.7	3.7	6.8
22	787.8	12.3	95.7	3.7	6.8
23	784.5	12.3	95.6	3.7	6.8
24	781.3	12.3	95.5	3.7	6.8
25	778.0	12.3	95.5	3.7	6.8
26	774.7	12.2	95.4	3.7	6.8
27	771.4	12.2	95.4	3.7	6.8
28	768.1	12.2	95.3	3.7	6.8
29	764.9	12.2	95.3	3.7	6.8
30	761.6	12.2	95.2	3.7	6.8
31	758.6	12.2	95.1	3.7	6.7
1/26/2016					
1	855.7	12.2	98.1	5.2	7.0
2	852.1	12.2	97.8	5.2	6.9
3	848.9	12.2	97.7	5.1	7.0
4	845.6	12.2	97.6	5.1	6.9
5	842.6	12.2	97.5	5.1	6.9
6	839.1	12.2	97.5	5.1	6.9
7	836.0	12.2	97.4	5.1	6.9
8	832.6	12.2	97.2	5.1	6.9
9	829.3	12.2	97.2	5.1	6.9
10	826.2	12.2	97.0	5.1	7.0

Table A-3. Reservoir 2 Profile Data at Station 60-1 for Dissolved Oxygen (DO), Temperature, and pH[a]

Sample Depth m	Elevation ft MSL	DO concentration mg/L	DO saturation %	Temperature °C	pH
11	822.9	12.2	97.0	5.1	6.9
12	819.6	12.2	96.9	5.1	6.9
13	816.3	12.1	96.8	5.1	6.9
14	813.1	12.1	96.8	5.0	6.9
15	809.5	12.1	96.7	5.0	6.9
16	806.5	12.1	96.6	5.0	6.9
17	803.2	12.1	96.6	5.0	6.9
18	799.9	12.1	96.5	5.0	6.9
19	796.7	12.1	96.4	5.0	6.9
20	793.1	12.1	96.3	5.0	6.9
21	790.1	12.1	96.2	4.9	6.9
22	786.8	12.1	96.2	4.9	6.9
23	783.5	12.1	96.1	4.9	6.9
24	779.9	12.1	96.0	4.9	6.9
25	777.0	12.1	95.9	4.9	6.9
26	773.7	12.1	95.8	4.9	6.9
27	770.1	12.1	95.8	4.9	6.9
28	767.1	12.1	95.9	4.9	6.9
29	763.5	12.1	95.7	4.8	6.9
30	760.2	12.1	95.4	4.7	6.9
31	757.0	12.0	95.3	4.7	6.9
2/9/2016					
1	855.5	12.2	98.9	5.6	7.0
2	852.2	12.2	99.0	5.5	7.0
3	849.1	12.2	99.0	5.5	7.0
4	845.6	12.2	98.9	5.5	7.0
5	842.4	12.2	98.8	5.5	7.0
6	839.5	12.2	98.7	5.5	6.9
7	835.8	12.2	98.6	5.5	6.9
8	832.6	12.2	98.5	5.5	6.9
9	829.3	12.1	98.4	5.5	6.9
10	826.2	12.1	98.4	5.5	6.9
11	822.9	12.1	98.3	5.5	6.9
12	819.3	12.1	98.1	5.5	6.9
13	816.3	12.1	98.0	5.5	6.9
14	813.1	12.1	98.0	5.5	6.9
15	809.5	12.1	98.0	5.5	6.9
16	806.5	12.1	97.8	5.5	6.9
17	803.2	12.1	97.8	5.5	6.9
18	799.9	12.0	97.7	5.5	6.9
19	796.3	12.0	97.6	5.5	6.9
20	793.1	12.0	97.6	5.5	6.9
21	789.8	12.0	97.5	5.5	6.9

Table A-3. Reservoir 2 Profile Data at Station 60-1 for Dissolved Oxygen (DO), Temperature, and pH[a]

Sample Depth m	Elevation ft MSL	DO concentration mg/L	DO saturation %	Temperature °C	pH
22	786.8	12.0	97.4	5.5	6.9
23	783.2	12.0	97.3	5.5	6.9
24	779.9	12.0	97.2	5.5	6.9
25	777.0	12.0	97.2	5.5	6.9
26	773.7	12.0	97.0	5.5	6.9
27	770.4	12.0	97.0	5.5	6.9
28	766.8	12.0	96.9	5.5	6.9
29	763.5	12.0	96.9	5.5	6.9
30	760.6	11.9	96.7	5.5	6.9
2/23/2016					
1	856.0	12.1	99.8	6.1	6.9
2	853.3	12.1	99.7	6.1	6.9
3	850.3	12.1	99.6	6.1	6.9
4	846.8	12.1	99.5	6.1	6.9
5	843.5	12.0	99.5	6.1	6.9
6	840.4	12.0	99.4	6.1	6.9
7	837.0	12.0	99.3	6.1	6.9
8	833.8	12.0	99.2	6.1	6.9
9	830.4	12.0	99.2	6.1	6.9
10	827.2	12.0	99.1	6.1	6.9
11	823.9	12.0	99.1	6.1	6.9
12	820.6	12.0	99.0	6.1	6.9
13	817.3	12.0	98.9	6.1	6.9
14	814.1	12.0	98.8	6.1	6.9
15	810.8	12.0	98.7	6.1	6.9
16	807.5	12.0	98.7	6.1	6.9
17	804.2	11.9	98.6	6.1	6.9
18	800.9	11.9	98.5	6.1	6.9
19	797.7	11.9	98.5	6.1	6.9
20	794.4	11.9	98.4	6.1	6.9
21	791.1	11.9	98.3	6.1	6.9
22	787.8	11.9	98.3	6.1	6.9
23	784.5	11.9	98.2	6.1	6.9
24	781.3	11.9	98.2	6.1	6.9
25	778.0	11.9	98.2	6.1	6.9
26	774.7	11.9	98.1	6.1	6.9
27	771.4	11.9	98.0	6.1	6.9
28	768.1	11.9	98.0	6.1	6.9
29	764.9	11.9	97.9	6.1	6.9
30	761.6	11.8	97.8	6.1	6.9
3/8/2016					
1	854.6	12.1	103.0	7.1	7.1
2	851.4	12.1	102.0	7.1	7.1

Table A-3. Reservoir 2 Profile Data at Station 60-1 for Dissolved Oxygen (DO), Temperature, and pH[a]

Sample Depth m	Elevation ft MSL	DO concentration mg/L	DO saturation %	Temperature °C	pH
3	848.1	12.1	102.0	7.1	7.1
4	844.6	12.0	102.0	7.1	7.1
5	841.4	12.0	102.0	7.1	7.1
6	838.2	12.0	102.0	7.1	7.1
7	834.8	12.0	102.0	7.1	7.1
8	831.7	12.0	102.0	7.1	7.0
9	828.4	12.0	102.0	7.0	7.0
10	825.2	12.0	102.0	7.0	7.0
11	821.9	12.0	101.0	6.9	7.0
12	818.3	12.0	100.0	6.7	7.0
13	815.0	12.0	100.0	6.5	7.0
14	811.7	12.0	100.0	6.5	7.0
15	808.5	12.0	100.0	6.5	7.0
16	805.5	12.0	99.7	6.4	7.0
17	801.9	12.0	99.7	6.3	7.0
18	798.9	11.9	99.5	6.3	7.0
19	795.7	11.9	99.4	6.3	7.0
20	792.4	11.9	99.3	6.3	7.0
21	788.8	11.9	99.2	6.3	7.0
22	785.8	11.9	99.1	6.3	7.0
23	782.2	11.9	99.1	6.3	7.0
24	779.3	11.9	98.9	6.3	7.0
25	776.0	11.9	98.8	6.3	7.0
26	772.7	11.8	98.6	6.2	7.0
27	769.1	11.8	98.5	6.2	7.0
28	766.1	11.8	98.4	6.2	7.0
29	762.9	11.8	98.2	6.2	7.0
30	759.6	11.8	98.1	6.2	7.0
3/22/2016					
1	856.6	12.2	102.0	6.8	7.0
2	853.5	12.2	102.0	6.8	7.0
3	850.2	12.2	102.0	6.7	7.0
4	846.8	12.1	102.0	6.7	7.0
5	843.6	12.1	101.0	6.7	7.0
6	840.2	12.1	101.0	6.6	7.0
7	837.2	12.1	101.0	6.6	6.9
8	833.9	12.1	101.0	6.5	7.0
9	830.5	12.1	101.0	6.5	7.0
10	827.2	12.1	101.0	6.5	6.9
11	823.9	12.1	100.0	6.5	6.9
12	820.6	12.1	100.0	6.5	7.0
13	817.3	12.1	101.0	6.5	7.0
14	814.1	12.1	100.0	6.4	7.0

Table A-3. Reservoir 2 Profile Data at Station 60-1 for Dissolved Oxygen (DO), Temperature, and pH[a]

Sample Depth m	Elevation ft MSL	DO concentration mg/L	DO saturation %	Temperature °C	pH
15	810.8	12.1	100.0	6.4	6.9
16	807.5	12.0	100.0	6.4	6.9
17	804.2	12.0	99.8	6.4	6.9
18	800.9	12.0	99.8	6.4	6.9
19	797.7	12.0	99.8	6.4	6.9
20	794.4	12.0	99.8	6.4	6.9
21	791.1	12.0	99.9	6.3	6.9
22	787.8	12.0	99.9	6.3	6.9
23	784.5	12.0	99.9	6.3	7.0
24	781.3	12.0	99.9	6.3	6.9
25	778.3	12.0	99.8	6.3	6.9
26	774.7	12.0	99.5	6.3	6.9
27	771.4	12.0	99.5	6.3	6.9
28	768.1	12.0	99.4	6.3	6.9
29	764.9	12.0	99.3	6.3	6.9
30	761.6	12.0	99.2	6.3	6.9
31	758.3	12.0	99.2	6.3	6.9
4/5/2016					
1	856.7	11.8	104.0	9.5	7.0
2	853.4	11.8	104.0	9.4	7.0
3	850.2	11.8	104.0	9.4	7.0
4	846.9	11.8	104.0	9.3	7.0
5	843.6	11.8	103.0	9.1	7.0
6	840.3	11.9	103.0	8.9	7.0
7	837.0	12.0	102.0	8.0	7.0
8	833.8	12.1	102.0	7.3	7.0
9	830.5	12.1	101.0	7.1	7.0
10	827.2	12.1	100.0	7.0	7.0
11	823.9	12.1	100.0	7.0	7.0
12	820.6	12.0	99.9	6.9	7.0
13	817.3	12.0	99.8	6.9	7.0
14	814.1	12.0	99.5	6.8	7.0
15	810.8	12.0	99.3	6.7	7.0
16	807.5	12.0	99.1	6.7	7.0
17	804.2	12.0	98.8	6.6	7.0
18	800.9	12.0	98.4	6.5	7.0
19	797.7	12.0	98.3	6.5	7.0
20	794.4	12.0	98.0	6.5	7.0
21	791.1	12.0	97.7	6.4	7.0
22	787.8	11.9	97.6	6.3	7.0
23	784.5	11.9	97.3	6.3	6.9
24	781.3	11.9	96.8	6.3	7.0
25	778.0	11.8	96.4	6.3	6.9

Table A-3. Reservoir 2 Profile Data at Station 60-1 for Dissolved Oxygen (DO), Temperature, and pH[a]

Sample Depth m	Elevation ft MSL	DO concentration mg/L	DO saturation %	Temperature °C	pH
26	774.7	11.8	96.3	6.3	6.9
27	771.4	11.8	96.1	6.3	6.9
28	768.1	11.7	95.4	6.3	6.9
29	764.9	11.7	95.2	6.3	6.9
30	761.6	11.6	95.0	6.2	6.9
31	758.3	11.6	94.5	6.2	6.9
4/19/2016					
1	855.7	11.0	106.0	12.2	7.0
2	852.4	11.0	106.0	12.1	7.0
3	849.0	11.1	106.0	11.8	7.0
4	845.8	11.1	105.0	11.8	7.0
5	842.3	11.2	105.0	11.3	7.0
6	839.2	11.3	104.0	10.3	7.0
7	835.9	11.4	104.0	10.0	7.0
8	832.7	11.5	104.0	9.8	7.0
9	829.2	11.5	103.0	9.3	7.0
10	825.9	11.6	103.0	8.9	7.0
11	822.6	11.6	102.0	8.5	7.0
12	819.6	11.7	102.0	8.1	7.0
13	816.0	11.7	101.0	8.0	7.0
14	813.1	11.7	101.0	7.9	7.0
15	809.8	11.6	100.0	7.8	7.0
17	802.9	11.6	99.5	7.6	7.0
18	799.9	11.6	99.3	7.5	7.0
19	796.7	11.6	98.7	7.2	7.0
20	793.1	11.6	97.9	7.0	7.0
21	789.8	11.5	97.6	6.9	7.0
22	786.5	11.6	97.6	6.7	7.0
23	783.2	11.5	96.0	6.6	7.0
24	780.3	11.4	95.9	6.5	7.0
25	777.0	11.4	95.3	6.5	7.0
26	773.4	11.4	95.1	6.5	7.0
27	770.1	11.4	94.9	6.5	7.0
28	766.8	11.3	94.5	6.4	7.0
29	763.5	11.2	93.7	6.4	7.0
30	760.6	11.2	93.2	6.4	6.9
31	757.3	11.1	92.7	6.4	6.9
16	806.5	11.5	99.3	7.6	6.9
5/3/2016					
1	854.6	10.3	103.0	14.2	7.2
2	851.2	10.3	103.0	14.0	7.2
3	848.0	10.5	102.0	13.0	7.2
4	844.7	10.6	102.0	12.5	7.2

Table A-3. Reservoir 2 Profile Data at Station 60-1 for Dissolved Oxygen (DO), Temperature, and pH[a]

Sample Depth m	Elevation ft MSL	DO concentration mg/L	DO saturation %	Temperature °C	pH
5	841.4	10.7	102.0	12.2	7.2
6	838.1	10.8	102.0	11.6	7.1
7	834.9	10.9	101.0	11.0	7.1
8	831.7	11.0	101.0	10.5	7.1
9	828.3	11.2	101.0	9.7	7.1
10	825.2	11.1	100.0	9.6	7.1
11	821.6	11.1	99.5	9.5	7.1
12	818.3	11.1	98.7	9.2	7.1
13	815.0	11.0	98.2	9.0	7.1
14	812.1	11.0	97.5	8.9	7.1
15	808.8	11.0	97.2	8.8	7.1
16	805.5	11.0	96.8	8.6	7.0
17	802.2	11.0	96.7	8.6	7.0
18	798.6	11.1	96.8	8.3	7.0
19	795.7	11.2	96.5	8.0	7.0
20	792.4	11.1	95.5	7.7	7.0
21	789.1	11.0	93.7	7.4	7.0
22	785.8	10.8	92.0	7.2	7.0
23	782.5	10.8	91.4	7.0	7.0
24	779.3	10.7	90.4	6.9	6.9
25	776.0	10.5	88.4	6.7	6.9
26	772.7	10.4	87.4	6.7	6.9
27	769.4	10.4	87.1	6.7	6.9
28	766.1	10.3	86.6	6.6	6.9
29	762.9	10.2	85.3	6.6	6.9
30	759.2	10.1	84.5	6.6	6.9
5/19/2016					
1	856.9	10.0	103.0	15.3	6.27 Q[b]
2	853.5	10.0	103.0	15.2	6.29 Q
3	850.1	10.1	102.0	14.9	6.30 Q
4	846.9	10.2	103.0	14.3	6.30 Q
5	843.6	10.5	103.0	13.2	6.32 Q
6	840.3	10.7	103.0	12.4	6.33 Q
7	837.0	10.8	103.0	12.0	6.34 Q
8	833.7	10.9	102.0	11.4	6.34 Q
9	830.5	10.8	101.0	11.3	6.33 Q
10	827.2	10.8	101.0	11.0	6.33 Q
11	823.9	10.8	100.0	10.8	6.33 Q
12	820.6	10.8	99.5	10.6	6.32 Q
13	817.3	10.8	99.4	10.4	6.32 Q
14	814.1	10.9	100.0	10.3	6.32 Q
15	810.8	10.9	98.9	9.9	6.32 Q
16	807.5	11.0	99.0	9.6	6.33 Q

Table A-3. Reservoir 2 Profile Data at Station 60-1 for Dissolved Oxygen (DO), Temperature, and pH[a]

Sample Depth m	Elevation ft MSL	DO concentration mg/L	DO saturation %	Temperature °C	pH
17	804.2	10.9	97.9	9.4	6.32 Q
18	800.9	10.9	97.3	9.1	6.33 Q
19	797.7	10.8	95.4	8.5	6.34 Q
20	794.4	10.6	92.7	8.1	6.33 Q
21	791.1	10.4	89.4	7.6	6.33 Q
22	787.8	10.4	88.6	7.4	6.33 Q
23	784.5	10.1	86.1	7.3	6.33 Q
24	781.3	10.0	85.6	7.3	6.33 Q
25	778.0	10.2	86.6	7.2	6.32 Q
26	774.7	10.2	86.7	7.1	6.32 Q
27	771.4	9.9	83.9	6.9	6.32 Q
28	768.1	9.7	82.1	6.9	6.31 Q
29	764.9	9.7	81.6	6.9	6.31 Q
30	761.6	9.5	80.0	6.8	6.31 Q
31	758.3	9.5	79.8	6.8	6.30 Q
5/31/2016					
1	855.6	10.0	104.0	15.8	6.9
2	852.3	10.0	104.0	15.7	6.9
3	849.2	10.0	103.0	15.6	6.9
4	845.9	10.0	103.0	15.5	6.9
5	842.5	10.3	102.0	13.4	7.0
6	839.1	10.4	102.0	13.0	7.0
7	835.9	10.5	100.0	12.1	6.9
8	832.8	10.4	99.5	11.9	6.9
9	829.3	10.5	99.0	11.6	6.9
10	826.2	10.4	98.2	11.5	6.9
11	822.9	10.4	97.7	11.4	6.9
12	819.3	10.4	97.3	11.2	6.9
13	816.3	10.3	96.3	11.0	6.9
14	813.1	10.3	95.5	10.9	6.9
15	809.8	10.2	94.5	10.7	6.9
16	806.5	10.2	94.0	10.4	6.9
17	803.2	10.3	94.1	10.1	6.9
18	799.6	10.3	93.8	9.9	6.9
19	796.3	10.1	90.6	9.4	6.9
20	793.1	10.0	88.0	8.4	6.9
21	789.8	10.0	87.0	8.0	6.9
22	786.5	9.7	83.0	7.6	6.9
23	783.5	9.3	79.9	7.5	6.9
24	780.3	9.4	80.3	7.4	6.9
25	777.0	9.6	82.0	7.3	6.9
26	773.7	9.6	81.8	7.2	6.9
27	770.4	9.4	80.1	7.1	6.9

Table A-3. Reservoir 2 Profile Data at Station 60-1 for Dissolved Oxygen (DO), Temperature, and pH[a]

Sample Depth m	Elevation ft MSL	DO concentration mg/L	DO saturation %	Temperature °C	pH
28	767.1	9.1	76.8	7.0	6.9
29	763.5	8.7	73.8	7.0	6.9
30	760.6	8.6	72.5	7.0	6.9
6/14/2016					
1	856.6	9.6	103.0	17.3	7.1
2	853.4	9.6	103.0	17.3	7.1
3	850.1	9.6	102.0	17.2	7.1
4	846.9	10.2	105.0	15.6	7.1
5	843.6	10.3	104.0	14.7	7.1
6	840.3	10.3	103.0	14.2	7.1
7	837.0	10.5	104.0	13.6	7.1
8	833.7	10.4	102.0	13.1	7.1
9	830.5	10.4	101.0	12.7	7.0
10	827.2	10.4	100.0	12.4	7.0
11	823.9	10.4	100.0	12.3	7.0
12	820.6	10.4	99.1	12.1	7.0
13	817.3	10.3	97.6	11.8	7.0
14	814.1	10.2	96.8	11.6	7.0
15	810.8	10.2	96.3	11.4	7.0
16	807.5	10.2	95.2	11.2	7.0
17	804.2	10.0	93.3	11.0	7.0
18	800.9	9.8	90.3	10.6	7.0
19	797.7	9.6	87.9	10.1	6.9
20	794.4	9.6	85.5	9.0	6.9
21	791.1	9.6	84.4	8.7	6.9
22	787.8	9.4	81.9	8.2	6.9
23	784.5	9.2	79.3	7.9	6.9
24	781.3	9.1	78.4	7.7	6.9
25	778.0	9.0	77.4	7.6	6.8
26	774.7	9.0	76.8	7.5	6.8
27	771.4	8.7	74.6	7.4	6.8
28	768.1	8.4	71.2	7.3	6.8
29	764.9	8.2	69.7	7.3	6.8
30	761.6	7.9	67.6	7.2	6.7
7/1/2016					
1	856.4	9.2	103.0	19.6	7.3
2	853.3	9.2	103.0	19.6	7.3
3	850.0	9.6	105.0	18.7	7.3
4	846.7	9.9	105.0	17.0	7.3
5	843.5	10.0	104.0	16.1	7.3
6	840.0	10.1	103.0	15.3	7.2
7	836.9	10.1	102.0	14.8	7.2
8	833.6	10.0	100.0	14.2	7.2

Table A-3. Reservoir 2 Profile Data at Station 60-1 for Dissolved Oxygen (DO), Temperature, and pH[a]

Sample Depth m	Elevation ft MSL	DO concentration mg/L	DO saturation %	Temperature °C	pH
9	830.3	10.0	98.8	13.9	7.1
10	827.1	9.9	97.6	13.6	7.1
11	823.8	9.8	96.4	13.4	7.1
12	820.5	9.8	95.0	13.1	7.1
13	817.2	9.7	94.7	13.0	7.0
14	814.0	9.7	93.4	12.8	7.0
15	810.7	9.6	91.8	12.5	7.0
16	807.4	9.6	91.9	12.1	7.0
17	804.1	9.7	91.7	11.8	7.0
18	800.8	9.7	90.2	11.3	7.0
19	797.6	8.9	82.1	10.6	6.9
20	794.3	9.0	80.7	9.6	6.9
21	791.0	8.8	78.1	9.1	6.9
22	787.7	8.7	76.9	8.8	6.9
23	784.4	8.4	72.6	8.3	6.8
24	781.2	8.0	69.6	8.2	6.8
25	777.6	8.1	70.4	8.0	6.8
26	774.6	8.2	70.8	7.9	6.8
27	771.3	7.9	68.0	7.8	6.8
28	768.0	7.7	65.6	7.6	6.8
29	764.8	7.2	61.7	7.5	6.7
30	761.5	7.1	60.7	7.5	6.7
7/12/2016					
1	855.6	9.2	104.0	19.9	7.1
2	852.3	9.2	104.0	19.8	7.1
3	849.1	9.4	104.0	19.3	7.1
4	845.9	9.7	104.0	17.8	7.2
5	842.6	9.7	102.0	16.7	7.2
6	839.1	9.7	101.0	16.0	7.2
7	836.0	9.9	101.0	15.3	7.2
8	832.7	9.9	101.0	14.8	7.2
9	829.4	9.8	99.0	14.5	7.2
10	826.2	9.8	97.6	14.2	7.2
11	822.9	9.7	96.8	13.9	7.2
12	819.3	9.7	95.6	13.7	7.2
13	816.0	9.6	94.8	13.5	7.1
14	813.1	9.6	94.5	13.4	7.1
15	809.8	9.5	93.0	13.2	7.1
16	806.5	9.4	91.4	13.0	7.1
17	802.9	9.3	89.8	12.7	7.1
18	799.9	9.2	88.3	12.3	7.1
19	796.7	9.0	84.0	11.3	7.1
20	793.4	8.8	80.2	10.2	7.2

Table A-3. Reservoir 2 Profile Data at Station 60-1 for Dissolved Oxygen (DO), Temperature, and pH[a]

Sample Depth m	Elevation ft MSL	DO concentration mg/L	DO saturation %	Temperature °C	pH
21	790.1	8.7	77.9	9.4	7.2
22	786.8	8.7	76.7	8.9	7.2
23	783.5	8.2	71.6	8.5	7.2
24	780.3	8.0	70.2	8.3	7.1
25	777.0	7.7	67.2	8.2	7.1
26	773.4	7.7	66.9	8.0	7.1
27	770.4	7.3	63.0	7.8	7.1
28	767.1	6.9	59.6	7.7	7.1
29	763.9	6.4	55.2	7.6	7.0
30	760.6	6.4	54.4	7.6	7.0
7/26/2016					
1	856.5	9.1	105.0	21.4	7.4
2	853.4	9.2	105.0	21.0	7.4
3	850.1	9.5	105.0	19.4	7.3
4	846.8	9.7	106.0	18.4	7.3
5	843.6	9.8	105.0	17.7	7.2
6	840.2	9.7	102.0	16.9	7.1
7	837.0	9.8	101.0	16.1	7.1
8	833.7	9.8	101.0	15.5	7.0
9	830.4	9.6	96.9	15.0	6.9
10	827.2	9.5	95.6	14.6	6.9
11	823.9	9.4	94.1	14.3	6.9
12	820.6	9.3	92.8	14.1	6.8
13	817.3	9.2	91.5	13.9	6.8
14	814.1	9.1	89.8	13.7	6.8
15	810.8	8.9	87.6	13.5	6.7
16	807.5	8.9	87.0	13.4	6.7
17	804.2	8.8	86.0	13.1	6.7
18	800.9	8.7	84.1	12.7	6.7
19	797.7	8.8	83.8	12.4	6.7
20	794.4	8.2	77.2	11.4	6.6
21	791.1	8.0	73.2	10.4	6.5
22	787.8	8.4	75.0	9.5	6.5
23	784.5	8.0	70.5	8.8	6.4
24	781.3	7.1	62.1	8.6	6.3
25	778.0	6.7	58.5	8.5	6.3
26	774.7	6.8	59.3	8.4	6.3
27	771.4	6.9	59.8	8.2	6.3
28	768.1	6.9	59.7	8.1	6.3
29	764.9	6.2	53.8	7.9	6.3
30	761.6	6.1	52.9	7.9	6.3
8/9/2016					
1	856.7	9.1	104.0	20.6	6.8

Table A-3. Reservoir 2 Profile Data at Station 60-1 for Dissolved Oxygen (DO), Temperature, and pH[a]

Sample Depth m	Elevation ft MSL	DO concentration mg/L	DO saturation %	Temperature °C	pH
2	853.4	9.1	104.0	20.6	6.8
3	850.2	9.0	104.0	20.6	6.9
4	846.9	9.1	104.0	20.6	6.9
5	843.6	9.6	107.0	19.3	6.9
6	840.3	9.9	109.0	18.5	6.8
7	837.0	10.1	108.0	17.5	6.8
8	833.8	10.0	106.0	16.8	6.8
9	830.5	9.8	102.0	16.0	6.8
10	827.2	9.3	95.9	15.5	6.7
11	823.9	9.2	94.6	15.2	6.7
12	820.6	9.2	94.0	15.0	6.7
13	817.3	9.2	92.6	14.7	6.7
14	814.1	9.0	90.8	14.5	6.7
15	810.8	9.0	89.8	14.3	6.7
16	807.5	8.9	88.5	14.1	6.6
17	804.2	8.8	87.6	13.9	6.6
18	800.9	8.8	87.3	13.7	6.6
19	797.7	8.8	86.1	13.4	6.6
20	794.4	8.4	81.1	12.6	6.6
21	791.1	7.8	74.2	11.7	6.5
22	787.8	7.6	69.7	10.5	6.5
23	784.5	7.2	64.5	9.5	6.5
24	781.3	6.6	59.1	9.2	6.4
25	778.0	6.6	58.8	8.9	6.4
26	774.7	6.4	56.3	8.8	6.4
27	771.4	6.1	53.7	8.7	6.4
28	768.1	6.1	53.4	8.5	6.4
29	764.9	5.7	49.5	8.3	6.4
30	761.6	5.5	48.1	8.2	6.3
31	758.3	5.1	44.5	8.1	6.3
8/23/2016					
1	856.4	8.8	102.0	21.4	7.4
2	853.2	8.8	102.0	21.3	7.4
3	850.2	8.9	102.0	21.3	7.3
4	846.6	9.0	104.0	21.2	7.2
5	843.3	9.5	105.0	19.1	6.7
6	840.2	9.4	102.0	18.3	6.9
7	836.8	9.3	99.9	17.5	6.9
8	833.7	9.3	97.4	16.7	6.8
9	830.5	8.7	90.1	16.1	6.6
10	827.2	8.6	89.0	15.8	6.6
11	823.9	8.5	87.0	15.3	6.6
12	820.3	8.5	86.3	15.1	6.5

Table A-3. Reservoir 2 Profile Data at Station 60-1 for Dissolved Oxygen (DO), Temperature, and pH[a]

Sample Depth m	Elevation ft MSL	DO concentration mg/L	DO saturation %	Temperature °C	pH
13	817.0	8.3	83.1	14.7	6.5
14	813.7	8.5	84.7	14.2	6.5
15	810.5	8.6	85.6	14.0	6.4
16	807.5	9.3	91.5	13.6	6.5
17	804.2	9.3	90.7	13.3	6.4
18	800.9	8.9	86.6	13.2	6.4
19	797.7	9.5	91.7	12.9	6.4
20	794.1	8.1	77.7	12.3	6.3
22	787.8	7.3	68.2	11.2	6.2
23	784.5	5.04[c]	46.0	10.3	6.3
24	781.3	5.7	51.5	9.7	6.1
25	778.0	5.5	49.1	9.5	6.0
26	774.7	5.3	47.7	9.4	6.0
27	771.4	5.3	47.3	9.1	6.0
28	768.1	5.4	47.2	8.9	6.0
29	764.5	5.2	45.3	8.7	5.9
30	761.6	4.9	42.8	8.6	5.9
31	758.3	3.9	34.1	8.4	5.9
9/6/2016					
1	855.6	9.3	103.0	18.9	7.2
2	852.3	9.3	103.0	18.9	7.2
3	849.1	9.3	103.0	18.9	7.2
4	845.7	9.3	103.0	18.9	7.2
5	842.4	9.3	103.0	18.9	7.2
6	839.3	9.4	102.0	18.0	7.2
7	836.0	9.2	98.8	17.4	7.1
8	832.7	9.0	95.9	17.0	7.1
9	829.5	9.0	94.9	16.6	7.1
10	826.2	9.1	95.5	16.5	7.0
11	822.9	9.2	96.3	16.3	7.0
12	819.6	9.2	96.4	16.1	7.0
13	816.3	9.2	96.1	15.9	7.0
14	812.7	8.9	91.4	15.4	7.0
15	809.8	9.1	92.6	15.0	7.0
16	806.5	9.3	94.3	14.6	7.0
17	802.9	9.5	95.9	14.2	7.0
18	799.9	9.5	95.6	14.2	7.0
19	796.7	9.6	94.8	13.6	7.0
20	793.4	9.5	93.7	13.5	7.0
21	790.1	9.2	89.6	12.6	7.0
22	786.5	7.8	74.5	11.8	6.9
23	783.5	7.5	70.8	11.5	6.9
24	779.9	6.4	59.0	10.6	6.8

Table A-3. Reservoir 2 Profile Data at Station 60-1 for Dissolved Oxygen (DO), Temperature, and pH[a]

Sample Depth m	Elevation ft MSL	DO concentration mg/L	DO saturation %	Temperature °C	pH
25	777.0	6.0	54.6	10.2	6.8
26	773.7	4.8	43.7	9.8	6.7
27	770.4	4.7	42.6	9.6	6.7
28	767.1	4.6	40.9	9.4	6.7
29	763.5	4.4	39.3	9.1	6.6
30	760.6	4.1	36.9	9.0	6.6
9/20/2016					
1	856.7	9.5	102.0	17.9	7.2
2	853.4	9.5	102.0	17.9	7.2
3	850.2	9.5	102.0	17.7	7.2
4	846.9	9.5	102.0	17.7	7.2
5	843.6	9.4	102.0	17.7	7.2
6	840.2	9.4	102.0	17.7	7.2
7	837.0	9.4	101.0	17.7	7.2
8	833.7	9.4	101.0	17.7	7.2
9	830.5	9.3	100.0	17.6	7.2
10	827.2	9.2	98.8	17.5	7.2
11	823.9	9.3	98.5	17.1	7.1
12	820.6	9.2	97.4	16.9	7.1
13	817.3	9.1	96.4	16.7	7.1
14	814.1	9.0	95.0	16.5	7.1
15	810.8	9.1	94.8	16.4	7.1
16	807.5	9.0	93.9	16.2	7.1
17	804.2	8.8	91.5	16.0	7.0
18	800.9	8.6	89.2	15.7	7.0
19	797.7	8.8	89.9	15.2	7.0
20	794.4	8.8	89.7	14.8	7.0
21	791.1	9.2	92.4	14.2	7.0
22	787.8	9.2	91.1	13.7	7.0
23	784.5	9.3	90.8	13.3	7.0
24	781.3	8.7	84.7	12.8	6.9
25	778.0	8.4	80.3	12.4	6.9
26	774.7	7.9	75.5	12.1	6.8
27	771.4	7.1	67.1	11.7	6.8
28	768.1	6.5	61.4	11.5	6.7
29	764.9	5.9	54.8	11.1	6.7
30	761.6	5.1	46.6	10.4	6.7
10/4/2016					
1	847.5	9.5	100.0	16.7	7.1
2	844.1	9.5	100.0	16.7	7.1
3	840.9	9.5	100.0	16.6	7.1
4	837.9	9.5	100.0	16.6	7.0
5	834.5	9.5	100.0	16.6	7.0

Table A-3. Reservoir 2 Profile Data at Station 60-1 for Dissolved Oxygen (DO), Temperature, and pH[a]

Sample Depth m	Elevation ft MSL	DO concentration mg/L	DO saturation %	Temperature °C	pH
6	831.3	9.4	99.8	16.6	7.0
7	828.0	9.4	99.7	16.6	7.0
8	824.6	9.4	99.6	16.6	7.0
9	821.4	9.4	99.5	16.6	7.0
10	818.2	9.4	99.4	16.6	7.0
11	814.9	9.4	99.3	16.6	7.0
12	811.6	9.4	98.9	16.6	6.9
13	808.3	9.3	98.8	16.6	7.0
14	805.1	9.3	98.7	16.6	6.9
15	801.8	9.2	97.0	16.5	6.9
16	798.2	9.1	96.3	16.4	6.9
17	795.2	8.6	89.7	16.2	6.8
18	791.9	8.6	89.7	16.2	6.8
19	788.7	4.77 FE[d]	45.1 FE	11.4 FE	6.14 FE
20	785.4	8.5	88.5	15.9	6.8
21	782.1	8.4	86.3	15.2	6.7
22	778.8	8.4	85.9	14.8	6.7
23	775.5	8.4	85.4	14.6	6.7
24	771.9	8.2	81.3	13.9	6.6
25	768.7	7.8	77.5	13.6	6.5
26	765.7	7.6	74.5	13.4	6.5
27	762.1	7.4	72.8	13.2	6.5
28	759.1	6.9	67.2	12.8	6.4
10/18/2016					
1	857.5	10.3	97.2	11.8	7.1
2	854.4	10.3	97.1	11.8	7.1
3	851.1	10.3	97.2	11.7	7.0
4	847.7	10.3	97.1	11.6	7.0
5	844.6	10.4	97.6	11.5	7.0
6	841.3	10.4	98.1	11.4	7.0
7	838.0	10.5	98.1	11.3	7.0
8	834.6	10.5	98.3	11.3	6.9
9	831.4	10.5	98.3	11.2	6.9
10	827.9	10.5	98.2	11.1	6.9
11	824.9	10.5	98.1	11.1	6.9
12	821.6	10.5	98.1	11.1	6.9
13	818.3	10.5	98.0	11.1	6.9
14	815.1	10.5	97.7	11.0	6.9
15	811.8	10.5	97.6	11.0	6.9
16	808.5	10.5	97.5	11.0	6.9
17	805.2	10.5	97.5	11.0	6.9
18	801.9	10.5	97.5	11.0	6.9
19	798.7	10.5	97.4	11.0	6.9

Table A-3. Reservoir 2 Profile Data at Station 60-1 for Dissolved Oxygen (DO), Temperature, and pH[a]

Sample Depth m	Elevation ft MSL	DO concentration mg/L	DO saturation %	Temperature °C	pH
20	795.4	10.5	97.3	11.0	6.9
21	791.8	10.5	97.3	10.9	6.9
22	788.5	10.5	97.2	10.9	6.8
23	785.5	10.5	97.1	10.9	6.9
24	782.3	10.5	97.1	10.9	6.8
25	778.7	10.4	97.0	10.9	6.8
26	775.7	10.5	97.0	10.8	6.8
27	772.4	10.5	97.1	10.8	6.8
28	769.1	10.5	97.2	10.8	6.8
29	765.9	10.5	97.2	10.8	6.8
30	762.2	10.5	97.2	10.8	6.8
31	759.0	10.5	97.2	10.8	6.8
11/1/2016					
1	855.5	10.7	98.7	10.6	7.1
2	852.3	10.7	98.6	10.6	7.1
3	849.0	10.7	98.6	10.6	7.1
4	845.7	10.6	98.4	10.6	7.1
5	842.5	10.6	98.3	10.6	7.0
6	839.1	10.6	98.1	10.5	7.0
7	835.9	10.6	97.9	10.5	7.0
8	832.6	10.6	97.7	10.5	7.0
9	829.2	10.6	97.3	10.3	7.0
10	826.2	10.6	97.2	10.2	7.0
11	822.6	10.6	97.3	10.1	7.0
12	819.6	10.6	97.2	10.1	7.0
13	816.3	10.6	97.1	10.1	7.0
14	813.1	10.6	97.2	10.1	7.0
15	809.8	10.6	97.1	10.1	7.0
16	806.2	10.6	97.1	10.0	7.0
17	802.9	10.6	97.1	10.0	7.0
18	799.9	10.6	97.1	10.0	6.9
19	796.7	10.6	97.0	10.0	6.9
20	793.1	10.6	96.7	10.0	6.9
21	789.8	10.6	96.6	10.0	6.9
22	786.8	10.6	96.6	10.0	6.9
23	783.2	10.6	96.4	10.0	6.9
24	780.3	10.6	96.4	10.0	6.9
25	777.0	10.6	96.2	10.0	6.9
26	773.7	10.6	96.1	10.0	6.9
27	770.1	10.5	96.0	10.0	6.9
28	767.1	10.5	95.9	10.0	6.9
29	763.9	10.5	95.7	9.9	6.9
30	760.2	10.5	95.5	9.9	6.9

Table A-3. Reservoir 2 Profile Data at Station 60-1 for Dissolved Oxygen (DO), Temperature, and pH[a]

Sample Depth m	Elevation ft MSL	DO concentration mg/L	DO saturation %	Temperature °C	pH
11/15/2016					
1	852.7	10.8	100.0	10.7	6.7
2	849.4	10.8	100.0	10.7	6.7
3	846.1	10.7	99.8	10.7	6.7
4	842.7	10.7	98.6	10.5	6.6
5	839.5	10.6	97.6	10.3	6.6
6	836.2	10.6	97.2	10.1	6.6
7	832.8	10.6	96.8	10.0	6.6
8	829.6	10.6	96.7	10.0	6.6
9	826.3	10.6	96.9	9.9	6.6
10	822.9	10.7	97.1	9.9	6.6
11	819.9	10.6	97.0	9.9	6.6
12	816.6	10.6	97.0	9.9	6.6
13	813.3	10.6	96.7	9.8	6.6
14	810.1	10.6	96.6	9.8	6.5
15	806.8	10.6	96.6	9.8	6.5
16	803.2	10.6	96.7	9.8	6.5
17	800.2	10.6	96.7	9.8	6.5
18	796.9	10.6	96.6	9.8	6.5
19	793.3	10.6	96.6	9.8	6.5
20	790.4	10.6	96.5	9.7	6.5
21	787.1	10.6	96.5	9.7	6.5
22	783.8	10.6	96.4	9.7	6.5
23	780.5	10.6	96.4	9.7	6.5
24	777.3	10.6	96.5	9.7	6.5
25	774.0	10.6	96.4	9.7	6.5
26	770.7	10.6	96.4	9.7	6.5
27	767.4	10.6	96.4	9.7	6.5
28	764.1	10.6	96.4	9.7	6.5
29	760.9	10.6	96.3	9.7	6.5
11/29/2016					
1	856.6	11.1	97.3	8.6	6.9
2	853.2	11.1	97.2	8.6	6.9
3	850.1	11.1	97.1	8.6	6.9
4	846.6	11.1	97.0	8.6	6.9
5	843.5	11.1	96.9	8.6	6.9
6	840.3	11.1	96.8	8.6	6.9
7	836.9	11.1	96.7	8.6	6.9
8	833.5	11.1	96.8	8.5	6.9
9	830.3	11.1	96.8	8.5	6.9
10	826.9	11.1	96.8	8.5	6.8
11	823.6	11.1	96.8	8.5	6.8
12	820.3	11.1	96.7	8.5	6.8

Table A-3. Reservoir 2 Profile Data at Station 60-1 for Dissolved Oxygen (DO), Temperature, and pH[a]

Sample Depth m	Elevation ft MSL	DO concentration mg/L	DO saturation %	Temperature °C	pH
13	817.3	11.1	96.6	8.4	6.8
14	813.7	11.1	96.6	8.4	6.8
15	810.8	11.1	96.6	8.3	6.8
16	807.5	11.1	96.7	8.3	6.8
17	804.2	11.1	96.7	8.3	6.8
18	800.6	11.1	96.7	8.3	6.8
19	797.3	11.1	96.6	8.3	6.8
20	794.4	11.1	96.5	8.2	6.8
21	790.8	11.1	96.5	8.2	6.8
22	787.8	11.1	96.5	8.2	6.8
23	784.2	11.1	96.4	8.2	6.8
24	780.9	11.1	96.4	8.2	6.8
25	777.7	11.1	96.3	8.2	6.8
26	774.4	11.1	96.3	8.2	6.8
27	771.1	11.1	96.2	8.2	6.8
28	768.1	11.1	96.3	8.1	6.8
29	764.9	11.1	96.2	8.1	6.8
30	761.2	11.1	96.2	8.1	6.8
31	758.3	11.1	96.2	8.1	6.8
12/13/2016					
1	855.5	11.8	96.3	5.9	FE[d]
2	852.3	11.8	96.2	5.9	FE
3	848.9	11.8	96.1	5.9	FE
4	845.8	11.8	96.1	5.9	FE
5	842.6	11.7	96.0	5.9	FE
6	839.1	11.7	95.9	5.9	FE
7	836.0	11.7	95.9	5.9	FE
8	832.7	11.7	95.7	5.9	FE
9	829.2	11.7	95.6	5.9	FE
10	826.2	11.7	95.6	5.9	FE
11	822.9	11.7	95.5	5.9	FE
12	819.6	11.7	95.5	5.9	FE
13	816.0	11.7	95.4	5.9	FE
14	813.1	11.7	95.3	5.9	FE
15	809.8	11.6	95.2	5.9	FE
16	806.2	11.6	95.1	5.9	FE
17	803.2	11.6	95.1	5.9	FE
18	799.6	11.7	95.2	5.8	FE
19	796.3	11.7	95.2	5.8	FE
20	793.4	11.7	95.2	5.8	FE
21	790.1	11.7	95.4	5.7	FE
22	786.5	11.7	95.4	5.7	FE
23	783.2	11.7	95.5	5.7	FE

Table A-3. Reservoir 2 Profile Data at Station 60-1 for Dissolved Oxygen (DO), Temperature, and pH[a]

Sample Depth m	Elevation ft MSL	DO concentration mg/L	DO saturation %	Temperature °C	pH
24	780.3	11.7	95.5	5.7	FE
25	777.0	11.7	95.5	5.7	FE
26	773.7	11.7	95.4	5.7	FE
27	770.4	11.7	95.4	5.7	FE
28	766.8	11.7	95.3	5.6	FE
29	763.9	11.7	95.3	5.6	FE
30	760.2	11.7	95.2	5.6	FE
31	757.3	11.7	95.0	5.6	FE
12/19/2016					
1	852.3	12.0	95.3	4.7	6.6
2	849.2	12.0	95.2	4.7	6.7
3	846.1	12.0	95.3	4.7	6.6
4	842.8	12.0	95.3	4.7	6.6
5	839.6	12.0	95.3	4.7	6.6
6	836.3	12.0	95.2	4.7	6.6
7	832.9	12.0	95.2	4.7	6.6
8	829.4	12.0	95.3	4.7	6.6
9	826.2	12.0	95.3	4.8	6.6
10	823.2	12.0	95.2	4.8	6.6
11	819.9	12.0	95.2	4.8	6.6
12	816.3	12.0	95.3	4.8	6.6
13	813.3	12.0	95.2	4.8	6.6
14	810.1	12.0	95.2	4.8	6.6
15	806.8	12.0	95.2	4.8	6.6
16	803.5	12.0	95.2	4.8	6.6
17	799.9	12.0	95.2	4.8	6.6
18	796.9	12.0	95.2	4.8	6.6
19	793.7	12.0	95.2	4.8	6.6
20	790.4	12.0	95.2	4.8	6.6
21	787.1	12.0	95.2	4.7	6.6
22	783.8	12.0	95.2	4.7	6.6
23	780.2	12.0	95.2	4.7	6.6
24	777.3	12.0	95.2	4.7	6.6
25	774.0	12.0	95.3	4.7	6.6
26	770.7	12.0	95.2	4.7	6.6
27	767.4	12.0	95.2	4.7	6.6
28	763.8	12.0	95.2	4.7	6.6
29	760.5	12.0	95.1	4.7	6.7
30	757.2	12.0	95.0	4.7	6.7
12/27/2016					
1	854.5	13.1	104.0	4.3	6.8
2	851.2	13.1	103.0	4.3	6.7
3	848.1	13.1	103.0	4.3	6.7

Table A-3. Reservoir 2 Profile Data at Station 60-1 for Dissolved Oxygen (DO), Temperature, and pH[a]

Sample Depth m	Elevation ft MSL	DO concentration mg/L	DO saturation %	Temperature °C	pH
4	844.7	13.1	103.0	4.3	6.7
5	841.5	13.1	103.0	4.3	6.7
6	838.2	13.1	103.0	4.3	6.7
7	834.9	13.1	103.0	4.3	6.7
8	831.5	13.1	103.0	4.3	6.7
9	828.4	13.1	103.0	4.3	6.7
10	824.9	13.1	103.0	4.3	6.7
11	821.6	13.1	103.0	4.3	6.7
12	818.3	13.1	103.0	4.3	6.7
13	815.3	13.1	103.0	4.3	6.7
14	811.7	13.1	103.0	4.3	6.7
15	808.8	13.1	103.0	4.3	6.7
16	805.2	13.1	103.0	4.3	6.7
17	802.2	13.1	103.0	4.3	6.7
18	798.6	13.1	103.0	4.3	6.7
19	795.7	13.1	103.0	4.3	6.7
20	792.4	13.1	103.0	4.3	6.7
21	788.8	13.1	103.0	4.3	6.7
22	785.8	13.1	103.0	4.3	6.7
23	782.2	13.1	103.0	4.3	6.7
24	778.9	13.1	103.0	4.3	6.7
25	776.0	13.1	103.0	4.3	6.7
26	772.7	13.1	103.0	4.3	6.7
27	769.1	13.1	103.0	4.3	6.7
28	766.1	13.1	103.0	4.3	6.7
29	762.5	13.1	103.0	4.3	6.7
30	759.2	13.1	103.0	4.3	6.8
31	756.0	13.0	102.0	4.3	6.6

[a]m is meters, ft MSL is feet above mean sea level, mg/L is milligrams per liter, °C is degrees Celsius
[b]Q denotes that results varied significantly from expected results; results in sampling immediately before and after showed pH in expected ranges

[c]This sample was collected out of sequence with the rest of the profile; data are not in line with the rest of the profile, indicating that the probe may not have stabilized at this depth before values were recorded
[d]FE denotes sampling probe malfunction; where required, resamples were collected

Appendix C

Bull Run HCP Research Report

Lower Bull Run River Spawning Gravel Research

April 2017
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 2016 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 2016 was within the range of what had been observed in all previous years (2010-2015) at all locations and flows, but less than it was in 2015. The largest accumulations of gravel were in the river channel immediately downstream of Larson's Bridge. 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 2016 to benefit spawning salmonids. This was the seventh 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 2016.

[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

Question 1: 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 only use 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. In 2011, these data were not available because there is no practical method for collecting and summarizing them. Therefore, the following analysis was not attempted.

The following key question and hypothesis were identified in the HCP.

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. 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 exceedence flow
- **614 cfs:** 50 percent average exceedence 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 exceedence flow
- **77 cfs :** 50 percent average exceedence 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 exceedence flow
- **77 cfs :** 50 percent average exceedence 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 exceedence 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 exceedence 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 per 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 2–6, 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 continued once per year for an additional five years, HCP Years 7–11. 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.

Provided that gravel supplementation at maintenance levels does not result in a rapid negative trend during HCP Years 7–11, the frequency of gravel surveys will be reduced to once every five years for the duration of the HCP.

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 10^{th} Percentile of Substrate Size. The sizes of particles corresponding to the upper and lower 10^{th} 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 2016 survey was conducted at a discharge flow that varied between 25 cfs and 106 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 0.1 and 6.0 inches in diameter along their intermediate axis for Chinook and between 0.1 and 4.0 inches 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

[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.

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.

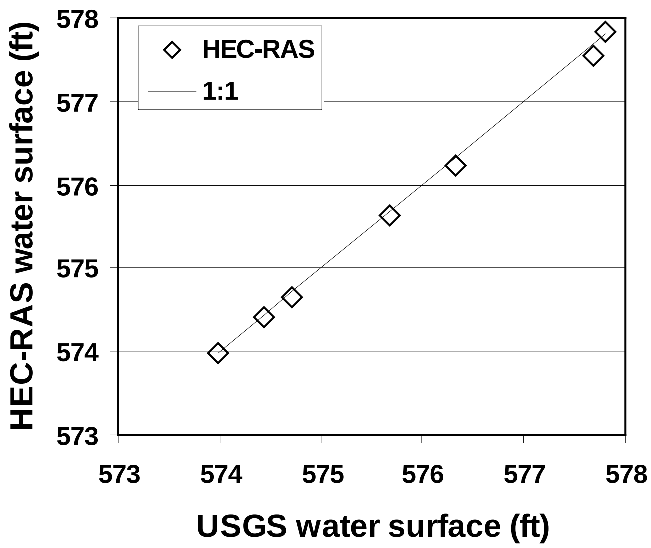

Figure 1. Comparison of HEC-RAS Model River Stage Results with USGS Stage/Discharge Curve Values

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 628 gravel patches with substrate sizes suitable for spawning Chinook were identified within the active channel in 2016, with a total of 44,956 square feet of combined surface area. Of these, 575 patches also had substrate sizes suitable for spawning steelhead, with a total of 39,670 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 2016 than the baseline average at all flows. This difference was statistically significant at all flows evaluated (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 1.

Table 1. Combined Surface Area of Steelhead Spawning Gravel Patches in the Lower Bull Run River, 2016

	120 cfs	614 cfs	1,405 cfs
2016 Survey Results	23,764 ft^2	29,652 ft^2	33,828 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 2016, 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=0.95, 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, 2016

	30 cfs	77 cfs	358 cfs
2016 Survey Results	20,431 ft^2	24,708 ft^2	29,293 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 2015, 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, 2016

	30 cfs	77 cfs	1,480 cfs
2016 Survey Results	20,431 ft^2	24,708 ft^2	37,498 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. Seven years of post-supplementation data on gravel surface area have been collected, which is adequate to begin 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 percent confidence equates with p=0.05).

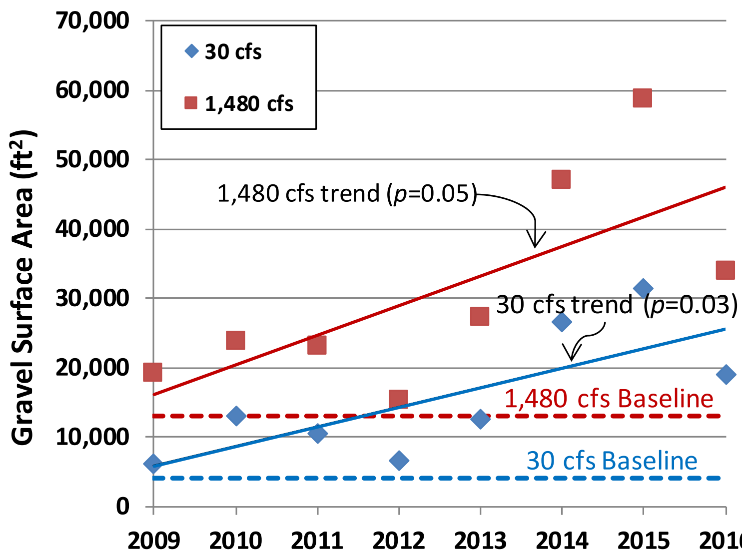

Figure 2. Trends in the Surface Area of Steelhead Spawning Gravel Wetted at 30 cfs and 1,480 cfs in Post-Treatment Years. Baseline Surface Areas are Indicated.

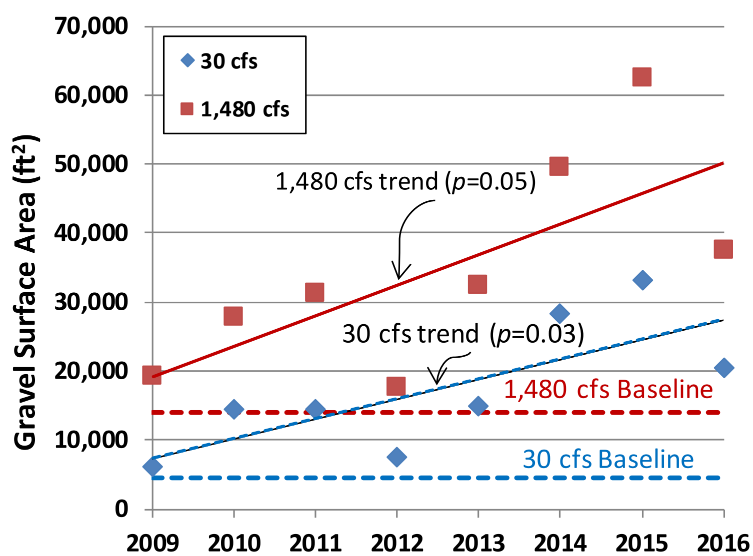

Figure 3. Trends in the Surface Area of Chinook Spawning Gravel Wetted at 30 cfs and 1,480 cfs in Post-Treatment Years. Baseline Surface Areas are Indicated.

7.3 Distribution of Spawning Gravel

7.3.1 Steelhead

In 2016, large accumulations of steelhead spawning gravel were observed immediately downstream of Larson's Bridge (Figure 4). Other accumulations were observed in the river segment between the Southside Bridge and Larson's Bridge. 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 has possibly been passing out of the river since 2014. Figures 5 and 6 compare the longitudinal distribution of steelhead spawning gravel in 2016 with previous post-treatment years and the baseline at flows that bracket the range of flows being evaluated.

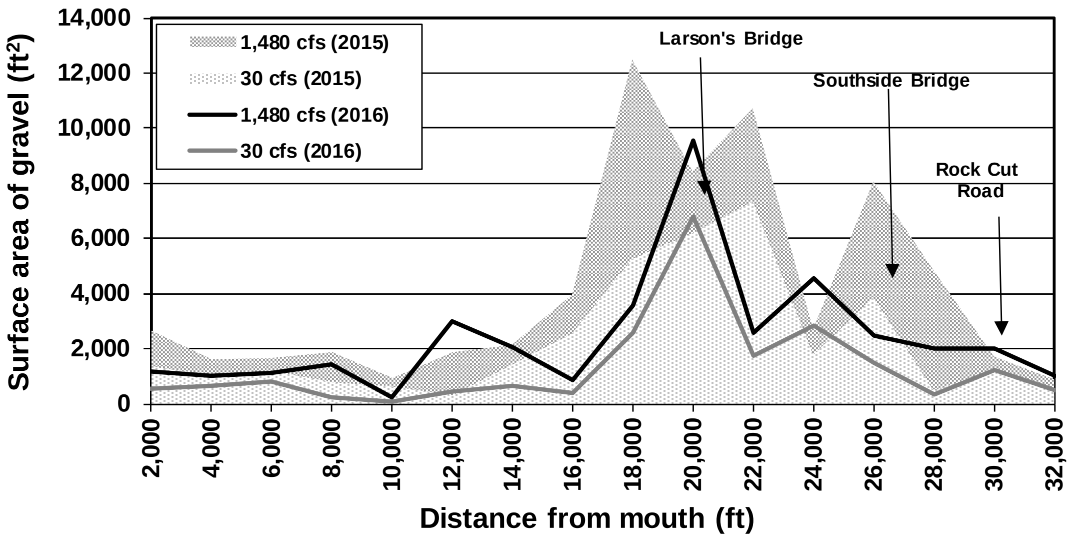

Figure 4. Longitudinal Distribution of Steelhead Spawning-Size Gravel Patches in the Lower Bull Run River in 2016 at 30 cfs and 1,480 cfs Compared to 2015

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 2016 were in the middle of the range of what was observed in previous years at all flows. The surface area of steelhead gravel wetted at the lowest flows (120 cfs and less) was between four and five times the baseline levels.

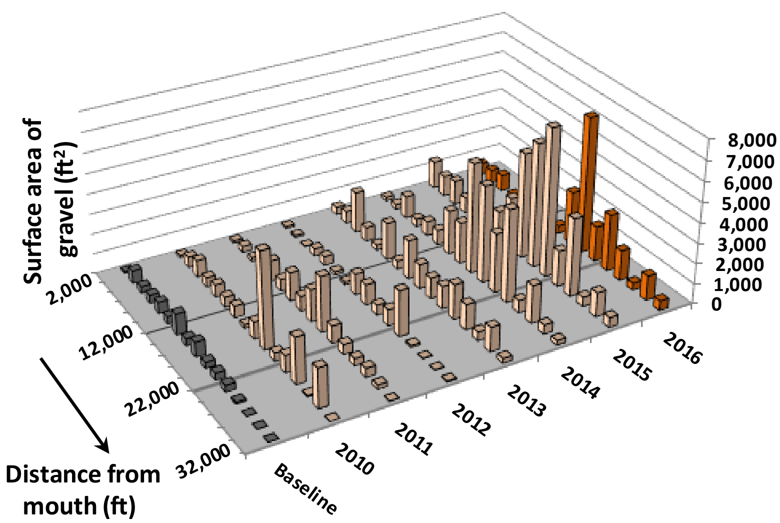

Figure 5. Longitudinal Distribution of Steelhead Spawning-Size Gravel Patches in the Lower Bull Run River in 2010-2016 Compared to the Baseline Average at 30 cfs

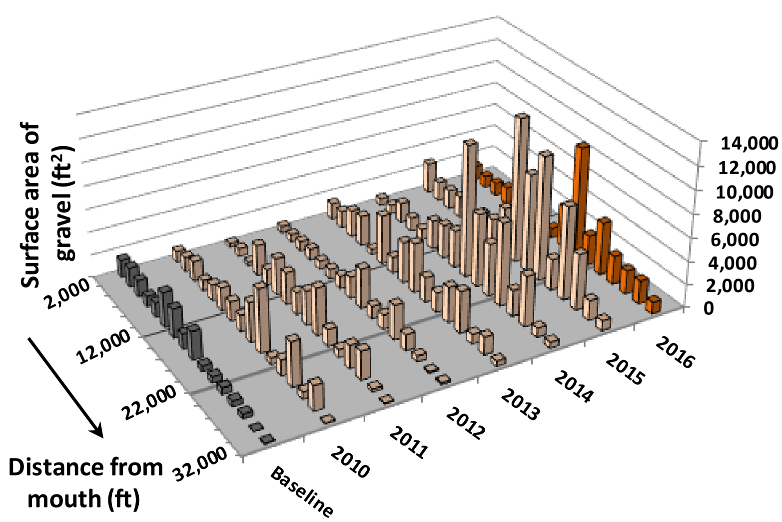

Figure 6. Longitudinal Distribution of Steelhead Spawning-Size Gravel Patches in the Lower Bull Run River in 2010-2016 Compared to the Baseline Average at 1,480 cfs

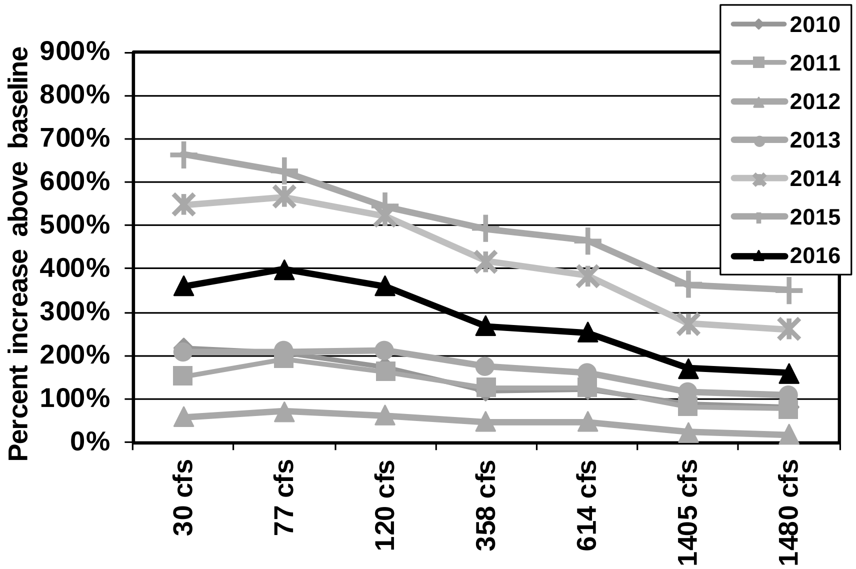

Figure 7. Increase in the Surface Area of Steelhead Spawning-Size Gravel Patches in 2016 above the Baseline Average for Various Flows Compared to Past Years.

7.3.2 Chinook

In 2016, large accumulations of Chinook spawning gravel were observed immediately downstream of Larson's Bridge (Figure 8). Other accumulations were observed in the river segment between the Southside Bridge and Larson's Bridge. 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 2016 with previous post-treatment years and the baseline at flows that bracket the range of flows being evaluated.

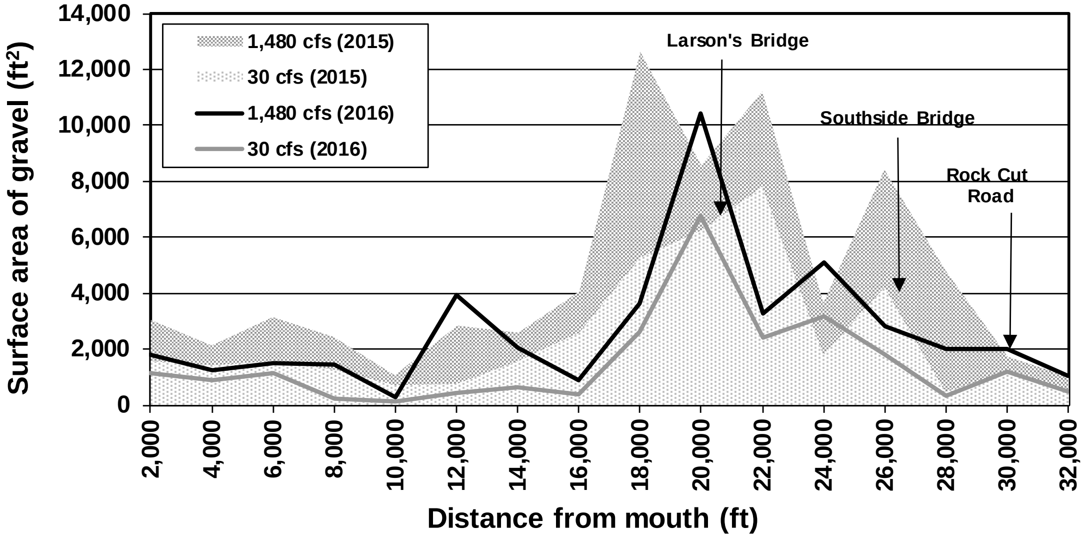

Figure 8. Longitudinal Distribution of Chinook Spawning-Size Gravel Patches in the Lower Bull Run River in 2016 at 30 cfs and 1,480 cfs Compared to 2015

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 2016 above the baseline were in the middle 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 four to five times the baseline levels.

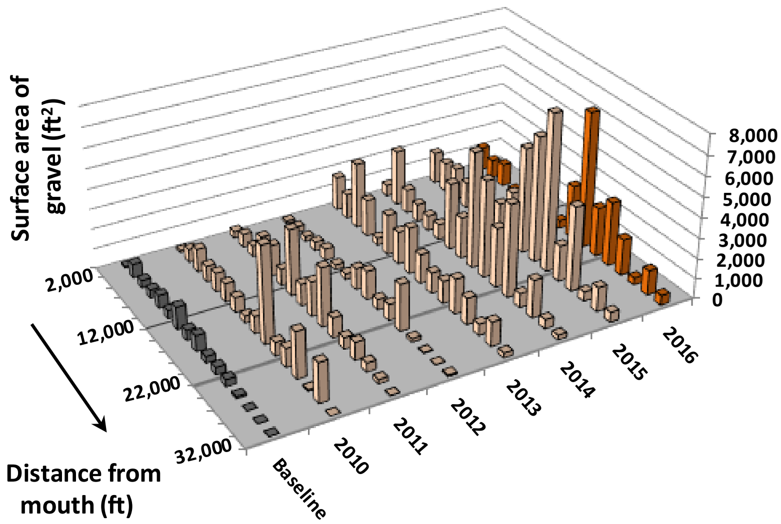

Figure 9. Longitudinal Distribution of Chinook Spawning-Size Gravel Patches in the Lower Bull Run River in 2010-2016 Compared to the Baseline Average at 30 cfs

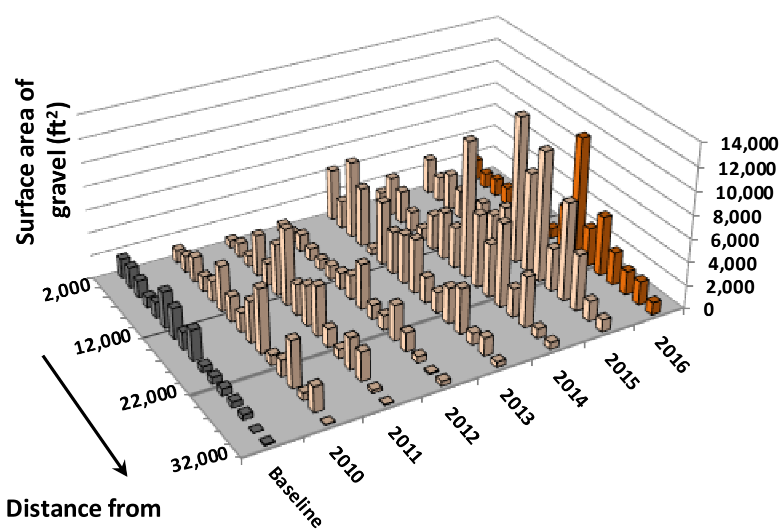

Figure 10. Longitudinal Distribution of Chinook Spawning-Size Gravel Patches in the Lower Bull Run River in 2010-2016 Compared to the Baseline Average at 1,480 cfs

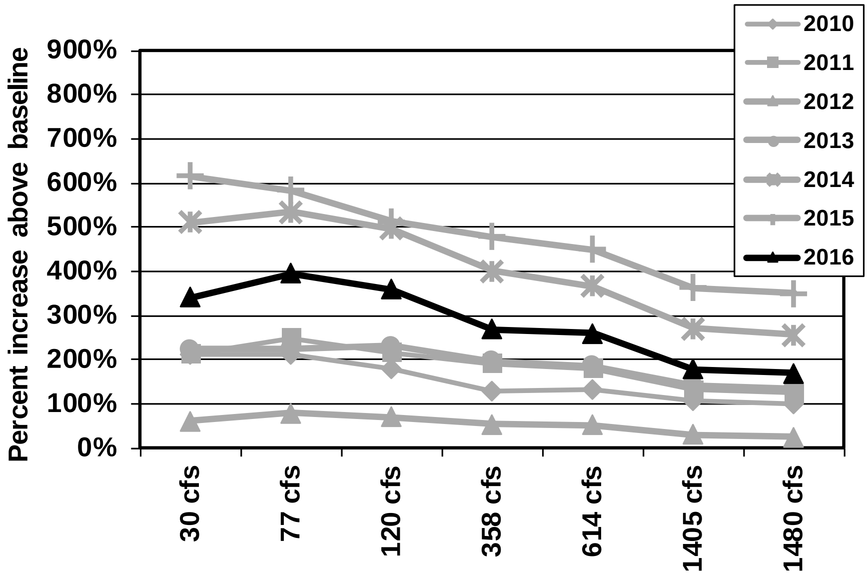

Figure 11. Increase in the Surface Area of Chinook Spawning-Size Gravel Patches in 2016 above the Baseline Average for Various Flows Compared to Past Years

8. Summary and Discussion

The total surface area of spawning-sized gravel was significantly greater in 2016 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 2016, however, was less than in 2015. Gravel was concentrated in portions of the Bull Run River immediately downstream of the Southside Bridge and Larson's Bridge gravel placement sites, with the largest accumulations downstream of Larson's Bridge. Gravel accumulations in the lowest 1.5 miles of the river were also greater than in baseline years, though less than in 2015. 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.

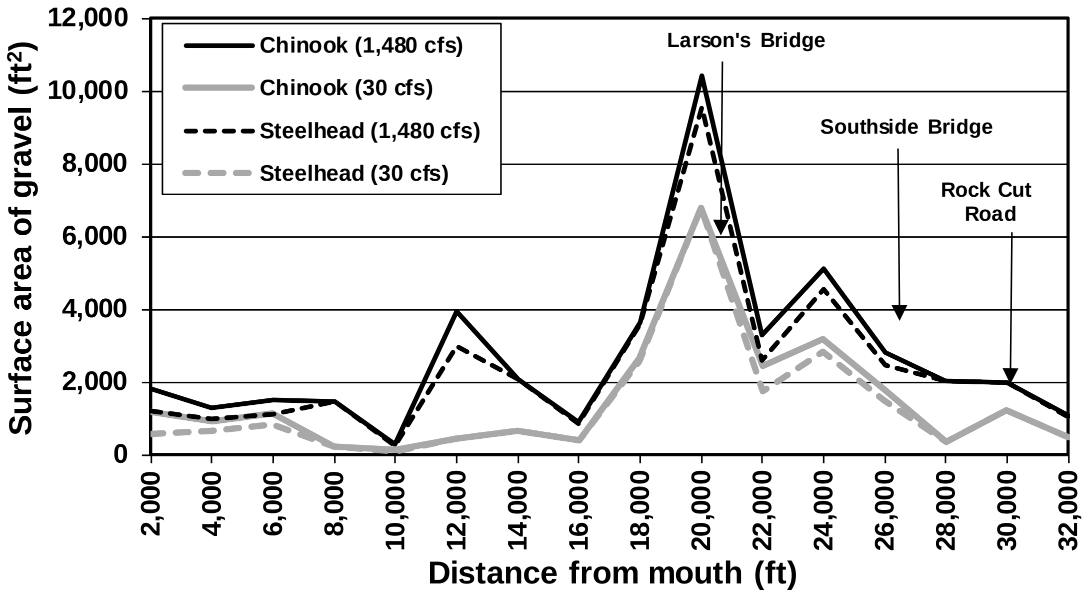

Figure 12. Comparison of Longitudinal Distribution of Chinook and Steelhead Spawning-Size Gravel Patches in the Lower Bull Run River in 2016 at 30 cfs and 1,480 cfs

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. Over 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 large decrease in spawning surface area observed from 2015 to 2016 could be attributable to either the decreased rate of gravel supplementation or the mobilization of gravel into the bottoms of deep pools. The rate of gravel supplementation was decreased from 1,200 cubic yards to 600 cubic yards per year after 2014. The 2016 gravel survey occurred after two years of the lower rate. The 2015 survey, however, observed record accumulations of gravel, despite being conducted after the first year at the lower rate of supplementation. It was suggested in 2012, after a peak flow of 9,330 resulted in decreased spawning gravel surface area, that relatively low and relatively high peak flows might result in larger observed gravel surface areas than peak flows of intermediate magnitude. Low peak flows might fail to fully mobilize recently introduced gravel. Intermediate peak flows might mobilize gravel into deep pools with slow water. High peak flows might be capable of remobilizing gravel that has accumulated in pool bottoms. The peak flow experienced by the lower Bull Run River during the winter previous to the 2016 gravel survey was 10,400 cfs—an intermediate magnitude—supporting the above 2012 assumptions. The record gravel accumulations observed in 2015, however, followed a low-to-intermediate magnitude peak flow of 8,700 cfs.

9. Works Cited

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Appendix D

Bull Run HCP Research Report

Total Dissolved Gases in the Bull Run River

April 2017

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 2016. No additional TDG data were collected in 2016 because the Bull Run River flows were not in the desired range for monitoring.

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 which 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.

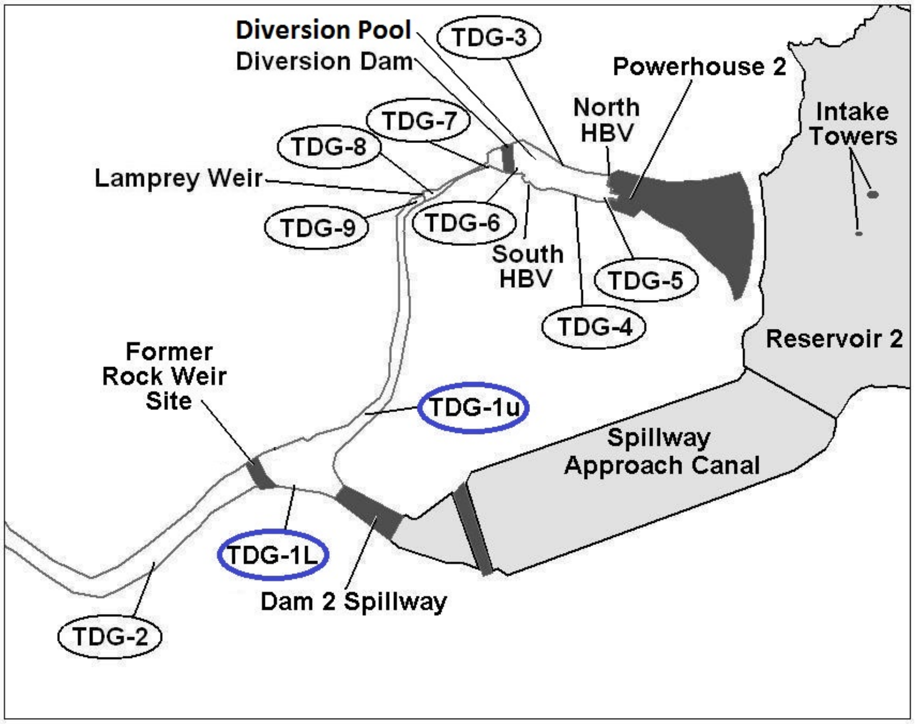

Figure 1. Locations of TDG Monitoring Sites Associated with Dam 2[a]

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

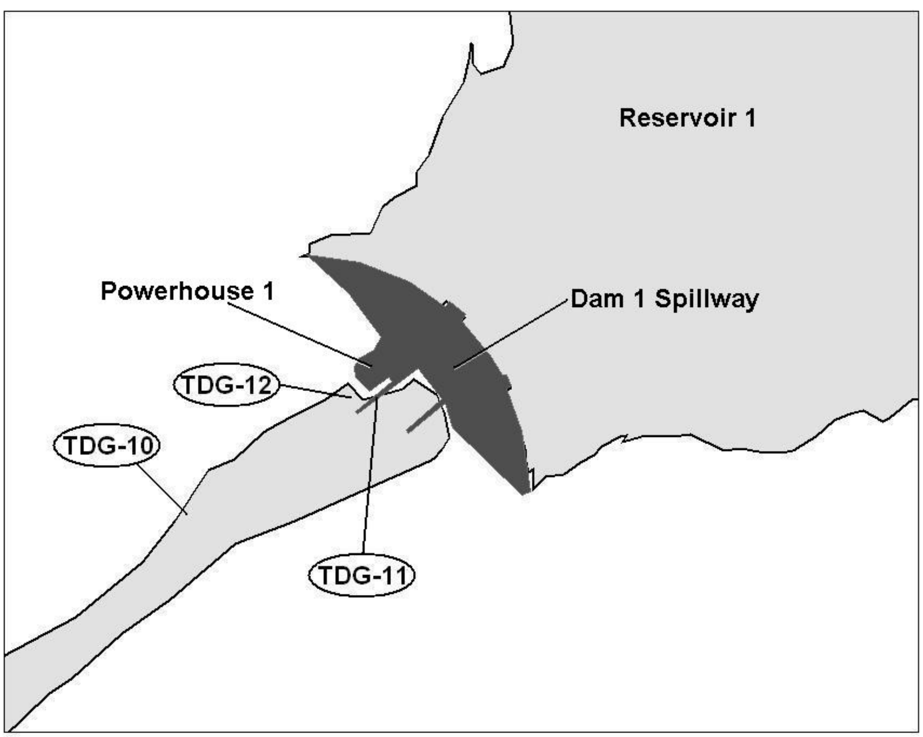

Figure 2. Locations of TDG Monitoring Sites Associated with Dam 1

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 June 30, 2015; it is currently estimated to be 5,638 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

No TDG data were collected in the Bull Run River in 2016. 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

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

Structure	Flow Ranges (cfs)	Remaining Number of Replicates
North HB Valve	While operating	3
Diversion Dam	Whenever Powerhouse 2 or HB valve readings are taken	3
Lamprey Weir	Whenever Powerhouse 2 or HB valve readings are taken	1
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 2,616 cfs, as shown in Figure 3. This left a range of flows between 2,616 and 5,689 cfs for which this site had the potential for 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 113 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.

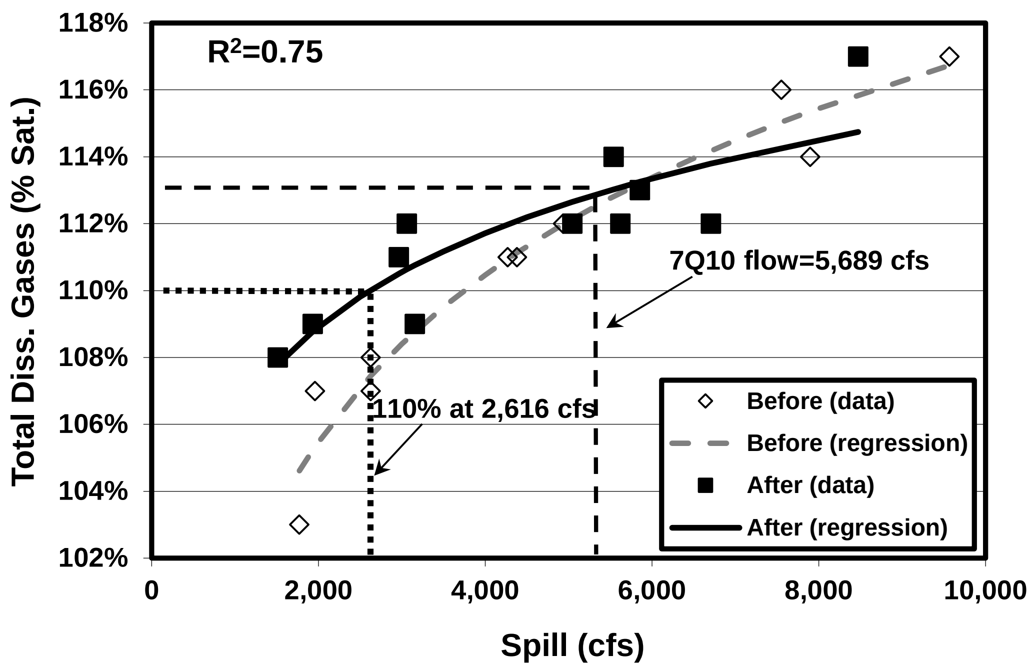

Figure 3. Relationship of TDG Percent Saturation to Flow over the Dam 2 Spillway (TDG-1L) After Rock Weir Removal Compared to Relationship After Rock Weir Removal

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.

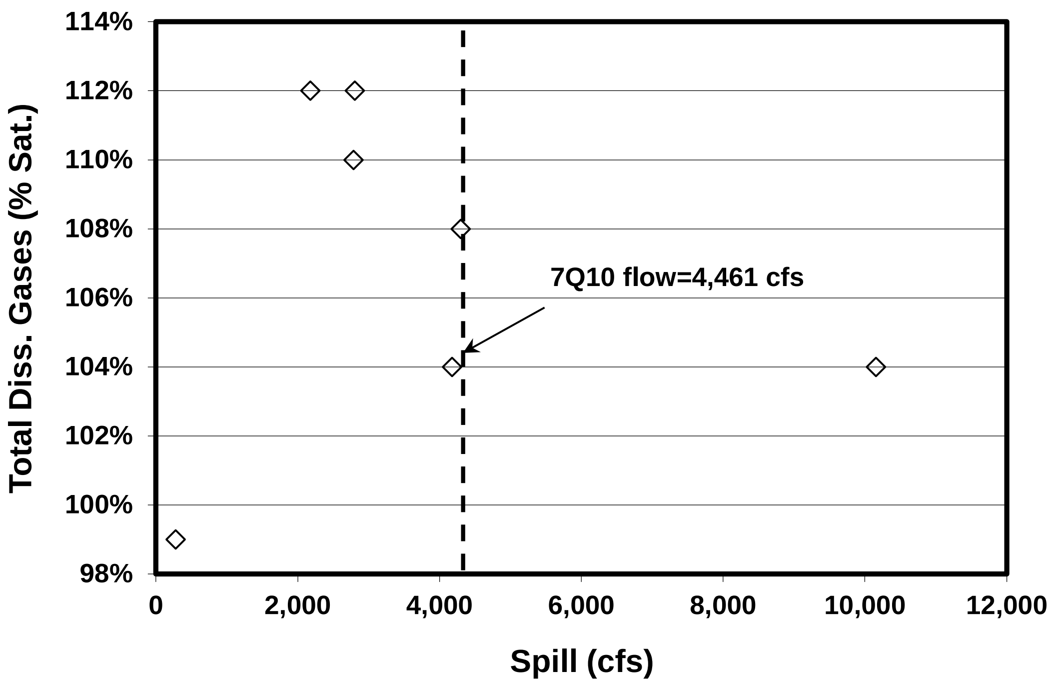

Figure 4. Relationship of TDG Percent Saturation to Flow over the Dam 1 Spillway (TDG-11)

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 105.3 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 110.1 percent saturation at the 7Q10 flow, as shown in Figure 5. The TDG level of the combined flow is predicted to exceed 110 percent saturation above 5,636 cfs. This leaves a narrow window of flows between 5,636 cfs and 5,689 cfs when the 110 percent TDG saturation threshold could theoretically be exceeded below the 7Q10 flow. TDG levels are predicted to be 110.1 percent at the 7Q10 flow, with dilution.

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 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.

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 two 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 5 will also change if Powerhouse 2 is operated at less than maximum capacity.

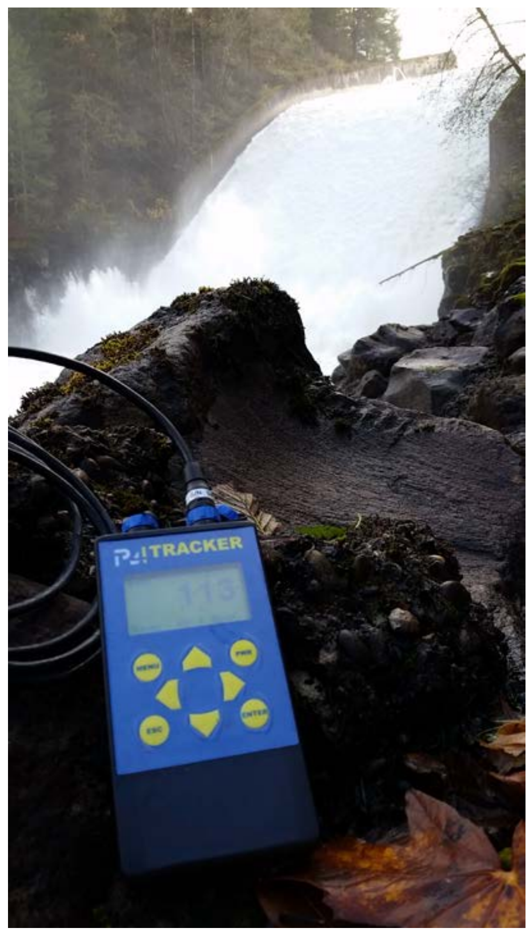

Figure 5. TDG Meter in Use Since 2012

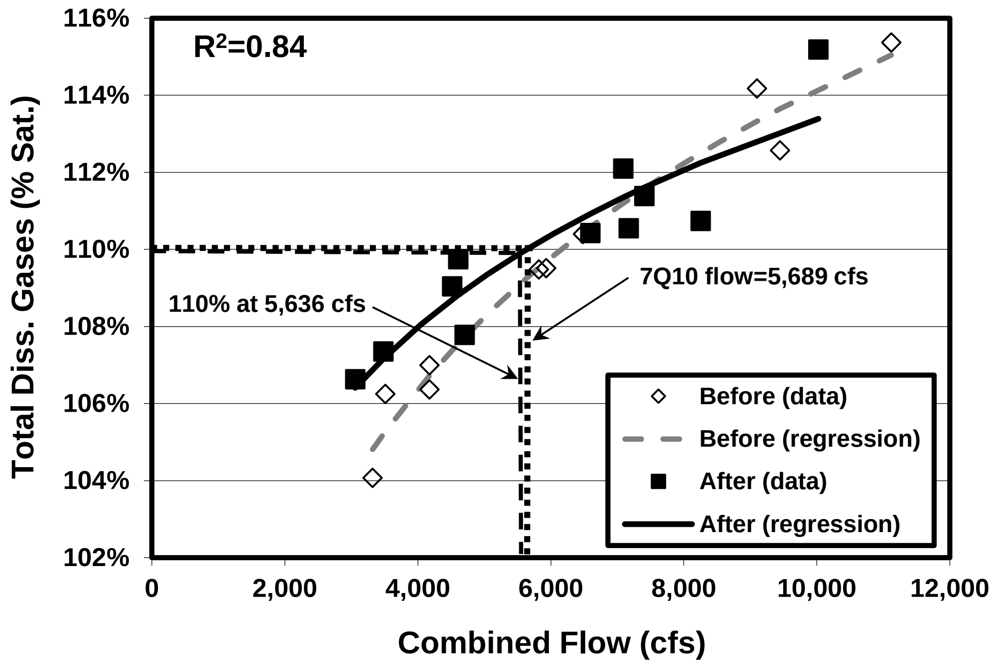

Figure 6. Relationship of TDG Percent Saturation to the Combined Flow of the Dam 2 Spillway and Powerhouse 2 After Rock Weir Removal Compared to Before Rock Weir Removal

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 6.

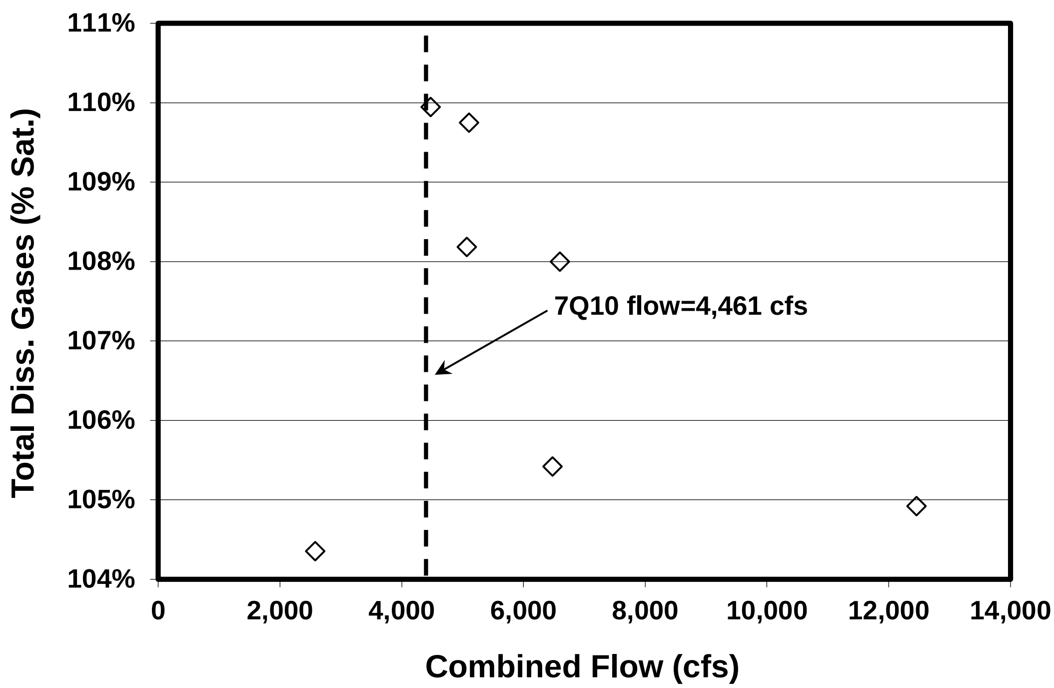

Figure 7. Relationship of TDG Percent Saturation to Combined Flow of the Dam 1 Spillway and Powerhouse 1

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 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.

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 7. Table 4 summarizes the average distances downstream at which various elevated TDG levels are predicted to dissipate to 110 percent.

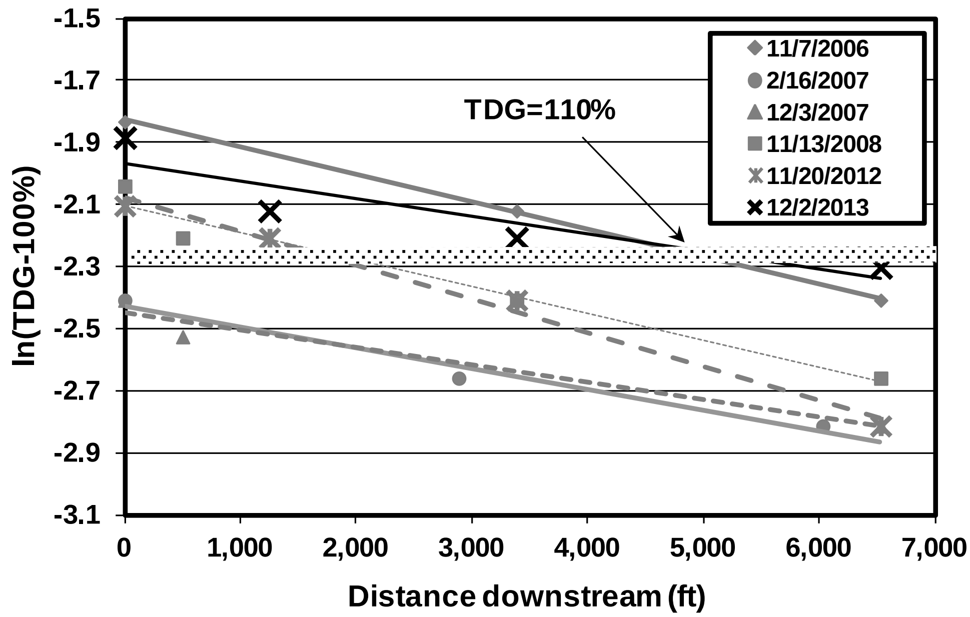

Figure 8. Dissipation of TDG Downstream of the Site of the Rock Weir at the Dam 2 Spillway Plunge Pool on Four Dates

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?

No TDG data were collected in 2016. TDG levels exceeded 110 percent locally at one site on two occasions and at another site on one occasion, 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 2,616 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 5,636 cfs.

The TDG levels at the Dam 2 spillway could be slightly higher than 110 percent under flows slightly lower than the 7Q10. This could occur if spillway flows were between 5,636 cfs and the 7Q10 flow of 5,689 cfs and no water was passed through the Diversion Pool. At the 7Q10 flow, TDG levels are predicted to be 110.1 percent.

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 2016, 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
12/28/2005	TDG-1a	109%	4,380	1,690

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)
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
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
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

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)
1/19/2012	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
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

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)
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
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
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)
12/2/2013	TDG-8	106%		1,700
11/18/2015	TDG-8	102%		620 (HBV)
12/9/2015	TDG-8	104%		1,515
11/14/2006	TDG-9	100%		1,714
2/16/2007	TDG-9	103%		1,699
12/3/2007	TDG-9	104%		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)
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

[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
12/2/2013	TDG-10	105%	2,909	2,200
11/18/2015	TDG-10	107%	4,178	0
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

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)
1/4/2005	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

Appendix E

Bull Run HCP Research Report

Lower Bull Run River Adult Chinook Population

April 2017
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 2016 regarding lower Bull Run River adult Chinook salmon population research. Weekly surveys of spawning and holding Chinook salmon were conducted from the end of August through early December. The surveyed portion of the lower Bull Run River includes the entire lower river from its mouth to the base of the Bull Run diversion dam at Headworks (river mile [RM] 6.0). In 2016, spawning surveys could not be conducted on seven occasions because of high flows. The peak adult Chinook count and minimum escapement[1] in 2016 were the highest since annual surveys were initiated in 2005. The cumulative redd count was in the middle of the range of what has been observed in past years. This year's seven missed surveys may have also contributed to a lower minimum escapement estimate and cumulative redd count.

In addition to the survey protocol described in the HCP, two additional surveys were conducted early in the season with modified protocols. 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. 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. No adult hatchery Chinook were observed in the Bull Run River during the first snorkel survey in early August, but a large number of adult hatchery Chinook were observed during the second snorkel survey, indicating that hatchery adult Chinook were able to circumvent the ODFW weir in mid-September. Other hatchery adults were observed during walking surveys in early September, which may have entered the river prior to the installation of the ODFW weir. Large numbers (>100) of sexually mature two-year old Chinook, called "mini-jacks" also returned to the Bull Run River in 2016 and were able to pass through the weir into the upper river because of their small size. Similar numbers of mini-jacks were observed in 2015.

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

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

in the Sandy River Basin by boat and on foot from 1996 to the present, and surveys on foot of fall Chinook adults and redds in index reaches in the lower Sandy River Basin from 1984 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.

For HCP Years 1–20 (2010–2029), PWB will annually count spawning Chinook salmon and redds in the lower Bull Run River. 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 2016. 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. A percentage of hatchery spring Chinook adults on the spawning grounds in the upper Sandy Basin is considered to be 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 early June 2016. Spawning survey protocols were adjusted in 2016 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 2016. Regional streams experienced record or near-record low flows and above-average air temperatures. Unusually warm stream temperatures can result from such conditions, which can result in an increase in mortality among adult salmon before they have had the chance to spawn. PWB wished to determine whether prespawning mortality was elevated in the Bull Run River in 2016 and whether there is a relationship between historic stream temperatures and level of prespawning mortality observed in the past.

3. Research Objectives

In 2016 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.
- 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.

Four additional key questions—to be answered by the lower Bull Run River adult Chinook population research—were pursued in 2016:

[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 ototlith'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).

- Does the number of adipose-clipped spring Chinook in the Bull Run River increase while the ODFW weir is in operation? This key question does not have an associated null hypothesis.
- 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 2016 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.

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 consistently occur before October 31 and, for this reason, reflect the spring Chinook run. Other statistics, such as cumulative redd count and percentage of hatchery fish, are influenced to varying degrees by the inclusion of fall Chinook.

[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.

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 Portland General Electric (PGE) 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 it 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 also 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 2016 were conducted from mid-August through late November. Seven weeks were missed because of high flows. Two of the surveys were snorkel surveys, one in August and one in September. 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
    - If no adipose fin, whether it has coded-wire tags (CWT). If CWT were present, researchers collected the snout

[4] Flows generally begin increasing with the autumn rains in October, making it possible, though difficult, for salmon to pass Larson's Falls.

- ♦ If an adipose fin was present, 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)
  - – Substrate size range (visual estimate of the range from approximately the 10th to the 90th percentile of substrate sizes, in inches)[5]
  - – Channel feature retaining the gravel patch (e.g., whether the redd is a behind 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 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.

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[5] Substrate sizes are discussed in the HCP, Appendix F. The HCP is available at www.portlandonline.com/water/46157.

Instead, surveys were conducted by two observers walking downstream on each side of the channel. 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 safely swim 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 cancelled.

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 before October 31 (corresponding to an approximate date used by ODFW to distinguish between 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 October 31, tissue samples were only collected from Chinook carcasses with adipose fins.

ODFW also conducted several independent surveys of adults and carcasses on portions the lower Bull Run River in September and October of 2016. 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 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.

Two surveys were conducted in 2016 following an adjusted protocol to provide data to ODFW personnel to evaluate OFDW'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, and to detect any large increase in the number of adult hatchery Chinook in the river. A large increase in the number of adult hatchery Chinook in the river might indicate that fish had managed to pass 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 in late August and mid and late September.

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) was 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 7 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

Ten weekly surveys were conducted in 2016 between August 10 and December 13; two followed modified protocols which included snorkeling, and 8 followed standard protocols (Figure 1). Figure 1 does not show one snorkel survey, which was conducted on August 10. Surveys were cancelled due to high flows on seven dates: October 18; November 1, 8, 15, and 29; and December 7 and 13. The last date a survey could be successfully conducted was November 22.

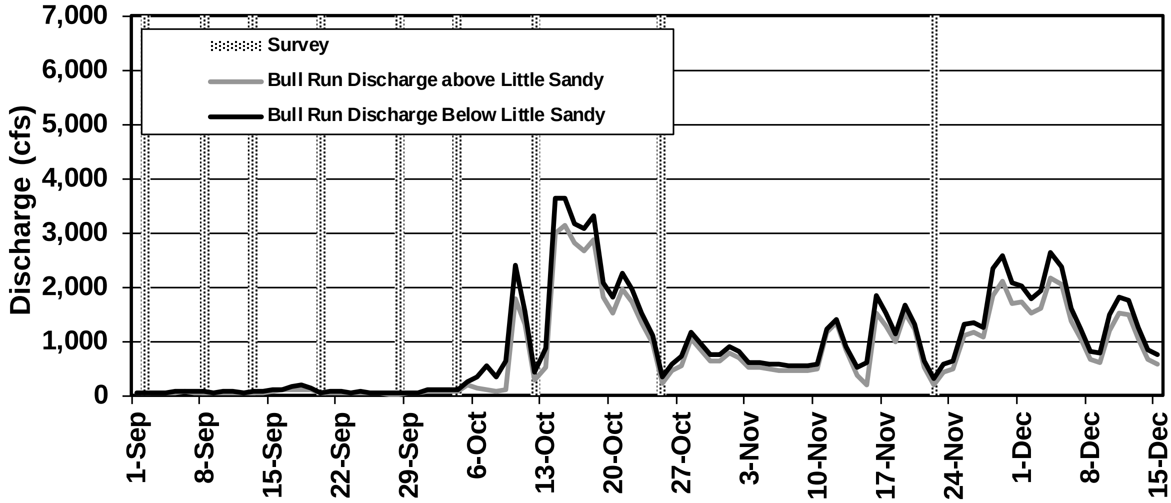

Figure 1. Bull Run River Discharge Above and Below the Little Sandy Confluence and Dates of Chinook Spawning Surveys in 2016.

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 2016 were the highest observed since the removal of Marmot Dam in 2007. The majority of Chinook observed at that time, however, were hatchery fish that had circumvented exclusion measures at the mouth of the Bull Run River. A snorkel survey of the lower Bull Run River was conducted on August 10, 2016, to count adult salmon above the ODFW weir. Thirty mini-jacks, but no adults were seen. Prior to September 20, large schools of adult Chinook salmon were observed downstream of the ODFW weir. At the time of the September 20 snorkel survey, the majority of the adults appeared to have circumvented the weir and were observed in pools between Bowman's Bridge and Larson's Bridge (Reaches 2, 3, and 4). The cumulative redd count, however, was in the middle of the range of previous years, as indicated in Table 1.

Table 1. Summary Statistics for Chinook Spawning Runs in the Lower Bull Run River, 2007–2016[a]

Year	Peak Count	Minimum Escapement	Cumulative Redd Count	% Hatchery (n)[b]	% Female (n)
2016	123	123	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. On the day of the Peak Count in 2016 (September 20) 97 live hatchery, 25 wild, and one unknown adult Chinook were observed in the Bull Run River during a snorkel survey.

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=16), but with a large amount of variation, as indicated in Figure 2. The average peak count prior to removal was 129 (±133 95% confidence interval). In the years after decommissioning, the average has been 54 (±113% confidence interval). There is no trend in the data observed between 2007 and 2016 (p=0.37).

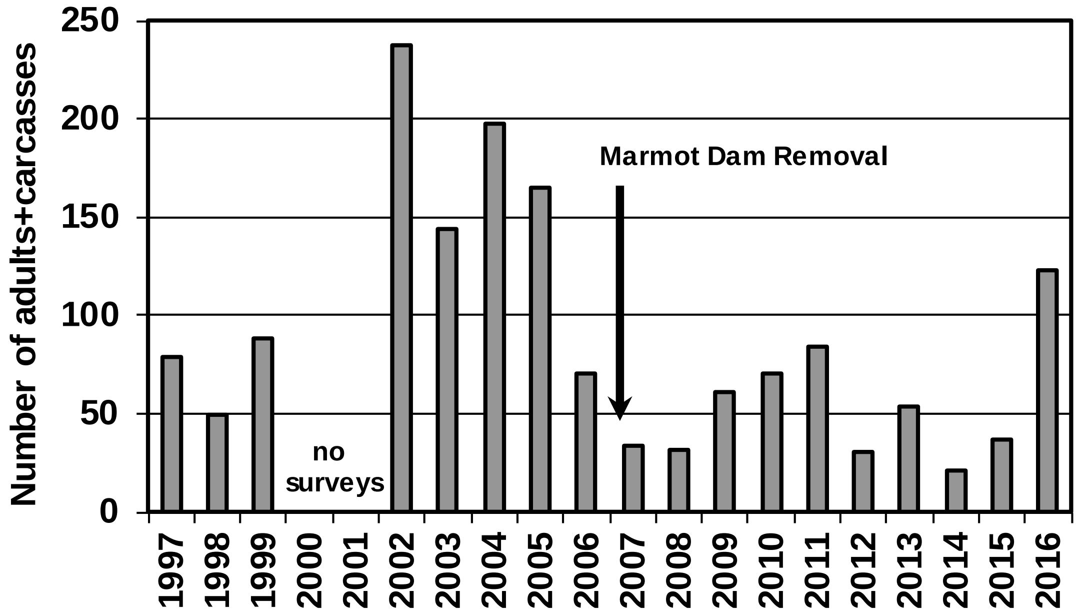

Figure 2. Chinook Salmon Peak Counts for All Years when Surveys Were Conducted

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 consistently occur 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. For this reason, this statistic can be legitimately compared across years, reflecting spring Chinook populations with little influence from fall Chinook. The minimum escapement estimate, cumulative redd count, and percent of hatchery fish and females, in contrast, can be heavily influenced by the inclusion of fall Chinook and, therefore, should be compared across years with caution. It is difficult to apply a cut-off date 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. In the future, genetic analysis may help to separate these combined statistics.

The relative size of the peak count of spring Chinook in the Bull Run River in 2016 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 3). 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=0.10, p=0.373 for years 2007-2016; see Figures 2 and 3).

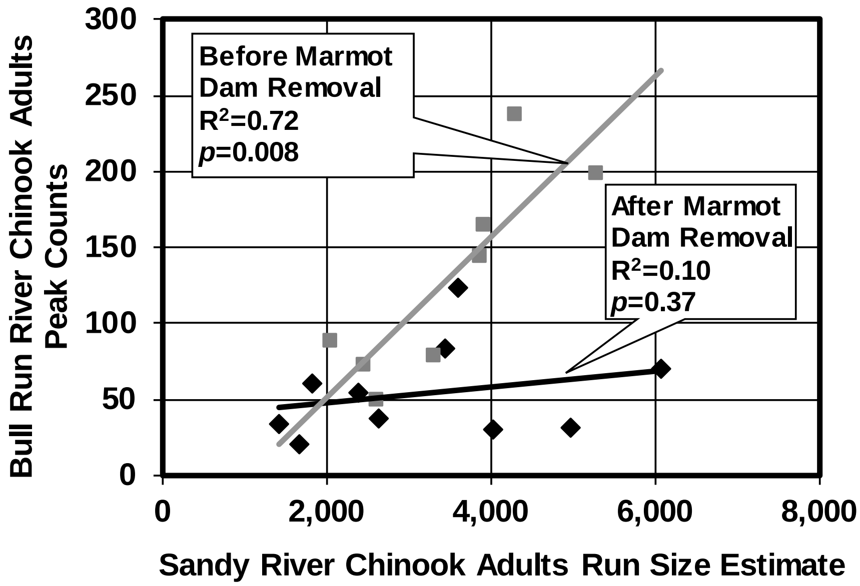

Figure 3. Relationship of Peak Counts of Adult Chinook in the Lower Bull Run River with Estimated Run Size of Spring Chinook in the Upper Sandy River Basin, Before and After the Removal of Marmot Dam

A large number of jacks were observed in the Bull Run River in 2016, as was observed in 2015. A total of 116 jacks were observed upstream of the ODFW weir while snorkeling on September 20. Jacks are sexually mature male salmon that return one to two years early to the river to spawn. Jacks, which are too small to compete directly with grown adult salmon for opportunities to spawn with adult females, nonetheless are able to contribute genetically to the following generation by “sneak-spawning,” and fertilizing a fraction of other salmon pairs’ eggs at the moment of spawning. The majority of jacks observed in the Bull Run River in 2016 are believed to have been “mini-jacks,” fish acclimated as smolts in the spring of 2016 in the Bull Run River and returning 4-5 months later.[6] Mini-jacks were small enough to pass upstream through the ODFW weir. A number of mini-jacks were captured and determined to be sexually mature. The reason for the high incidence of mini-jacks in 2015 and 2016 is unknown.

7.2.2 Timing

Adult Chinook salmon were observed in the Bull Run River throughout the survey period, but peaked in late September. As Table 2 documents, the peak fish count and minimum escapement both occurred on the same day in late September and the peak redd count occurred in late October.

Table 2. Timing of Adult Chinook Peak Counts, Highest Minimum Escapement Estimate, and Peak Redd Count, 2007–2016

Year	Peak Count	Minimum Escapement	Peak Redd Count
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 & 22
2007	Oct. 24	Oct. 24	Oct. 18

Most of the large number of hatchery adult Chinook observed on September 20 are believed to have passed upstream of the ODFW weir during relatively high flows in mid-September, but at least a few had passed earlier. No adult Chinook were observed while snorkeling the lower Bull Run River on August 20, although visibility was poor. Up to 25 spring Chinook were observed in early September, holding in deep pools in the Bull Run River. At least some of these were hatchery fish. As of September 15, only 12 Chinook adults had been intentionally passed upstream of the weir by ODFW[7], and they were all

[6] ODFW Biologist Todd Alsbury, pers. comm.

[7] ODFW uses the Bull Run weir to sort returning Chinook adults. Wild fish are passed upstream to spawn in the Bull Run River. Hatchery fish are removed.

wild. The remaining fish observed in early September may have entered the river before the weir was installed in early June. It is likely that the large number of hatchery adult Chinook observed while snorkeling on September 20 passed upstream of the ODFW weir between September 16 and 19, during higher-than-usual releases of water from upstream dams to comply with downstream water temperature targets (Figure 4).

The peak count would probably have been much smaller if no snorkel surveys had been conducted. Half as many adult fish were seen during the traditional walking survey conducted the week after the peak count (63 adult Chinook on September 28 compared with 123 adult Chinook on September 20), despite similar survey conditions. Adult salmon are difficult to count in late August and early September while holding in deep pools, but become more detectable later in the year with the standard protocol as they move into shallower water to spawn.

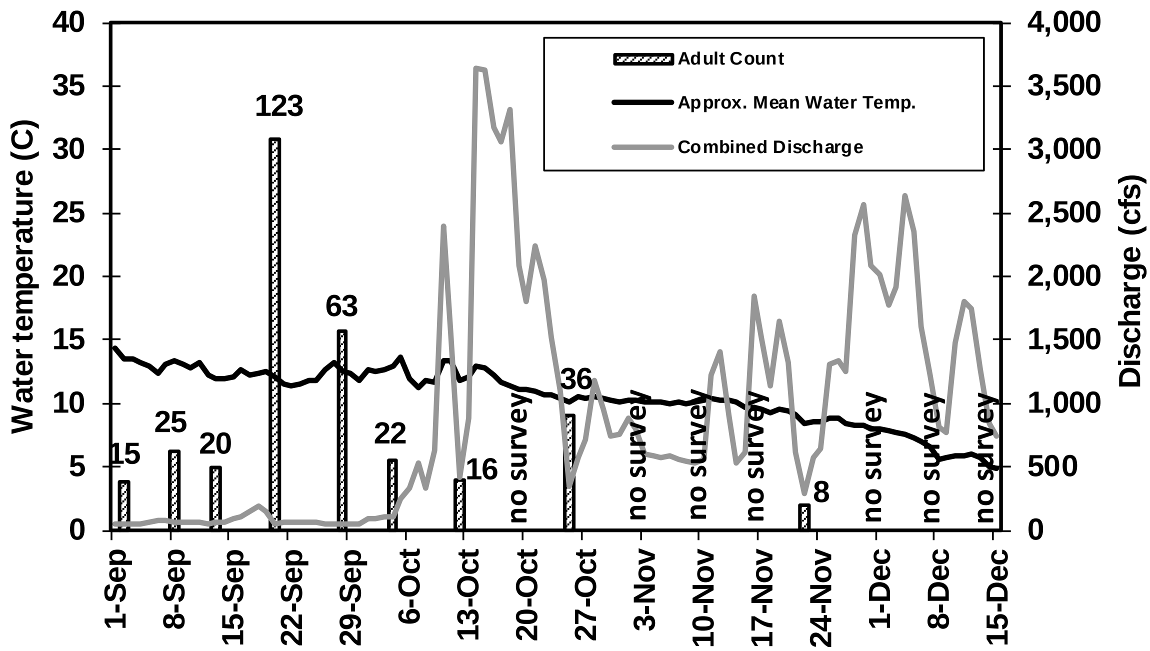

Figure 4. Environmental Variables[a] that May Be Useful in Explaining Chinook Salmon Run Timing in the Lower Bull Run River in 2016

[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 near the middle of the range of years since Marmot Dam was removed in 2007 (Table 1). This contrasts with the record peak adult count minimum escapement estimate. 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. It is unclear why the unusually large number of hatchery adult Chinook observed holding in the lower Bull Run River in late September did not result in an unusually large number of redds.

7.3.2 Timing

Chinook salmon redds were observed in the Bull Run River between September 28 and November 22. The date of the peak Chinook redd count was October 25. Figure 5 summarizes the timing of redd construction and compares it to the timing of adults observed in the lower Bull Run River. Figure 5 also includes the cumulative redd count.

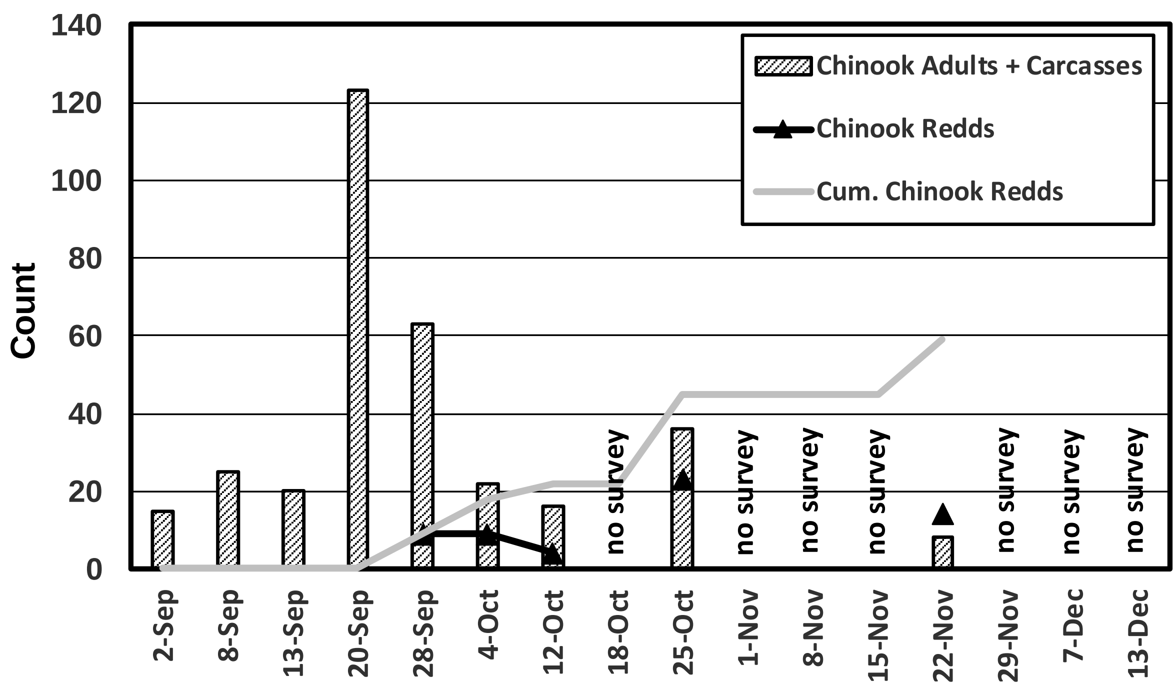

Figure 5. Comparison of the Timing of the Presence of Adult Chinook Salmon and the Construction of Redds in 2016

Redd counts on both October 25 and November 22 probably represent the accumulation of multiple weeks of spawning effort. The October 18 survey and the November 1-15 surveys were cancelled due to high flows. The October 25 and November 22 redd counts, therefore, may have consisted of two weeks' worth and four weeks' worth of spawning activity, respectively. Some redds may also have been obscured by the movement of gravel by high flows, especially between the October 12 and October 25 surveys.

7.4 Carcasses

7.4.1 Hatchery Fish

The percentage of Chinook carcasses of both spring and fall runs in the lower Bull Run River that were of hatchery origin was relatively high in 2016 (39.1 percent) based on a sample size of 23 carcasses for which the status of the adipose fin could be determined. The actual percentage of hatchery fish may have been higher than 39.1 percent. During the September 20 snorkel survey, 122 live adult Chinook were observed. Of the individuals for which the status of the adipose fin could be determined, 80 percent were of hatchery origin. Additionally, some 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 2016, the percentage of hatchery spring Chinook appeared to be the highest it has been since the ODFW weir was installed. The percentage of carcasses considered spring Chinook carcasses in 2016 that were of hatchery origin was 52.9 percent based on a sample size of 17 carcasses. The estimates for 2013, 2014, and 2015 were 22.6 percent (n=31), 4.8 percent (n=21), and 39.0 percent (n=40), respectively. These estimates are placed in the context of the full Bull Run spawning survey record in Figure 6. No identifiable hatchery carcasses were found during the one November survey.

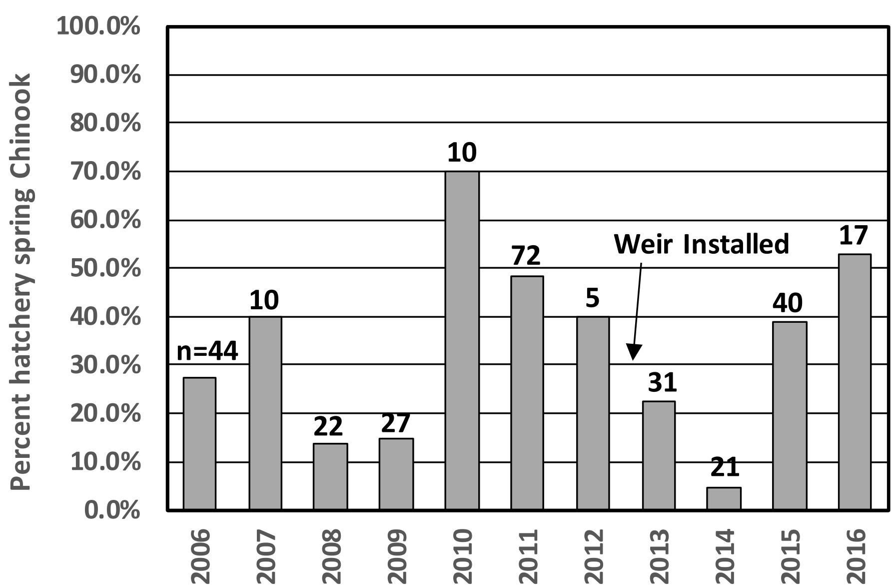

Figure 6. Estimated Percent Hatchery Spring Chinook Adults Spawning in the Bull Run River Over Time, based on Carcass Recoveries. The number of carcasses incorporated into each estimate is given above the respective column.

The percentage of hatchery Chinook estimated from carcass recoveries did not include live counts or carcass recoveries of mini-jacks, which were primarily of hatchery origin.

7.4.2 Sex Ratio

Nearly two thirds of the Chinook carcasses recovered in 2016 were female. Of the 27 Chinook carcasses observed in the Bull Run River in 2016, 25 were intact enough to determine sex. Of these 25, 16 (64.0 percent) were female.

Females have tended to make up a larger percentage of carcasses recovered in the lower Bull Run River in the past. Their percentage has ranged between 52.9 percent and 76.9 percent in seven out of ten 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.

Differences in marine survival can come about due to differences in (for instance) size, which, in turn, can influence susceptibility to predation or harvest. Female middle-of-eye-to-posterior-scale (MEPS) lengths were greater than male MEPS lengths in the Bull Run River in 2016. In 2016, female Chinook carcasses had an average length of 82.0 cm and male carcasses had an average length of 64.3 cm.

Life history differences can, in theory, lead to differences in sex ratio if, for example, a significant number of one gender return at a different age than the other. A portion of male Chinook salmon return 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.

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

No prespawning mortality of spring Chinook salmon was observed in the Bull Run River in 2016. There appears to be a 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 8, Table 3). 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 last year that a seven-day average of daily maximum stream temperature above 19.5 °C occurred in the lower Bull Run River was 2013. The last year that prespawning mortality was observed in the lower Bull Run River was 2012.

Figure 7. Evaluating Prespawning Mortality

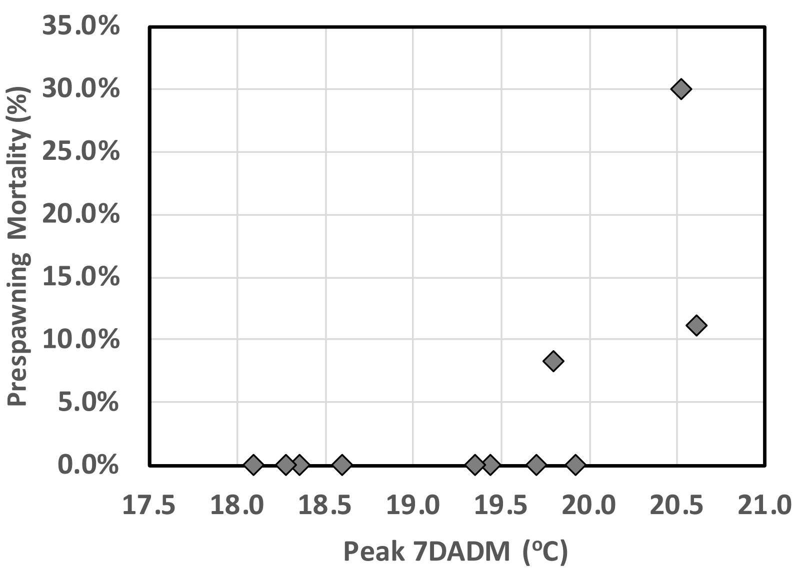

Figure 8. Relationship between Peak Seven-Day Average Daily Maximum Stream Temperature (7DADM) and Pres-Spawning Mortality in the Lower Bull Run River, 2006–2016.

Table 3. Peak 7DADM and Corresponding Observed Prespawning Mortality, 2006–2016

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%	123

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 123 adult Chinook salmon entered the Bull Run River upstream of the ODFW weir to spawn in 2016. The peak daily count of live adults plus carcasses was also 123.

- **How many Chinook salmon redds are built in the Bull Run River each year?**

  A total of 59 Chinook redds were identified in the Bull Run River in 2016.

- **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 August 10 and November 22, 2016. The peak date was September 20, 2016. Chinook redds were observed between September 28 and November 22, 2016. The peak date for redd observation was October 25.

- **What percentage of the spawning Chinook salmon are of hatchery origin (clipped adipose fin) and what percentage are female?**

  In 2016, 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 39.1 percent. The percentage of females among the observed Chinook salmon carcasses in which sex could be determined was 64 percent.

- **Does the number of adipose-clipped spring Chinook in the Bull Run River increase while the ODFW weir is in operation?**

  In 2016, the number of adipose-clipped spring Chinook holding in the Bull Run River appeared to increase dramatically in late September, while the ODFW weir was in operation. The evidence indicates that a large number of adipose-clipped spring Chinook adults were able to circumvent the ODFW weir during a period of elevated flows.

- **What percentage of spring Chinook salmon, holding in the Bull Run River while the ODFW weir is in operation, are of hatchery origin?**

  Snorkel surveys were conducted on August 10 and September 20. No adult Chinook salmon were observed on August 10. The percentage of hatchery spring Chinook observed while snorkeling on September 20 was 80.0 percent. The status of 1 out of 123 fish could not be determined on September 20.

- **What percentage of the spawning spring Chinook salmon are of hatchery origin (clipped adipose fin)?**

  In 2016, 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 before the end of October were spring Chinook—was 53 percent. This was the highest percentage observed in the lower Bull Run River since the installation of the ODFW weir at Dodge Park in 2013.

- **Was prespawning mortality of spring Chinook salmon observed in 2016? What is the relationship between stream temperature and observed prespawning mortality in the lower Bull Run River?**

  No prespawning mortality of spring Chinook salmon was observed in 2016. Prespawning mortality among female Chinook salmon appears to increase above approximately 19.5 ^{o}C. Water temperatures of this magnitude last occurred in the lower Bull Run in 2013, although no prespawning mortality was observed that year either.

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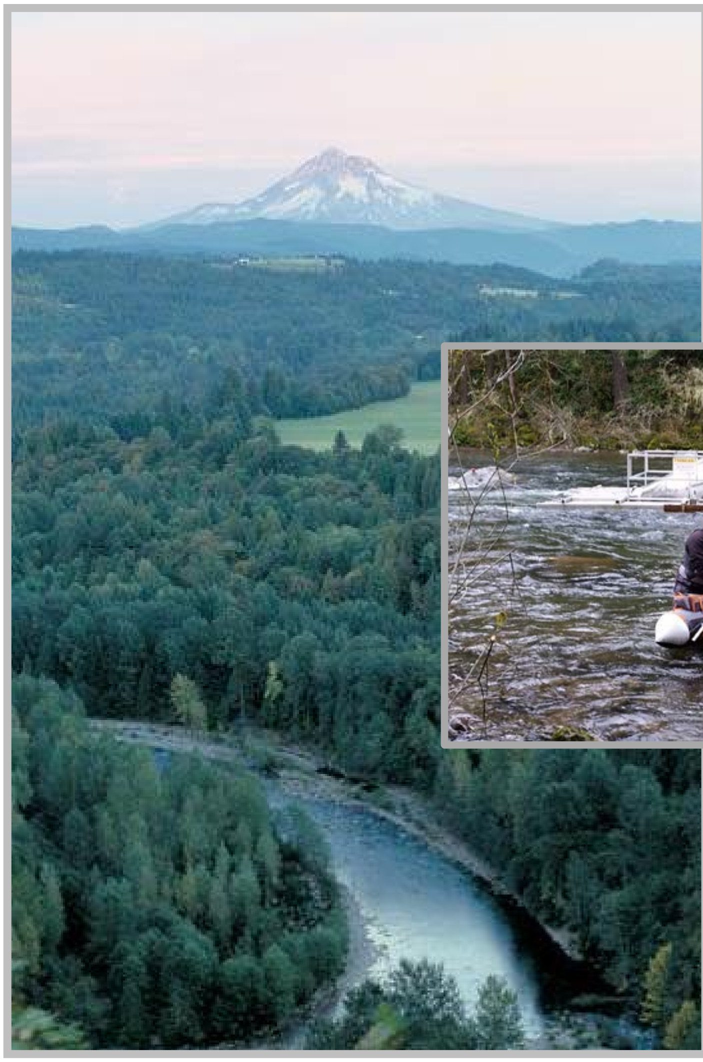
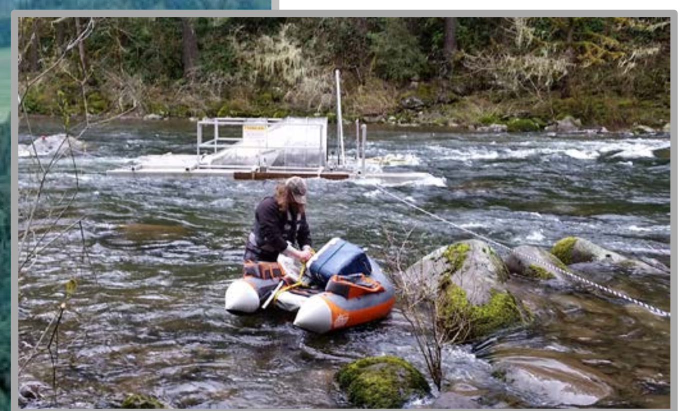

Appendix F. Sandy River Basin Smolt Monitoring

2016

April 2017

Burke Strobel, Portland Water Bureau

Photo (left) of Mount Hood and Sandy River provided by Josh Kling/Western Rivers Conservancy

Photo (right) of Bull Run smolt trap provided by the Portland Water Bureau.

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1. Summary

The Portland Water Bureau, the U.S. Forest Service, and the Oregon Department of Fish and Wildlife collaborated in 2016 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 eight streams: Still Creek, Clear Creek, Salmon River, Cedar Creek, Little Sandy River, Bull Run River, Gordon Creek, and Beaver Creek. Population estimates and fork length distribution, condition factor, and emigration statistics were calculated for steelhead and coho smolts in all eight streams, but no condition factor analysis was conducted on fish from Cedar Creek. The average age of smolts was calculated by aging fish using fish scale samples collected between 2009 and 2015.

Trapping efforts were hampered somewhat in 2016 by vandalism at one trap, a release of hatchery Chinook smolts from an acclimation pond upstream of another trap, and low-flow periods in three streams. Trapping challenges did not hinder the generation of population estimates any site. Low flows, however, forced an early end to trapping in Cedar Creek, Bull Run, Gordon Creek, and Beaver Creek.

Preliminary Sandy River Basin-level population estimates were calculated for each year from 2009 to 2016. Freshwater productivity (smolts per adult) was also estimated, with the help of age data, for steelhead adult year classes 2010 to 2013 and for each coho adult year class from 2007 to 2014.

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 of a given age than high-elevation streams, in general.

Steelhead and coho smolts from different streams in the Sandy River Basin also showed significant differences in mean condition factors. Condition factors correlated negatively with fork length for coho, but only weakly for age 2 steelhead.

Steelhead smolts emigrated earlier than coho smolts, on average, in all streams. Coho smolts emigrated from low-elevation streams earlier than from high-elevation streams.

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 are shorter on average for a given age in higher-elevation streams than in lower elevation streams, as is seen in coho, but this fact is masked by their older average age.

2. Introduction

2.1 Background

In 2016, 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 (Figure 1), 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.

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).

[1] To learn more about the HCP, visit http://www.portlandoregon.gov/water/55040.

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 $((\text{weight}/(\text{fork length}^3))\times 100{,}000)$
- Mean date of emigration (by species)

Beginning in 2014, a collaboration between PWB and ODFW provided age information from scale samples collected by PWB and USFS between 2009 and 2014. 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. Over 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 will eventually be applicable to the entire index area. Information that is collected will be immediately applicable at the scale of individual tributaries.

Figure 1. Gordon Creek trap, with wood pontoons to avoid vandalism

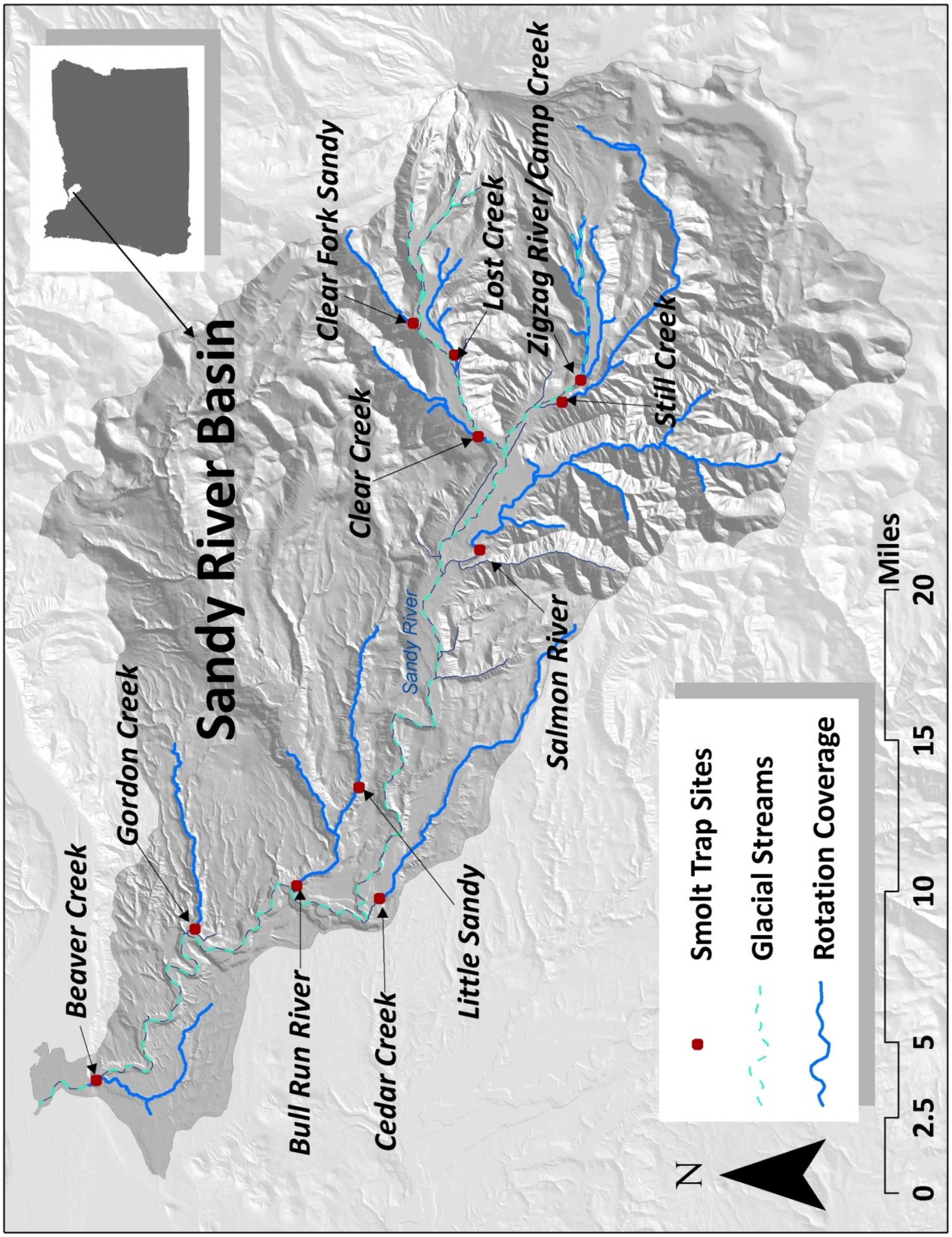

Figure 2. Sandy River Basin—Smolt trap sites, streams covered by rotating smolt trap study, and streams receiving glacial runoff

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	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 also been trapped in 2010, 2013, and 2016 because of the particular value of the resulting data.

3.1.2 Sampling in 2016

Smolt production was monitored in Still Creek, Clear Creek, Salmon River, Cedar Creek, the Little Sandy River, the Bull Run River, Gordon Creek, and Beaver Creek in 2016. 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 (Figure 2). A motor was added to the Beaver Creek trap in 2015 to continue trapping despite low stream flows. The Still Creek, Clear Creek, and Salmon River traps were checked and maintained by USFS Zigzag Ranger District staff and volunteers. ODFW staff checked and maintained the Cedar Creek trap. PWB staff checked and maintained the Little Sandy River, Bull Run River, Gordon Creek, and Beaver Creek traps. All traps were operated seven days per week throughout the season to the 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 Cedar Creek smolt trap upstream of the Cedar Creek Hatchery water intake

A variety of factors contributed to time periods when traps were not in operation in 2016. Low flows hampered trapping in Clear Creek, Cedar Creek, and Beaver Creek. Five days were missed on the Bull Run River to avoid capturing hatchery Chinook smolts released.

Beaver Creek suffered some vandalism when an attempt was made to steal the motor. The attempt was unsuccessful and no days were missed.

The trapping season ended early because of low flows in Cedar Creek, Bull Run, Gordon Creek, and Beaver Creek.

Table 3. Dates of operation and the number of days traps did not operate in the Sandy River Basin in 2016

Stream[a]	Trap In	Trap Out	Down Time (Days)
Still Creek	March 28	June 23	1
Clear Creek	April 1	June 19	4
Salmon River	March 28	June 23	1
Cedar Creek	March 24	May 31	18
Little Sandy River	March 8	June 8	2
Bull Run River (without the Little Sandy River)	March 8	June 8	6
Gordon Creek	March 8	June 8	0
Beaver Creek	March 8	June 3	7

[a]Streams are presented in order from highest-elevation Still Creek 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 larger than 50 millimeters (mm) that 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 2015 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. Smolts captured in the Bull Run River trap. Smolts receive aeration and temperature control and are processed in small batches.

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 efficiency$_{stratum}$; 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 down-time 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 2016, 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 2016, 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 2016 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 & 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 2016

		Period						
Site[a]	Species	1	2	3	4	5	6	7[b]
Still Creek	Steelhead	0.130	0.167	0.106	0.170	0.170	0.170	—
	Coho	0.178	0.277	0.380	0.430	0.494	0.439	—
Clear Creek	Steelhead	0.010	0.010	0.010	0.074	0.073	0.073	—
	Coho	0.186	0.168	0.141	0.259	0.311	0.073	—
Salmon River	Steelhead	0.032	0.032	0.032	0.032	0.032	0.032	—
	Coho	0.186	0.168	0.141	0.259	0.311	0.073	—
Cedar Creek	Steelhead	0.308	0.308	0.107	0.107	0.500	0.308	—
	Coho	0.176	0.176	0.292	0.292	0.232	0.176	—
Little Sandy River	Steelhead	0.600	0.600	0.600	0.087	0.067	0.067	—
	Coho	0.400	0.400	0.269	0.269	0.269	0.286	—
Bull Run (without Little Sandy River)	Steelhead	0.035	0.035	0.035	0.044	0.060	0.064	—
	Coho	0.053	0.053	0.053	0.053	0.100	0.102	—
Gordon Creek	Steelhead	0.132	0.132	0.132	0.160	0.129	0.129	—
	Coho	0.171	0.171	0.171	0.215	0.215	0.215	—
Beaver Creek	Steelhead	0.067	0.067	0.067	0.111	0.111	0.111	—
	Coho	0.188	0.188	0.188	0.167	0.167	0.167	—

[a]Streams are presented in order from highest-elevation Still Creek to lowest-elevation Beaver Creek.

[b]There was no seventh two-week trapping period in any stream because those traps were not operated long enough due to low flows or other factors.

4.1.2 Subbasin Population Estimates

Monitored smolt production was relatively high in 2016. As has been observed in the past, more steelhead smolts emigrated from the Bull Run River than from all other monitored streams combined. The Bull Run River, Salmon River, and Beaver Creek all produced more steelhead smolts that in any previous monitored year (Table 9). The majority of coho smolts from monitored streams emigrated from the Salmon River, as is summarized in Table 5. The Bull Run River produced the largest number of coho smolts and the Salmon River produced the second largest number of coho smolts of their previous monitored years. The Beaver Creek 2016 coho smolt estimate was greatly reduced from the previous two years' estimates. Exhibit A summarizes the total captures at all trap sites.

A portion of the emigration of smolts from Still Creek and the Salmon River may have been missed. A small number of steelhead and coho smolts were caught on the first day of trapping in the Salmon River, and coho were still being caught on the last day of trapping in Still Creek. Trapping in each of these streams in 2016 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.

The variances associated with estimates in several streams were large relative to the estimates themselves in 2016. 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). Cedar and Beaver Creek estimates were the least precise for steelhead and the Bull Run River and Beaver Creek estimates were least precise for 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 2016

	Steelhead		Coho	
Stream[a,b]	**Estimate**	**95% CI**	**Estimate**	**95% CI**
Still Creek	3,143	27%	5,013	7%
Clear Creek	1,201	37%	2,366	8%
Salmon River	14,443	48%	18,399	13%
Cedar Creek	426	72%	2,028	20%
Little Sandy River	1,357	62%	332	32%
Bull Run River (without Little Sandy)	26,392	31%	3,289	48%
Gordon Creek	1,150	39%	694	35%
Beaver Creek	994	86%	385	57%

[a]Confidence intervals are expressed as percentages of the associated estimates.

[b]Streams are presented in order from highest-elevation Still Creek to lowest-elevation Beaver Creek.

Of all streams monitored in 2016, 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. Cedar Creek 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 2016

	Steelhead		Coho	
Streams[a]	**Smolts/mile**	**Smolts/1,000 ft^2**	**Smolts/mile**	**Smolts/1,000 ft^2**
Still Creek	214.23	1.20	690.82	2.84
Clear Creek	235.49	1.44	463.92	2.85
Salmon River	519.53	1.31	702.25	1.69
Cedar Creek	28.98	0.15	98.64	0.51
Little Sandy River	230.00	0.69	56.27	0.17
Bull Run River (without Little Sandy)	3,179.76	6.82	396.27	0.85
Gordon Creek	154.59	0.74	96.39	0.46
Beaver Creek	129.09	1.13	50.00	0.44

[a]Streams are presented in order from highest-elevation Still Creek to lowest-elevation Beaver Creek.

Of all streams monitored in 2016, both coho smolt production per unit of stream length and coho smolt production per unit of surface area were highest in the Salmon River. Still Creek had the second-highest production of coho smolts per unit of surface area, nearly identical to the Salmon River. Beaver Creek had the lowest coho smolt production per unit stream length and Little Sandy River had the lowest coho smolt production per unit surface area.

4.1.3 Sandy River Basin Index Area Population Estimates

At least three 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 Tables 7, for steelhead, and 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 5 and 6, respectively.

Table 7. Statistics for steelhead subbasin smolt trap population estimates compiled from the Sandy River Basin Index Area, 2009–2016

	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	4	5	2	4	19	3	2	7	7	3	2
Average	510	73	1,378	8	1,823	9,109	462	1,869	15,651	1,421	794
St. Dev.[a]	511	130	1,059	6	1,593	5,321	313	470	7,425	727	196

[a]Standard Deviation (St. Dev.) describes the spread of individual subbasin estimates around their average.

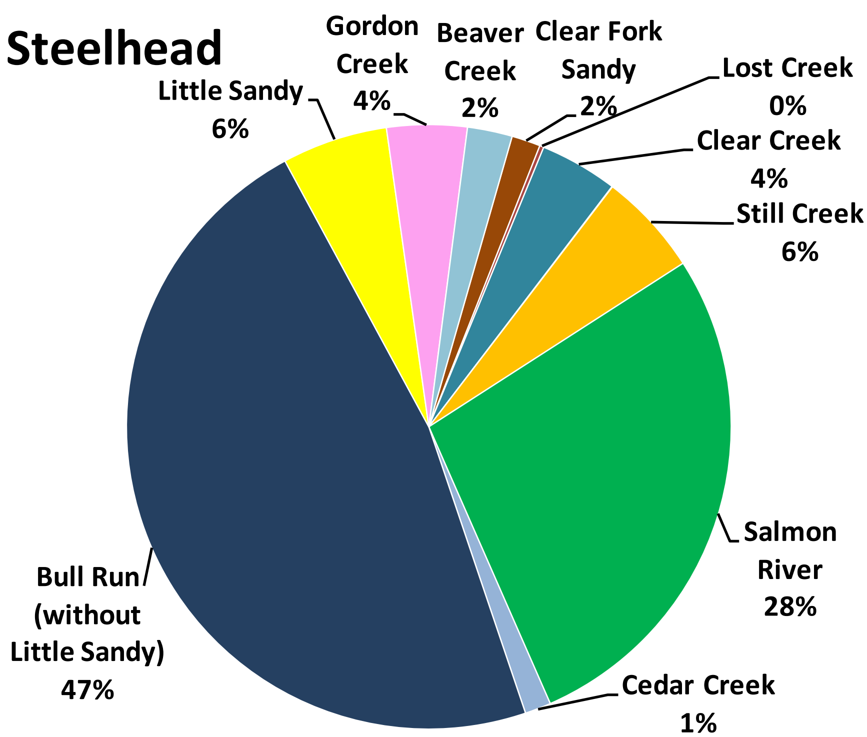

Figure 5. Average relative contributions of monitored streams to steelhead smolt production in the Sandy River Basin Index Area, 2009–2016

Table 8. Statistics for coho subbasin smolt trap population estimates compiled from the Sandy River Basin Index Area, 2009–2016

	Clear Fork Sandy	Lost Creek	Clear Creek	Zigzag River	Still Creek	Salmon River	Cedar Creek	Little Sandy	Bull Run	Gordon Creek	Beaver Creek
n	5	4	2	4	21	3	2	6	6	3	1
Average	953	14	2,702	0	3,863	15,009	1,942	243	1,426	831	1,482
St. Dev.[a]	591	30	1,011	0	2,149	6,058	695	264	1,107	247	1,151

[a]Standard Deviation (St. Dev.) describes the spread of individual subbasin estimates around their average.

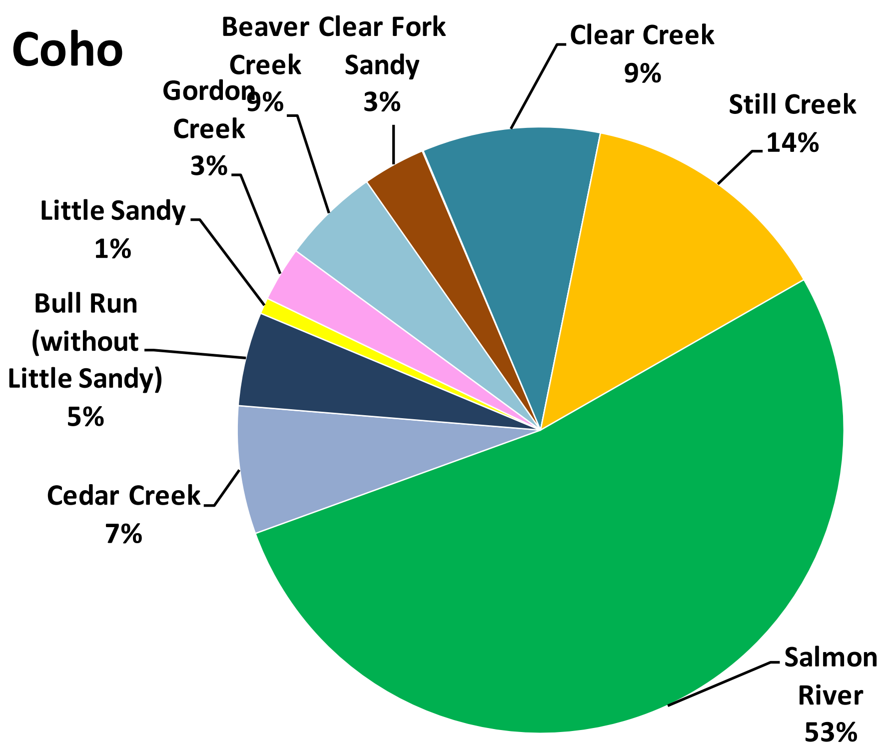

Figure 6. Average relative contributions of monitored streams to coho smolt production in the Sandy River Basin Index Area, 2009–2016

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 eight years of the Sandy River Basin Smolt Monitoring Plan period (2009–2016). 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 initial 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	510	5	2,514	8	3,709	7,331		160	6,637	2,483	794
	196%	na	83%	na	87%	142%		153%	96%	97%	40%
2010	4	73	1,466	5	138	3,419		416	11,701	1,421	794
	na	352%	142%	na	102%	77%		56%	149%	100%	40%
2011	510	1	1,466	1	4,958	7,331		1,552	7,750	839	794
	196%	na	142%	na	15%	142%		51%	33%	63%	40%
2012	510	73	1,466	13	1,236	5,819		1,856	12,495	1,421	794
	196%	352%	142%	na	39%	20%		67%	59%	100%	40%
2013	967	12	1,466	8	1,293	12,755	169	1,569	25,399	1,210	794
	51%	55%	142%	na	38%	47%	56%	40%	36%	122%	40%
2014	510	73	418	14	1,341	7,331	791	2,395	17,490	1,421	603
	196%	352%	38%	na	42%	142%	68%	39%	43%	100%	53%
2015	136	304	1,466	8	4,834	7,331	462	2,483	17,341	1,421	785
	73%	63%	142%	149%	38%	142%	133%	36%	24%	100%	34%
2016	510	73	1,201	8	3,192	14,443	426	1,357	26,392	1,150	994
	196%	352%	8%	149%	7%	48%	72%	62%	31%	39%	86%

[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	953	0	3,838	0	5,528	15,009	0	0	661	994	1,482
	122%	0%	24%	0%	21%	90%		0%	109%	41%	75%
2010	1,646	14	2,702	0	3,911	11,077	0	37	2,708	831	1,482
	51%	438%	99%	0%	12%	53%		50%	68%	58%	75%
2011	953	0	2,702	0	6,325	15,009	0	39	483	557	1,482
	122%	0%	99%	0%	9%	90%		166%	61%	70%	75%
2012	953	14	2,702	0	4,144	8,838	0	0	314	831	1,482
	122%	438%	99%	0%	28%	14%		0%	141%	58%	75%
2013	853	0	2,702	0	5,435	21,721	2,589	706	2,010	1,080	1,482
	29%	0%	99%	0%	12%	18%	44%	35%	57%	50%	75%
2014	953	14	1,902	0	6,322	15,009	1,208	473	1,009	831	2,680
	122%	0%	20%	0%	8%	90%	14%	85%	200%	58%	41%
2015	618	68	2,702	0	8,159	15,009	1,942	116	937	831	1,380
	59%	111%	99%	0%	8%	90%	70%	103%	58%	58%	14%
2016	953	14	2,366	0	5,043	18,399	2,028	332	3,289	694	385
	122%	438%	37%	0%	27%	13%	20%	32%	48%	35%	57%

[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 7 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]

	Steelhead		Coho	
Year	**Estimate**	**95% CI**	**Estimate**	**95% CI**
2009	24,151	54.2%	28,465	48.1%
2010	19,436	91.7%	24,408	28.2%
2011	25,202	43.9%	27,550	50.3%
2012	25,682	31.6%	19,278	18.8%
2013	45,642	24.6%	38,578	13.5%
2014	32,386	40.3%	30,401	45.3%
2015	36,571	32.0%	31,762	43.7%
2016	49,746	21.8%	33,503	10.5%

[a]Confidence intervals are expressed as percentages of the associated estimates.

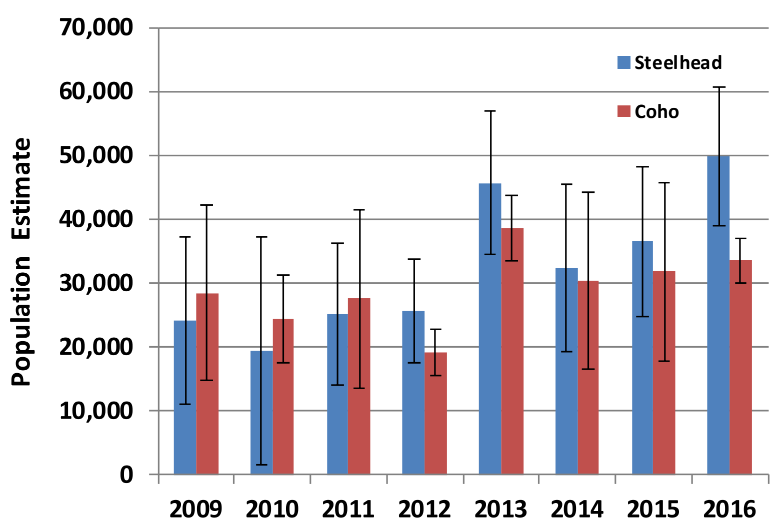

Figure 7. Sandy River Basin Index Area steelhead and coho smolt population estimates and 95% confidence intervals

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 coho smolts are plotted against the number of coho spawners in the parent generation in Figure 8. Also plotted in Figure 8 is a spawner/recruit curve fitted to the Sandy River Basin 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:

$$R = \frac{\propto S}{(1 + {}^{S}/_{K})} \qquad \text{(Equation 4)}$$

where R is the number of recruits, 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. No Beverton-Holt spawner/recruit curve was fitted to steelhead data because there are too few data points.

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, and age 3 in proportions that varied by stream. Coho smolts are assumed to have emigrated only at ages 2 and 3.[3]

Table 12. Estimates of freshwater productivity for steelhead in the Sandy River Basin Index Area, 2010–2013

Steelhead Spawners		Steelhead Smolts		Freshwater Productivity
Year	**Estimate**	**Year**	**Estimate**	**Smolts Per Adult**
2010	2,100	2011-13	28,089	13
2011	527	2012-14	41,390	78
2012	391	2013-15	29,339	76
2013	3,767	2014-16	34,185	9

3 According to aging convention, for steelhead, an age 1 smolt is the offspring of adults which spawned the previous spring, approximately 12 months before. For coho, an age 1 smolt is the offspring of adults which spawned the previous fall, approximately 5-6 months before (ODFW 2014).

Table 13. Estimates of freshwater productivity for coho salmon in the Sandy River Basin Index Area, 2010–2014

Coho Spawners		Coho Smolts		Freshwater Productivity
Year	**Estimate**	**Year**	**Estimate**	**Smolts Per Adult**
2007	753	2009-10	27,887	37
2008	1,277	2010-11	25,152	20
2009	1,677	2011-12	27,081	16
2010	795	2012-13	20,023	25
2011	3,619	2013-14	36,911	10
2012	1,198	2014-15	27,965	23
2013	756	2015-16	28,814	38
2014	6,111	2016-17	31,360	5

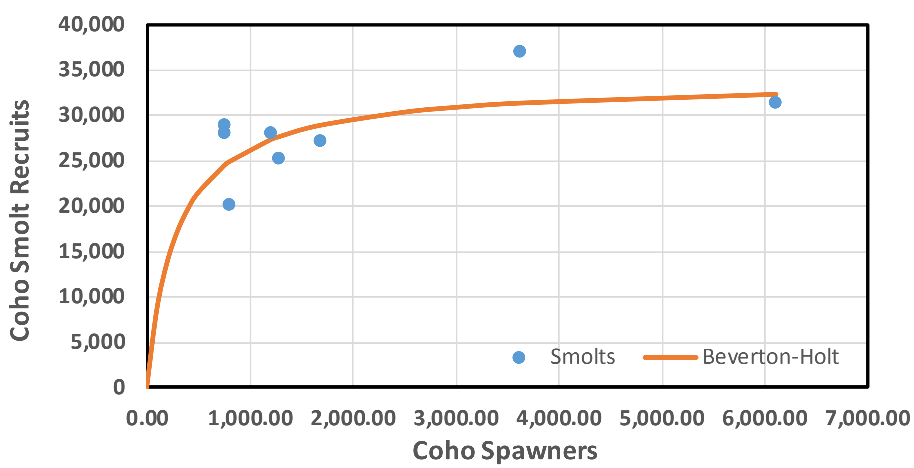

Figure 8. Coho spawners compared to resulting coho smolts in the Sandy River Basin Index Area, spawner years 2007–2014

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 9), although steelhead production decreased in 2016. 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 a moderate number of coho smolts in 2016. This was the seventh 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. Thus far, the number of coho fry caught in the Little Sandy trap in a given year has 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.

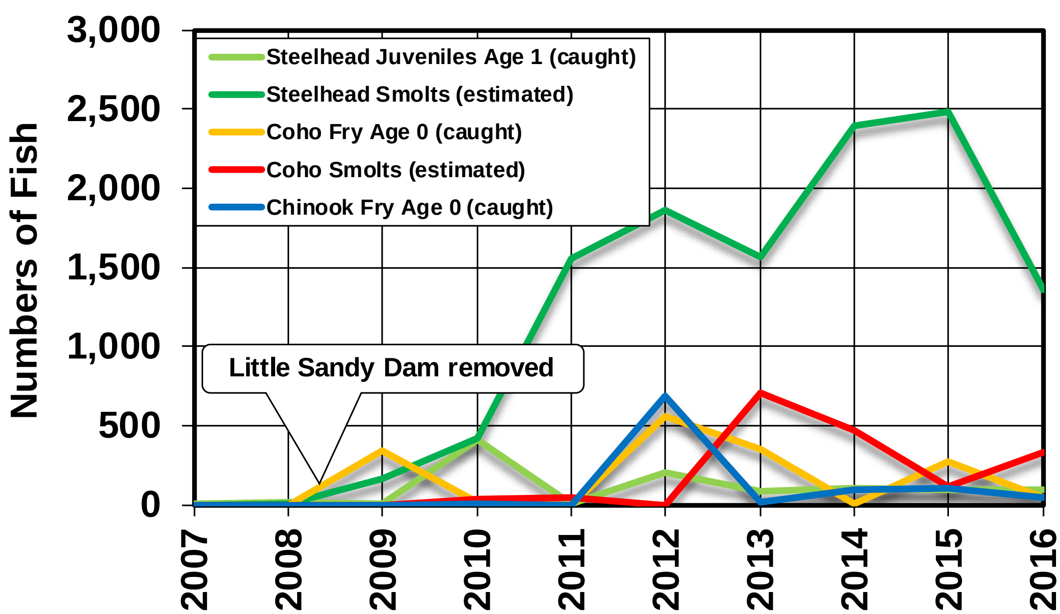

Figure 9. Recolonization of the Little Sandy River by steelhead, coho, and Chinook after the removal of the Little Sandy Dam

4.2 Fork Lengths

Steelhead and coho average fork lengths varied across monitored streams in 2016, 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, $\alpha=0.05$, $p<<0.001$ for both tests). Steelhead smolts emigrating from the Bull Run River were significantly longer than those emigrating from other monitored streams, as has been observed in previous years. Beaver Creek steelhead smolts were the shortest. Bull Run coho smolts were significantly longer, on average, than those from any other stream except for Beaver Creek. Still Creek 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 2016

		Weighted			
Streams[a]	**n**[b]	**Mean Fork Length (mm)**	**St. Dev. (mm)**	**Minimum (mm)**	**Maximum (mm)**
Still Creek	407	158	17	110	219
Clear Creek	169	154	15	113	195
Salmon River	461	166	18	101	231
Cedar Creek	43	144	22	95	195
Little Sandy	130	161	17	102	198
Bull Run (without Little Sandy)	1323	170	19	95	237
Gordon Creek	159	156	25	112	280
Beaver Creek	67	139	19	107	204

[a]Streams are presented in order from highest-elevation Still Creek to lowest-elevation Beaver Creek.
[b]n= Number of fish for which fork lengths were determined

Figure 10 shows frequency distributions for steelhead smolt fork lengths. The results of the pair-wise comparisons are summarized below Figure 10.

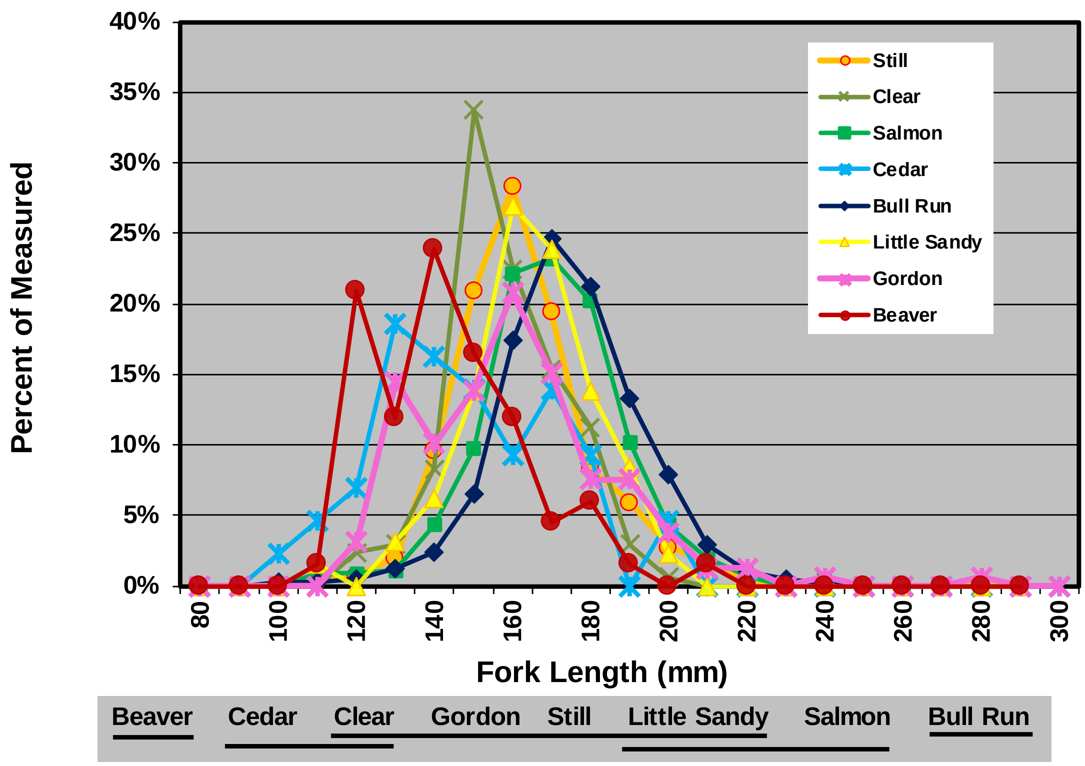

Figure 10. Steelhead smolt fork length frequency distributions for Sandy River Basin traps in 2016[a]

[a]Results of pair-wise statistical comparisons are presented from left to right, shortest to longest.

In Figure 10, 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 Cedar Creek are not statistically distinguishable from those from Clear Creek, but are significantly shorter than those from Gordon Creek. Steelhead smolts from Clear Creek are not statistically distinguishable from those from Gordon Creek, Still Creek, or Little Sandy).

Smolt age information reveals that different age distributions among streams obscure differences in steelhead growth. Figure 11 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 2016 were made using aging results from 2015 or averages from previous years. Upper-basin steelhead have comparable mean fork lengths to steelhead from lower in the basin. Little Sandy steelhead have been relatively small consistently (see Table 14). 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.

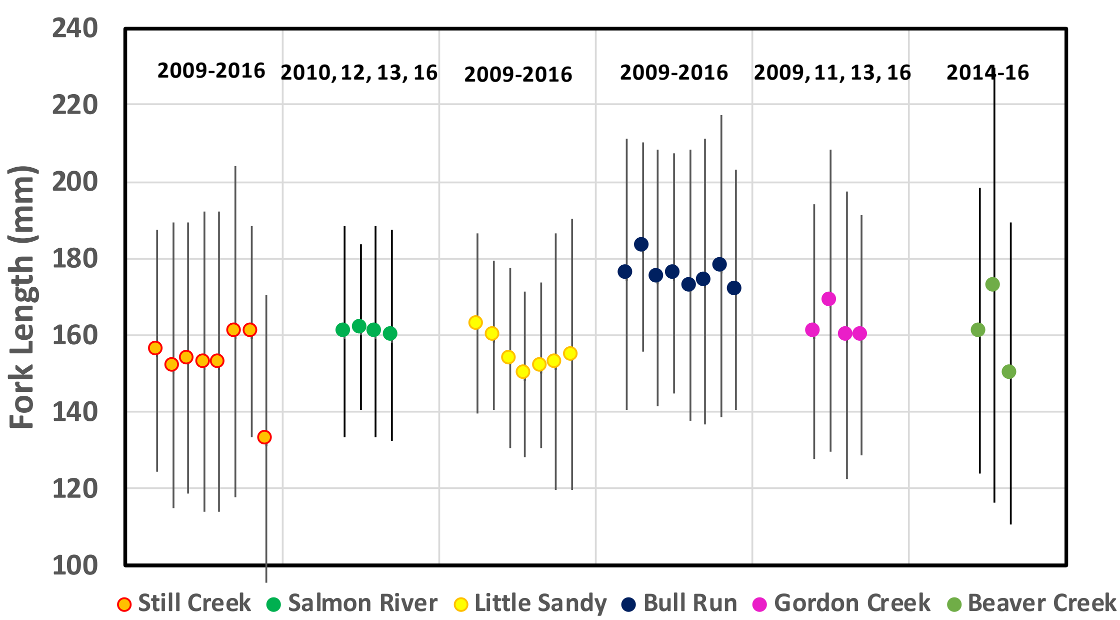

Figure 11. Weighted mean fork lengths of age 2 steelhead smolts for all Sandy River Basin streams and years for which age distribution data and fork length data exist.

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 2016

Streams[a]	n[b]	Weighted Mean Fork Length (mm)	Weighted St. Dev. (mm)	Minimum (mm)	Maximum (mm)
Still Creek	1127	101	10	68	129
Clear Creek	752	105	10	75	130
Salmon River	1445	104	12	66	147
Cedar Creek	370	109	10	80	158
Little Sandy	93	106	12	53	127
Bull Run (without Little Sandy)	306	119	11	89	180
Gordon Creek	147	107	9	70	130
Beaver Creek	59	119	17	82	156

[a]Streams are presented in order from highest-elevation Clear Creek to lowest-elevation Beaver Creek.
[b]n= Number of fish for which fork lengths were determined

Figure 12 shows frequency distributions for coho smolt fork lengths. The results of the pair-wise comparisons are summarized below Figure 12.

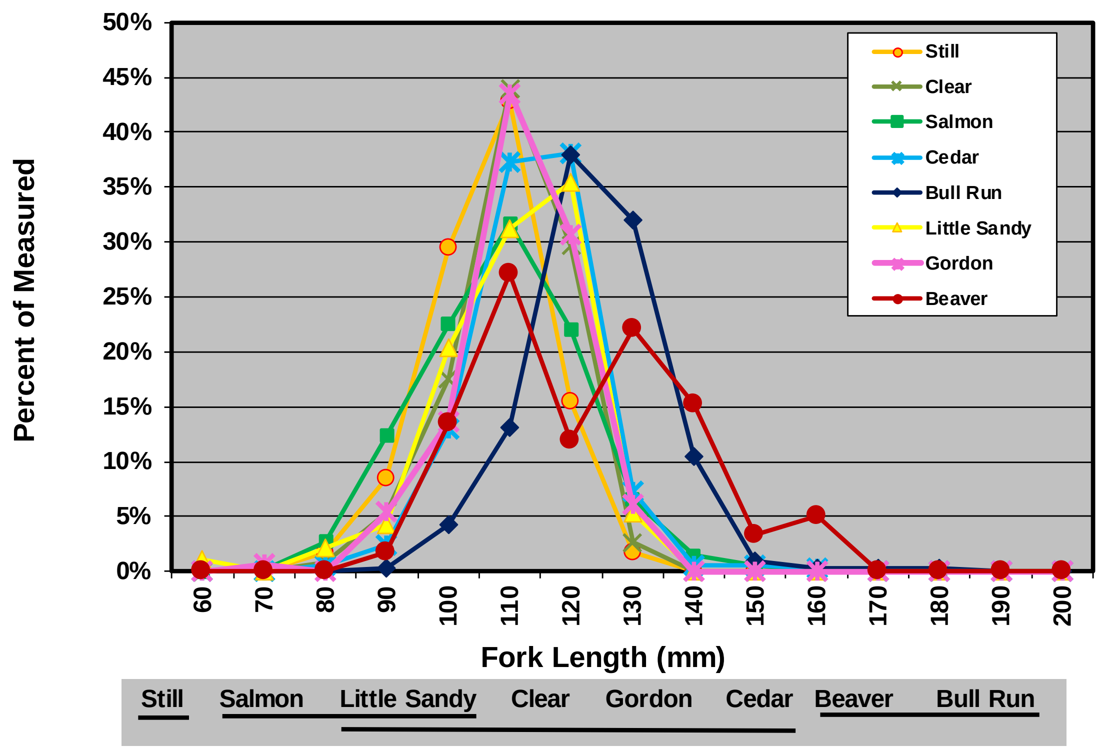

Figure 12. Coho smolt fork length frequency distributions for Sandy River Basin traps in 2016[a]
[a]Results of pair-wise statistical comparisons are presented from left to right, shortest to longest.

In Figure 12, 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., Bull Run coho are statistically indistinguishable from coho from Beaver Creek, but both are significantly longer than coho from all other streams. Salmon River coho are significantly shorter than Clear Creek coho, but not Little Sandy coho).

Smolt age information reveals that very few emigrating coho smolts in the Sandy River Basin are older than age 2, though 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 2016 (Figures 13 and 14). Bull Run steelhead had significantly lower condition factors (were thinner) than steelhead from other streams monitored in 2016. Gordon Creek and Clear Creek had the highest condition factors (were fattest) for steelhead and coho smolts, respectively, of streams monitored in 2016. Figures 13 and 14 show the results of Tukey test multiple comparisons of condition factors for these two species across monitored streams. The weights of Cedar Creek steelhead and coho were not measured, so their condition factors were not evaluated relative to the other streams.

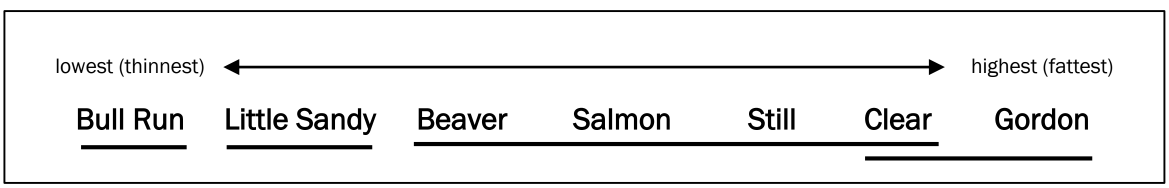

Figure 13. Steelhead smolt results of Tukey test multiple comparisons of condition factors for Sandy River streams monitored in 2016

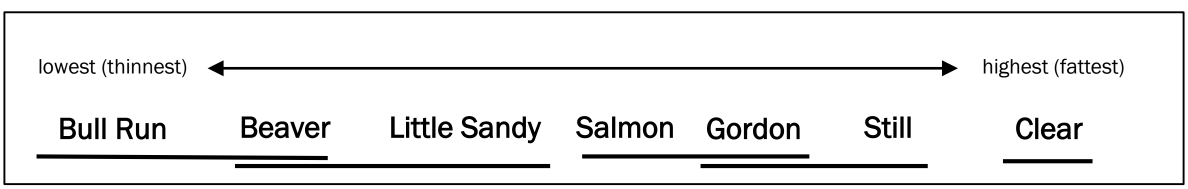

Figure 14. Coho smolt results of Tukey test multiple comparisons of coho smolt condition factors for Sandy River streams monitored in 2016

4.4 Emigration Dates

The weighted mean and peak dates of emigration were earlier in the lowest-elevation streams for both steelhead and coho (Figures 15 and 16). Bull Run and Little Sandy coho underwent a relatively late emigration in 2016. The weighted mean and median emigration dates for the trapping period are summarized, along with the estimated peak emigration date for the population and the dates of first and last capture, in Tables 16 and 17 for steelhead and coho, respectively.

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 2016

	Weighted					
Streams[a]	Mean Emigration (Trapping)	St. Dev.	Median Emigration (Trapping)	Peak Emigration	Earliest Date	Latest Date
Still Creek	27-Apr	13	1-May	2-May	29-Mar	30-May
Clear Creek	29-Apr	11	2-May	5-May	1-Apr	29-May
Salmon River	2-May	16	3-May	2-May	28-Mar	8-Jun
Cedar Creek	24-Apr	9	25-Apr	25-Apr	24-Mar	16-May
Little Sandy	27-Apr	10	25-Apr	25-Apr	10-Mar	25-May
Bull Run	25-Apr	15	25-Apr	25-Apr	8-Mar	3-Jun
Gordon Creek	14-Apr	16	15-Apr	18-Apr	8-Mar	21-May
Beaver Creek	6-Apr	12	6-Apr	2-Apr	10-Mar	15-May

[a]Streams are presented in order from highest-elevation Still Creek 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 2016

	Weighted					
Streams[a]	Mean Emigration (Trapping)	St. Dev.	Median Emigration (Trapping)	Peak Emigration	Earliest Date	Latest Date
Still Creek	16-May	18	18-May	20-May	29-Mar	23-Jun
Clear Creek	10-May	15	14-May	16-May	1-Apr	19-Jun
Salmon River	7-May	21	5-May	25-Apr	28-Mar	20-Jun
Cedar Creek	1-May	15	30-Apr	25-Apr	24-Mar	27-May
Little Sandy	5-May	17	16-May	16-May	10-Mar	25-May
Bull Run	6-May	18	13-May	16-May	9-Mar	1-Jun
Gordon Creek	3-May	17	6-May	16-May	8-Mar	4-Jun
Beaver Creek	18-Apr	21	18-Apr	11-May	8-Mar	1-Jun

[a]Streams are presented in order from highest-elevation Still Creek to lowest-elevation Beaver Creek.

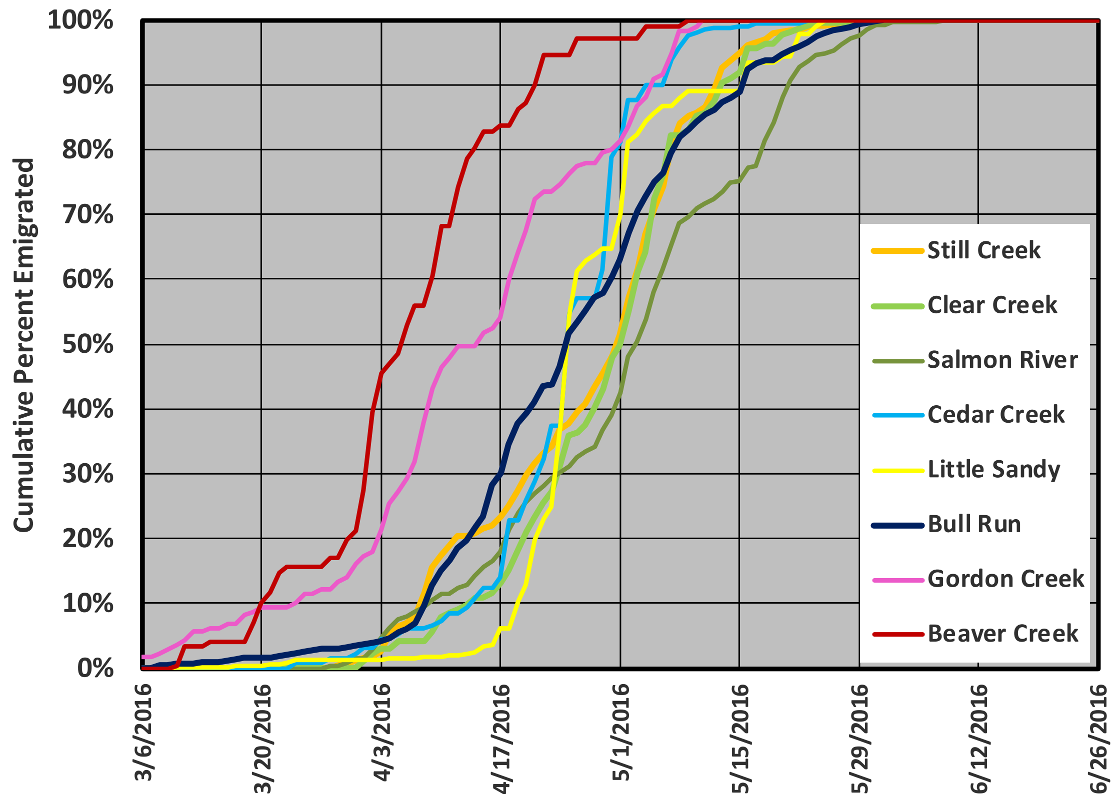

Figure 15. Steelhead smolt cumulative percentage of total emigration from Sandy River streams monitored in 2016. Steepest portions of each curve indicate peak capture periods.

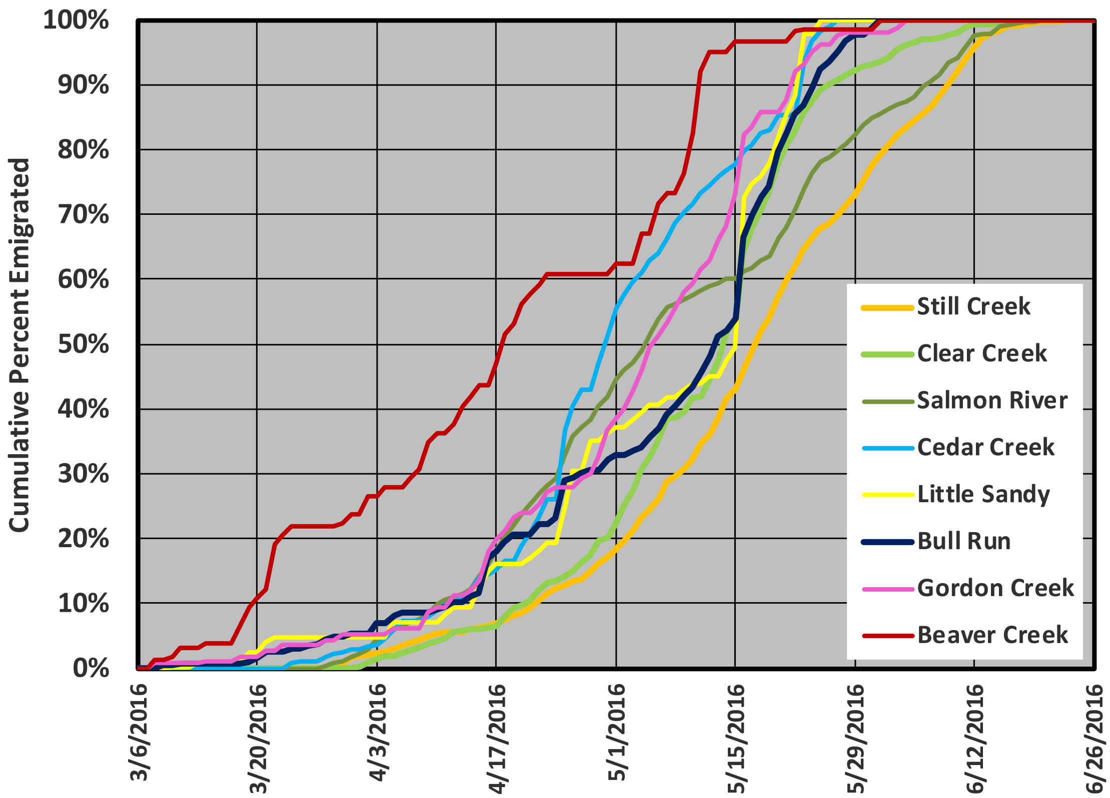

Figure 16. Coho smolt cumulative percentage of total emigration from Sandy River streams monitored in 2016. Steepest portions of each curve indicate peak capture periods.

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. 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.

Table 18. Steelhead smolt weighted mean age and age distribution for Sandy River streams, 2009–2015

Stream	Weighted Average Age	Age 1	Age 2	Age 3	Age 4
Still Creek	2.42	1.5%	56.6%	40.0%	1.9%
Clear Fork	2.41	0.0%	58.5%	41.5%	0.0%
Clear Creek	2.14	5.8%	75.0%	18.4%	0.8%
Salmon River	2.21	1.8%	75.9%	21.5%	0.8%
Cedar Creek	1.91	9.8%	89.4%	0.9%	0.0%
Little Sandy	2.26	1.7%	71.0%	27.3%	0.0%
Bull Run	2.13	4.5%	78.6%	16.6%	0.3%
Gordon Creek	2.00	19.9%	59.7%	20.4%	0.0%
Beaver Creek	1.34	67.5%	30.9%	1.6%	0.0%

Table 19. Coho smolt weighted mean age and age distribution for Sandy River streams, 2009–2015

Stream	Weighted Average Age	Age 1	Age 2	Age 3	Age 4
Still Creek	2.04	0.0%	96.9%	3.1%	0.0%
Clear Fork	2.00	0.0%	100.0%	0.0%	0.0%
Clear Creek	1.98	3.1%	95.4%	1.5%	0.0%
Salmon River	2.01	0.0%	99.3%	0.7%	0.0%
Little Sandy	2.00	0.0%	100.0%	0.0%	0.0%
Cedar Creek	2.04	0.1%	95.4%	4.5%	0.0%
Bull Run	2.00	0.0%	100.0%	0.0%	0.0%
Gordon Creek	2.00	0.0%	100.0%	0.0%	0.0%
Beaver Creek	1.98	5.0%	92.6%	2.4%	0.0%

5. Discussion

5.1 Smolt Population Estimation

Most steelhead and coho smolt population estimates were high compared to the previous seven years of the Sandy River Basin Smolt Monitoring Program, though some were unusually low. The Bull Run and Salmon rivers experienced record or near-record production of steelhead and coho smolts. Beaver Creek had a record high steelhead estimate but unusually low coho estimate. The Little Sandy had an unusually low steelhead estimate.

The low Beaver Creek coho estimate and high steelhead estimate may be the result of extremely low water conditions in the creek the previous summer and the generally high Sandy River Basin Index Area steelhead smolt emigration, respectively. Beaver Creek experienced extended periods of very low water and high water temperatures in 2015. Conditions were likely lethal for cold-water fish like rearing coho except for areas of refuge, such as pools with groundwater inputs. Steelhead smolts may have included fish that originated elsewhere in the Sandy River Basin but overwintered in Beaver Creek. Steelhead smolts emigrating from Beaver Creek tend to have a complex fork length distribution, with two or three modes, suggesting groups of fish reared under differing conditions or of different ages. The large number of steelhead emigrating from other streams in the Sandy River Basin may have translated into a larger number of steelhead entering Beaver Creek to overwinter.

The description of smolt production by various streams in the Sandy River Basin could be complicated to an unknown degree by movement of fish between subbasins either before or during the time of smolt emigration. A total of 7 hatchery (adipose-clipped) steelhead smolts were captured in the Bull Run trap from early March to early May 2016. These fish would have entered the Bull Run after being released, swimming upstream beyond the Bull Run trap and then being captured on their way back downstream. Although these fish were not included in the Bull Run steelhead population estimate, their presence highlights 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 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 characteristics among streams. Of a total of 1,007 steelhead marked in tributaries upstream of Bull Run using paint marks, none were recaptured in the Bull Run trap, lending further credence to the assumption that such movement between streams is at least not occurring to a significant degree during the spring months. Large numbers of hatchery steelhead have been observed straying into the Bull Run River only in 2014, although 37 were also observed in 2015. It is possible that the movements of hatchery steelhead in 2014 and 2015 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. 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 2016. 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 2016 (7.8 percent compared with 5.1 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.

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 result in an inflated estimate. Consequences of this effect are discussed more fully in Strobel 2010. Steelhead marked and recaptured at the Bull Run trap were shorter by 5 mm, on average, than steelhead originally marked. It is unlikely that this small difference would result in different swimming abilities.

The initial estimates of steelhead productivity (smolts per adult) were hampered in 2014 and 2015 by difficulties encountered generating adult steelhead spawner estimates in previous years. No estimates of the number of steelhead spawners in the Sandy River basin was 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). 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 after 20 years of annual smolt monitoring, in 2029

The preliminary calculations made in 2016 and those to be made in future years will improve with the collection of additional data.

5.2 Fork Lengths

The observed differences in fork length distribution for steelhead and coho smolts among Sandy River Basin streams monitored in 2016 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, though 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 discern between the effects of growth and age.

5.3 Condition Factors

In 2016, condition factors for both steelhead and coho smolts were generally negatively related to both fork length and elevation of stream. 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 in generally inactive overwintering fish associated with warmer water temperatures could result in greater use of fat stores.

5.4 Emigration Dates

Steelhead and coho smolts generally emigrated earlier from low-elevation streams than from higher-elevation streams. Both species, however, had emigration timing in the Bull Run that was more similar to that of higher-elevation streams. Similar patterns have been observed in most previous years, especially for coho. These differences in emigration timing could simply be contingent on environmental conditions (e.g., water temperature warms earlier in the year in the lower basin) or could reflect life-history differences contributing to life-history diversity in the Sandy River Basin.

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.

6. Findings, Conclusions, and Recommendations

- Population estimates or approximations could be generated for steelhead and coho smolts in eight streams in 2016.
- Steelhead and coho smolt estimates were generally relatively high in 2016. The Bull Run had record high steelhead and coho smolt estimates. The Salmon River had a record high steelhead estimate and the second-highest coho estimate on record. Beaver Creek had a record high steelhead estimate but unusually low coho estimate. The Little Sandy had an unusually low steelhead estimate.
- Estimates of steelhead and coho smolt production were generated for the entire Sandy River Basin Index Area for years 2009–2016. More precise estimates will be generated once additional years of smolt monitoring data are available.
- Estimates of freshwater productivity (smolts per adult) were generated for steelhead for parental years 2010–2013 and for coho for parental years 2007–2014.
- Steelhead and coho smolt fork lengths showed significant differences among monitored streams in the Sandy River Basin in 2016. High-elevation streams produced shorter fish of a given age than low-elevation streams, similar to what has been observed in previous years. An exception was Beaver Creek, which produced steelhead that were relatively short for a given age.
- Steelhead and coho smolts from different streams in the Sandy River Basin showed significant differences in the average condition factor in 2016. In general, streams with longer smolts of both species showed lower condition factors.
- Coho smolts emigrated earlier from low-elevation streams than from high-elevation streams in 2016. Steelhead throughout the Sandy River Basin showed similar emigration timing. Steelhead emigrated, on average, earlier than coho.
- 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.
- These data represent the eighth installment of a long-term data set that will help both evaluate the viability of Sandy River steelhead and coho and guide the restoration efforts that seek to ensure their continued existence.

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. In addition to the funds provided by the involved agencies (the Portland Water Bureau, U.S. Forest Service, and Oregon Department of Fish and Wildlife) smolt monitoring efforts were also supported by a grant from Portland General Electric. Special thanks to the dedicated field crews that installed, maintained, and removed the numerous traps and checked them on a daily basis in all weather and desperately low flows. Crew personnel included Steve Schaaf, Jon Mueller, and Trevor Diemer from PWB; Emi Ikeda, Kevin Perkins, Jacob Sleasman, and Haley McDonel from USFS; and Matt Lackey, Charles Baker, Jen Krajcik, and Dave VanAmburgh, from ODFW. Additionally, Don Mensch, Christy Slovacek, Bob and Carla Heade, and Gordy Garoutte contributed countless invaluable volunteer hours to help out with the USFS smolt traps.

Seven years' worth of smolt scale samples were aged by the ODFW Fish Life History Analysis Project in Corvallis, Oregon for this project. For their effort and the discussions with lab leader Ben Clemens of what the results mean, we are extremely grateful. Thanks also to Eric Brown and Jonathon Nott of the ODFW Oregon Adult Salmonid Inventory and Sampling Project (OASIS) for supplying adult steelhead and coho spawner estimates.

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Exhibit A. All Species and Life Stages Captured at Smolt Traps in the Sandy River Basin in 2016

	Still Creek	Clear Creek	Salmon River	Cedar Creek	Little Sandy River	Bull Run River	Gordon Creek	Beaver Creek
Bluegill	0	0	0	0	0	0	0	42
Catfish	0	0	0	0	3	0	0	2
Chinook Fry	0	0	3	81	38	232	1,481	566
Chinook Smolts (Wild)	0	0	0	0	0	0	0	1
Chinook Smolts (Hatchery)	0	0	0	0	0	47	0	0
Coho Fry	14	10	123	31	35	7	39	15
Coho Smolts	2,086	1,195	3,417	370	94	299	148	121
Cutthroat Juveniles	0	2	0	0	0	0	0	0
Cutthroat Smolts	17	19	10	5	3	7	14	1
Cutthroat Adults	2	12	1	4	5	1	6	0
Longnose Dace	49	13	1,450	0	190	1,092	1,413	17
Speckled Dace	0	0	0	0	0	1	16	138
Banded Killifish	0	0	0	0	0	0	0	3
Pacific Lamprey Adult	0	6	58	3	2	3	16	12
Lamprey Amocete	0	24	18	104	0	1	132	35
Northern Pikeminnow	0	0	0	0	0	6	1	120
Oriental Weatherfish	0	0	0	0	0	0	0	5
Peamouth	0	0	0	0	0	0	0	20
Pumpkinseed	0	0	0	0	0	0	0	2
Rainbow Trout	30	37	10	0	4	6	2	0
Salmonid Fry[a]	123	629	404	35	21	74	4,927	1,708
Redside Shiner	0	0	0	0	0	2	0	123
Sucker	0	0	0	0	0	84	34	7
Sculpin	1	4	43	1	2	44	159	141
Steelhead Adult	2	4	0	1	0	1	0	0
Steelhead Fry	0	0	7	191	60	43	631	23

	Still Creek	Clear Creek	Salmon River	Cedar Creek	Little Sandy River	Bull Run River	Gordon Creek	Beaver Creek
Steelhead Juvenile	219	119	410	3	94	107	121	58
Steelhead Smolts (Wild)	419	172	486	43	133	1,319	159	134
Steelhead Smolts (Hatchery)	0	0	0	0	0	7	0	0
Whitefish Adult	1	4	8	0	1	0	0	0

[a]Chinook, coho, and steelhead fry were too numerous to identify individually in most streams. Salmonid fry were subsampled.

Appendix G. 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 2010–2016

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

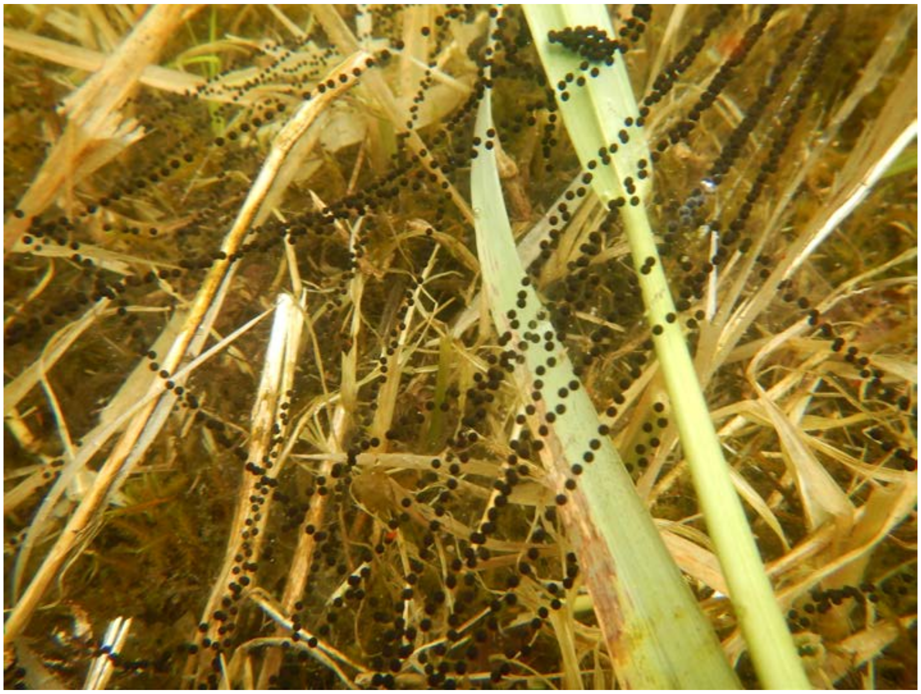
Item 9. November 18, 2014, letter from David G. Shaff, PWB, to Kim Kratz, NMFS, requesting confirmation that the Habitat Conservation Plan (HCP) Implementing Agreement documents the City's commitment to forgo consumptive use of the Little Sandy River and serves as the Little Sandy Flow Agreement for 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

There was no correspondence for the 2016 HCP Compliance Year.



Appendix H

Bull Run HCP Research Report

Western Toad Monitoring for Reservoir Operations Measure R-3

April 2017
John Deshler
City of Portland Water Bureau

Contents

1. Summary

The City of Portland Water Bureau (PWB) was in full compliance with its Habitat Conservation Plan obligations in 2016 with regard to reservoir operations measure R-3, Reed Canarygrass Removal. The reed canarygrass was cut and raked off of three areas along the north bank of the upper end of Bull Run Reservoir 1 on April 27. In addition, the grass was cut and raked away a second time, on September 12, to improve breeding and rearing habitat for the following year.

Measure R-3 is intended to benefit western toads (*Bufo boreas*) and northern red-legged frogs (*Rana aurora*). Evaluating the effectiveness of PWB's efforts to improve toad and frog breeding habitat at the three areas was not part of the 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 of the first year of monitoring.

The cutting and removal of the reed canarygrass appeared to warm the water slightly, by an estimated 0.6 °C, relative to control (uncut) sites. However, toads did not appear to select the treated (cut) sites over the control sites for breeding. Toads laid eggs at only one of the three treated sites. Most adult toads in amplexus (breeding position) and most toad eggs were at two sites among dense stands of reed canarygrass. However, the selection of sites for egg laying may have been driven by water temperature, the availability of water (depth), and the location of conspecifics (other toads of the same species to breed with), rather than the presence or absence of reed canarygrass.

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 three 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 three areas.

Measure R-3 is based on the premises that (1) toad eggs need warm water to properly develop, (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 may develop properly.

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 the first year.

3. Objectives

The objectives of western toad monitoring are to determine:

- whether the water is warmer where grass is cut and removed,
- whether toads select treated (cut) sites for egg laying, and if so, which ones,
- the timing of breeding onset (the start of egg laying), and
- the magnitude and duration of the breeding effort (number of breeding adults and points of oviposition, first and last dates of egg laying).

An overarching goal of monitoring is to determine how management of the Reservoir 1 water level may affect toad breeding. More 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 monitoring at the three areas.

During this first year of monitoring, an attempt was made to gain initial information and familiarity with toad breeding at the sites. Additional years of monitoring will be needed to achieve the long-term objectives, and monitoring methods and objectives may change, depending on the findings from initial observations.

4. Monitoring Methods

Toad monitoring was conducted in the spring. The monitoring focus was in the month of May when breeding adults and eggs have sometimes been observed at the areas in prior years. In 2016, the monitoring period was April 5 through June 29. Of the eight field survey days, five were in May. Grass cutting occurred on April 27.

Three areas were monitored; each area had a treatment site and a control (uncut) site. At each treatment and control site, a wooden stake was placed in the ground to mark the center of the site. See Figure 1 for the locations of the three areas and the treatment and control sites.

Water Temperature

During the first field survey day, water temperature probes were attached to the base of each stake. The probes collected water temperature hourly throughout the monitoring period.

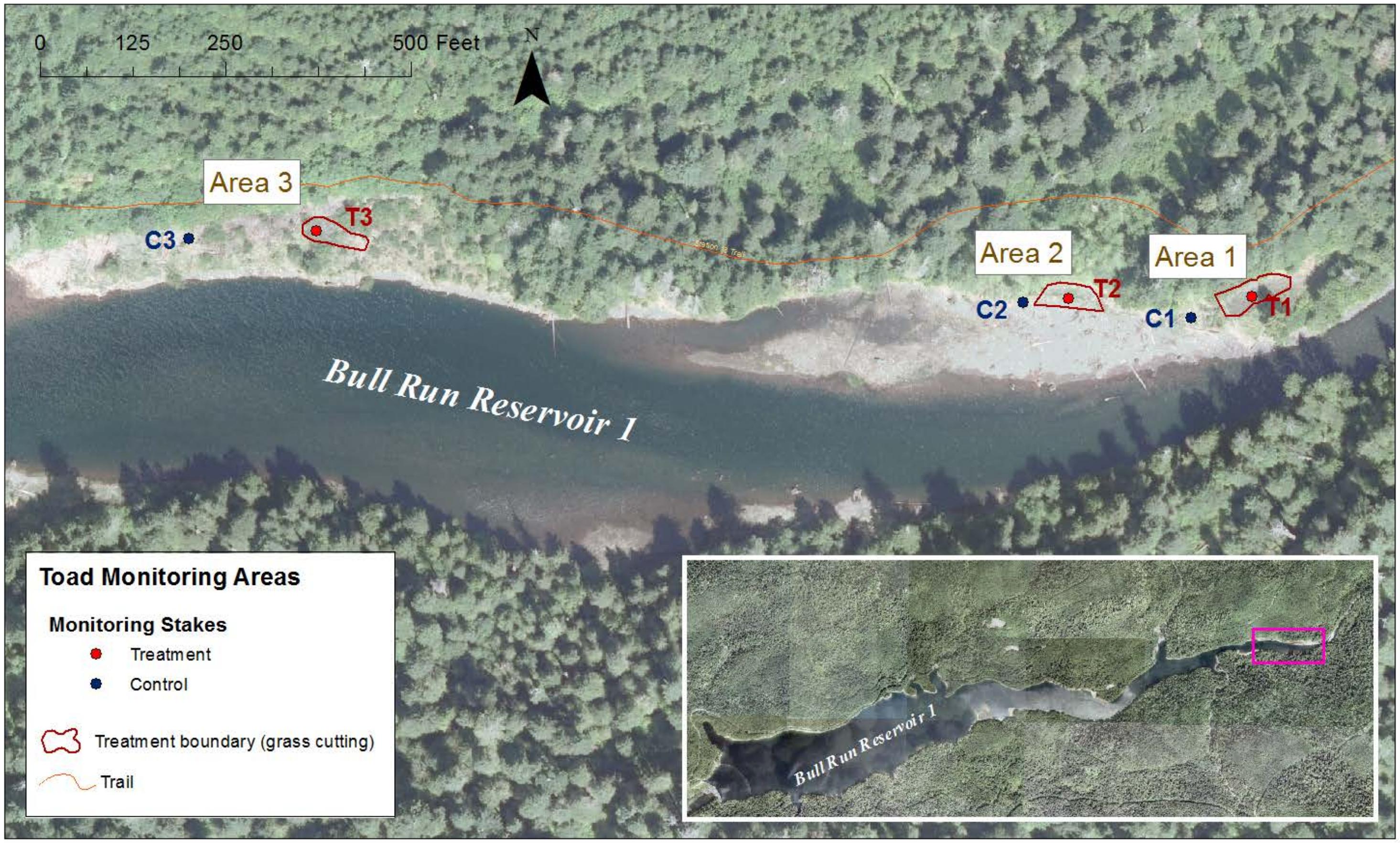


Figure 1. Toad Monitoring Areas

During each field survey day, all three areas were visited and reed canarygrass height and water depth were measured at the stake of each treatment and control site. Reed canarygrass height was determined by finding the tallest stem within a one-meter radius of the stake. If water was present at the stake, water temperature was collected at depths of 30 and 60 centimeters (cm).

Breeding Site Selection

A site was considered a breeding site if eggs or breeding pairs in amplexus (mating position) were observed there.

During each survey, adult toads, pairs in amplexus, new points of egg oviposition, and juvenile toads (tadpoles and toadlets) were counted at each site. 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).

5. Analysis

Water Temperature

To determine whether water temperature is affected by grass cutting and removal, comparisons of water temperature were made between the treatment and control sites of each area.

Pairwise *t*-tests were used to compare temperatures when ≥30 cm of standing water was present at both the treatment and control site of an area.

The comparisons were based on data from the temperature probes collected during the first 14 days of May, soon after the grass had been cut. The temperature readings collected during field survey days were not used, because on those days, the sites were often too dry or shallow to collect meaningful data.

6. 2016 Results and Discussion

Water Temperature

The water temperatures at the treatment sites of Area 1 and Area 2 were, on average, 0.6 °C warmer than at the control sites. At Area 1, the treatment site averaged 14.8 °C, compared to just 14.2 °C at the control site ($t = 4.69$, $P < 0.0001$, $df = 169$). Similarly, at Area 2 the treatment site averaged 14.6 °C, compared to just 14.0 °C at the control site ($t = 8.38$, $P < 0.0001$, $df = 17$).

Conversely, at the Area 3 the water at the control site was 0.3 °C warmer than at the treatment site, on average. At Area 3 the treatment site averaged only 12.2 °C, compared to 12.5 °C at the control site ($t = 2.37$, $P = 0.019$, $df = 277$). So temperatures were about 2 °C lower at Area 3 than at the other two areas.

At Area 3, the difference in temperature between the treatment and control site, and the lower average temperatures relative to the other areas, may have been caused by cool water flowing directly into the area from a small stream. The stream input was closest to the treatment site which may explain why the treatment site was, on average, slightly cooler than the control site. Because of the potential effect of the stream, Area 3 was omitted from the final assessment of whether the grass cutting affected water temperature.

In summary, for 2016 it appeared that cutting the grass had a small, warming effect on water temperature at the treatment sites of Areas 1 and 2, but additional years of monitoring data are needed to fully test the effect of grass cutting on water temperature. The warming affect in 2016 appeared to be independent of slight differences in the elevation of the monitoring stakes. At Area 1, the treatment stake was 0.28 meters (m) higher (the water was 0.28 m shallower) than at the control stake. At Area 2, the treatment stake was 0.05 m lower (the water was 0.05 m deeper).

For future years of monitoring, the stakes will be moved slightly to make them more equal in elevation. Also, to make temperature comparisons more consistent across sites and areas, the temperature probes will be attached to a float that keeps them at a constant depth, rather than being fixed to the bottom of the stake.

Breeding Site Selection

Toads laid eggs at one of the treatment sites and two of the control sites (see Figure 1). Most eggs were laid in Area 1, the eastern area. No breeding occurred at Area 3 (the western area) or at the treatment site of Area 2 (the central area). In mid-May, when reservoir levels dropped such that none of the monitoring stakes were wetted, eggs were deposited in an uncut area at the fringes of C2, the Area 2 control site.

Eggs and adults in amplexus (breeding position) were first observed at the control and treatment sites of Area 1 on May 3. This was the initial pulse of breeding effort during which 15 breeding pairs were observed in amplexus and thousands of eggs were found in one, broad point of oviposition at C1, the control site that was within a dense stand of reed canarygrass. At C1, eleven pairs of toads were in amplexus and other adult toads were observed and heard vocalizing. Three small points of oviposition were at T1, the treatment site, where four pairs of toads were observed.

On May 17, a second pulse of breeding was observed at Area 2, in an area of dense reed canarygrass at the fringes of site C2. On this date, five pairs in amplexus and at least seven other adults were observed at the site. A few other breeding adults and points of oviposition were observed later in May, but no other large pulses of breeding effort.

The last evidence of breeding was detected on May 31: three adults and three points of oviposition at C1.

In summary, in 2016 most eggs were laid at sites with dense stands of reed canarygrass. The toads selected only one of the treatment (cut) sites for laying eggs, and did so during a few days in early May. During most of the breeding period, the toads used sites with reed canarygrass.

The choice of breeding sites appeared to be driven by water temperature, water depth, and the presence of conspecifics (toads of the same species), rather than the presence or absence of reed canarygrass. It has been established that toads begin breeding when the water at breeding sites reaches 14 °C, and that they choose sites with calm water that is typically ≤ 0.6 m deep (Marc Hayes, Washington Department of Fish and Wildlife, personal communication). Area 1, both the treatment and control sites, appeared to be the only area with the proper conditions for breeding in early May, so toads aggregated there to compete for mates and lay eggs. Much of Area 2 may have been avoided because it was initially too deep, then too dry. Breeding did not occur at Area 2 until the water level dropped approximately two meters in mid-May, creating a broad, flat area where the water was ≤ 0.6 m deep and the temperature was ≥ 14 °C. Area 3 may have avoided because it was nearly 2 °C cooler than the other areas. One adult was observed at Area 3 in mid-April, but that was the only time toads were observed using that area in 2016.

The breeding sites with reed canarygrass where most of the toads laid eggs in 2016 are not typical for the species. As a rule, western toads select sunny, shallow, calm-water breeding sites that have a bare mineral substrate and are nearly devoid of vegetation (Charlotte Corkran, Northwest Ecological Institute, and Marc Hayes, Washington Department of Fish and Wildlife, personal communications). The breeding habitat at the upper end of Bull Run Reservoir 1 may have been more like the typical sites used by toads, at least in terms of vegetation. A photograph from approximately 1985 shows 12 pairs of toads breeding at site T1 where there was no reed canarygrass at the time, although some short, sparse, native vegetation was present. Today, toads seem to be using the upper end of Bull Run Reservoir —even the areas with dense reed canarygrass—despite the potentially less-optimal habitat conditions for breeding.

During surveys, counting of adults was challenging and the number of adults may have been underestimated. The reed canarygrass hindered visibility, and surveyors avoided moving through areas where eggs were in the water.

Due to fluctuations in the level of Reservoir 1, eggs at all but one of the points of oviposition were known to have been stranded and desiccated. Low steam flows and high ambient temperatures, created the conditions that caused Reservoir 1 to be drawn down soon after eggs were deposited in both early and mid-May. Additional years of monitoring are necessary for an analysis of the timing, requirements, and outcomes of toad breeding in relation to reservoir levels.

7. 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.