2019 LOWER DESCHUTES RIVER WATER QUALITY REPORT

Deschutes River Alliance
May 2020

KEY FINDINGS:

- Selective water withdrawal continues to result in exceedances to the Deschutes Basin's water quality standards.
- Water temperature exceeded the state water quality standard during the period designated for salmon and steelhead spawning and egg incubation.
- Dissolved oxygen concentration is not being managed to adequately protect incubating trout eggs and fry.
- Excessively high pH levels above the state water quality standard occurred and large diel swings were recorded. Large diel swings in pH and dissolved oxygen are an indicator of excess nutrients in the water leading to high amounts of algae and aquatic plant biomass.

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Cover Photo: Lower Deschutes River. Photo by Rick Hafele.

ACKNOWLEDGMENTS

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In addition, a special thanks to these organizations that have provided critical funding needed for this study: Patagonia, Clabough Foundation, Clark-Skamania Flyfishers, Jubitz Foundation, Maybelle Clark Macdonald Fund, American Fly Fishing Trade Association, and the Tualatin Valley Chapter of Trout Unlimited.

Last, thanks to all those not mentioned here who care about the Deschutes River and have contributed hours of their time and money to better understand the river's changing ecology and protect its health. Many hundreds of people and numerous companies and foundations have made it possible to keep this work moving forward - THANK YOU.

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LIST OF ABBREVIATIONS

CFS - **Cubic Feet per Second**

CTWSRO - **Confederated Tribes of the Warm Springs Reservation of Oregon**

DEQ - **Department of Environmental Quality**

DO - **Dissolved Oxygen**

DRA - **Deschutes River Alliance**

IGDO - **Intergravel Dissolved Oxygen**

OAR - **Oregon Administrative Rules**

PGE – **Portland General Electric**

Project - **Pelton Round Butte Hydroelectric Project**

RM - **River Mile**

SWW Tower - **Selective Water Withdrawal Tower / Tower**

USBR - **United States Bureau of Reclamation**

USGS - **United States Geological Survey**

WQMMP - **Water Quality Management and Monitoring Plan**

7-DADM - **7-Day Average Daily Maximum**

BACKGROUND

The installation and implementation of the Selective Water Withdrawal (SWW) Tower at the Pelton Round Butte Hydroelectric Project (hereinafter Project), in late 2009, was the single largest anthropogenic change that has been imposed on the lower Deschutes River since the three dams were completed in 1964. The Water Quality Management and Monitoring Plan (WQMMP), part of the Project's Clean Water Act Section 401 Certification for its operations, mandates continued monitoring of the impacts of this change on the lower Deschutes River. A thorough discussion of the Tower's construction and operation was covered in the Deschutes River Alliance's 2016 water quality report (DRA 2017).

PGE's 2019 Water Quality Study Report for the Pelton Round Butte Project and the Lower Deschutes River:

To monitor and model water quality in the Project area, the licensees – Portland General Electric (PGE) and the Confederated Tribes of Warm Springs, Oregon (CTWSRO) – hired the consulting firm MaxDepth Aquatics Inc. From 2015-2017, MaxDepth Aquatics collected water quality data in the three tributaries of Lake Billy Chinook, the three reservoirs of the Project, and in multiple locations on the lower Deschutes River. Their final report - *Water Quality Study for the Pelton Round Butte Project and Lower Deschutes River: Monitoring & Modeling* (Eilers & Vache 2019) – was released in June 2019 (hereinafter: PGE Water Quality Study).

Deschutes River Alliance water quality reports and studies:

Since 2013, the Deschutes River Alliance (DRA) has implemented several independent studies to assess the impacts of the Tower on aquatic life and water quality. The results of these studies are posted online in annual science reports. This report presents the results of water quality monitoring in the lower Deschutes River in 2019. Other reports are available on the DRA website: http://www.deschutesriveralliance.org/.

Our 2019 results and prior years' findings agree with several conclusions from the PGE Water Quality Study (Eilers & Vache 2019):

1. High daytime pH and large diel swings in pH and dissolved oxygen (DO) indicate that the lower Deschutes River has become eutrophic.[1]
2. Operation of the SWW Tower results in surface water discharge from Lake Billy

[1] DRA Lower Deschutes River Water Quality Reports (DRA 2015, 2017, 2018, 2019c)

Chinook into the lower Deschutes River. The surface water in Lake Billy Chinook is comprised primarily of "poor" water quality from the Crooked River Basin.[2] Crooked River nutrient inputs into Lake Billy Chinook are disproportionately higher for nitrates (NO3) compared to the nitrate contributions from the Metolius and Deschutes rivers.[3] These differences in water quality primarily reflect differences in land use, with agriculture the primary use in the Crooked River Basin.[4] Additional agricultural pollutants, including the pesticide chlorpyrifos, were recently reported in the lower Deschutes River by the Oregon Department of Environmental Quality (DEQ) at levels that exceed the toxicity limits for fish, other aquatic life forms, and humans set by the Environmental Protection Agency.[5] Contamination of the river with bacteria (*e. coli*) from cattle-grazing is also a concern in the Crooked River Basin.[5]

3. Operation of the SWW Tower results in the transport of planktonic, or free floating, algae and cyanobacteria from the surface of Lake Billy Chinook into the lower Deschutes River. This increases turbidity in the lower Deschutes River and contains algae that are not commonly found in streams.
4. Increased water temperatures, compared to pre-SWW Tower averages, now occur in the lower Deschutes River from winter through early summer.
5. Increased water temperatures and increased nitrate pollution in the lower Deschutes River are the likely cause of observed excessive algal growth including the growth of nuisance diatom species that form felt-like mats of algae on stream substrate.[6]

[2] Deschutes Basin Water Quality Status and Action Plan—Summary 2011 (ODEQ 2012)

[3] DRA Lake Billy Chinook Water Quality Study Results (DRA 2016)

[4] DRA Water Quality and Land Use Report (DRA 2019b)

[5] 2018/2020 Integrated Report (ODEQ 2018/2020)

[6] Lower Deschutes River Macroinvertebrate Hatch Activity Survey Results (Hafele 2014)

INTRODUCTION

In 2019, the DRA continued to monitor water quality at the DRA Monitoring Site in the lower Deschutes River (Figure 1). As in previous years a multi-parameter data sonde was used to collect hourly water quality measurements.

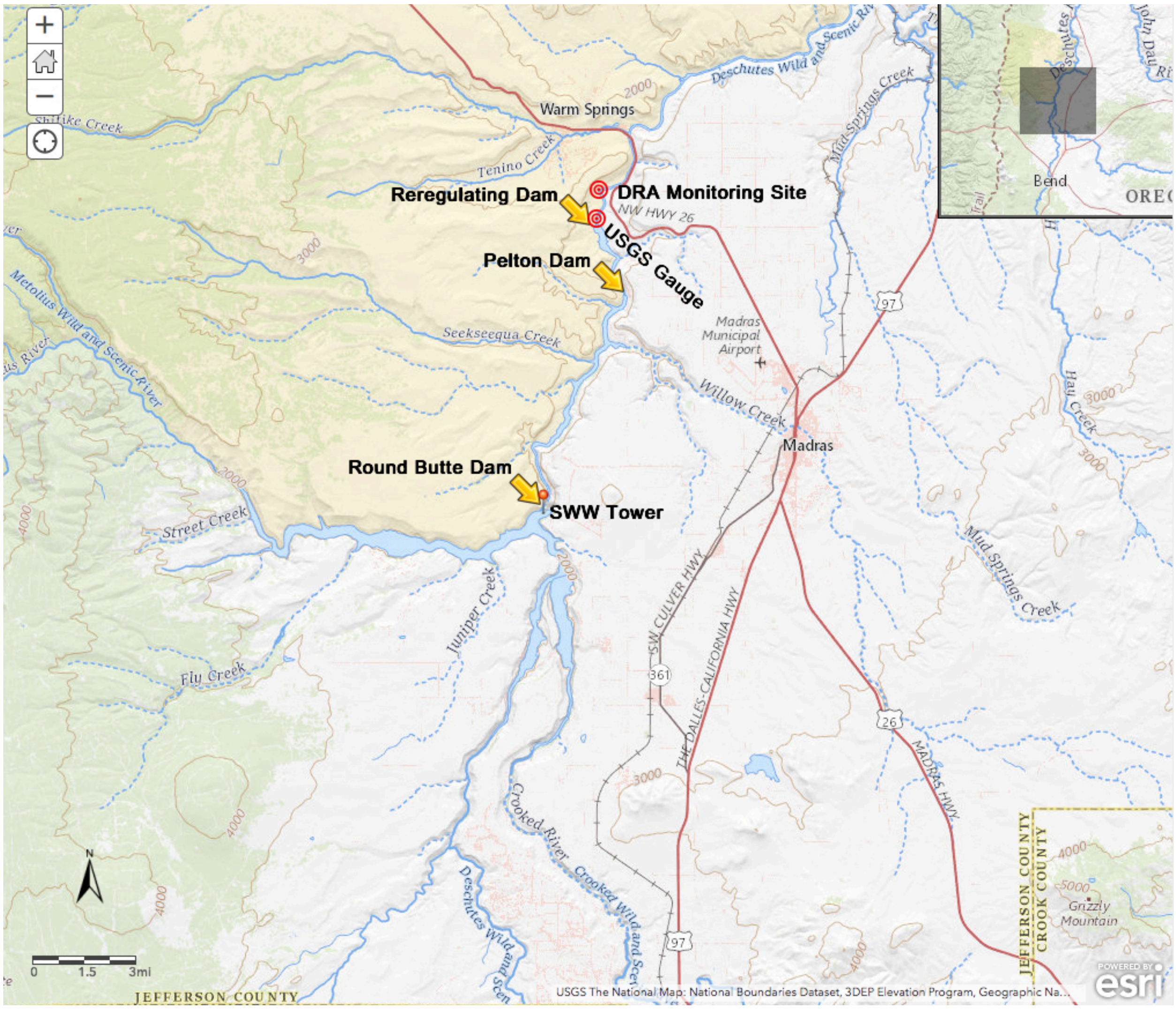

Figure 1. The three dams jointly owned by Portland General Electric and Confederated Tribes of Warm Springs, Oregon: Round Butte Dam (creates Lake Billy Chinook reservoir), Pelton Dam (creates Lake Simtustus reservoir), and the Reregulating Dam (creates the reregulation reservoir). The USGS gauging station and DRA monitoring site are located downstream of the Reregulating Dam.

Operation of the SWW Tower and resulting release of surface water from Lake Billy Chinook, the reservoir behind Round Butte Dam, continued throughout 2019. As in previous years, 100% surface water was released from the winter through spring.

Some changes in operations at the Tower, however, have occurred from 2017-2019 by releasing surface water mostly at night (PGE: Our Story…). These new "night blend" operations typically occur during the downstream juvenile fish migration period from March-June to increase capture efficiencies for out-migrating juvenile salmonids at the Tower (a primary objective of the SWW Tower, PGE & CTWSRO 2019). In addition, modeling done in the PGE Water Quality Study (Eilers & Vache 2019) showed slight improvements in multiple water quality parameters using the "night blend" scenario.

Various blends of surface and bottom water are mixed and released downstream from Lake Billy Chinook during part of the year. In general, this period can last from May-October, to meet temperature management targets in the lower Deschutes River outlined in the WQMMP. Surface water, or any blend of surface and bottom water, is released only during periods of power production at the Round Butte Dam. When turbines at the dam are not running, no water is released from Lake Billy Chinook. Near constant streamflow in the lower Deschutes River is maintained by the release of a continuous flow of water from the reregulation reservoir located behind the Reregulating Dam, the third and most downstream dam of the three-dam complex. Pelton Dam and Lake Simtustus make up the middle dam and reservoir (Figure 1).

Because of temperature stratification, Lake Billy Chinook's surface water is composed primarily of the warmer water from the Crooked River. This warm surface water carries a high concentration of nutrients and other pollutants compared to the cool water near the bottom of Lake Billy Chinook, which is comprised primarily of the cold and clean Metolius River water. As a result, the DRA has long advocated for the restored release of a significant percentage of bottom water into the lower Deschutes River. Such changes would provide immediate benefit. However, it is also essential, for the long-term health of the entire basin that Crooked River water quality be addressed. The DRA's 2019 monitoring work in the Crooked River is presented in a separate report.

OBJECTIVES AND KEY QUESTIONS

The monitoring objectives of this study included (DRA 2019a):

1. To determine how water quality for the key parameters of temperature, pH, and DO change on an hourly basis.
2. To determine which, if any, of these parameters exceed Oregon's water quality standards for the Deschutes Basin and, if so, how frequently.
3. To assess how different water years affect water quality.

SAMPLING METHODS

To answer these questions a multi-parameter data sonde (YSI Model EXO 2, Figure 2) was installed at the DRA monitoring site. The site is approximately one mile below the Reregulating Dam tailrace at river mile (RM) 99 of the lower Deschutes River (Figure 1). The monitoring site is the same location DRA sampled in prior years. This location is close enough to the Reregulating Dam tailrace to rule out other potential influences on water quality, but far enough downstream to allow the river time to show a response to water released from the Project.

Figure 2. YSI EXO 2 multi-parameter data sonde.

The YSI data sonde was calibrated against lab standards for all parameters before being deployed in the field and programmed to record hourly readings. The following water quality parameters were measured: temperature, DO, pH, conductivity, and turbidity. Field installation occurred after high flow conditions subsided. The sonde was successfully deployed from May 13, 2019 1600 hours through December 12, 2019 1200 hours. The data sonde was placed in an area of laminar flow in approximately three feet of water with probes positioned four to six inches above the stream bottom.

A central self-cleaning wiper cleans the optical sensors to avoid inaccurate results due to bio-fouling. The precision of the data sonde sensors was checked during initial deployment and repeated once a month with field audits using meters independent of the data sonde (APPENDIX A). Data downloads were made during several field audits and batteries were replaced as needed. The final field audit and data download were completed when the sonde was removed from the river on December 12, 2019. Quality control and assurance procedures were followed throughout the study (APPENDIX B).

In addition to monitoring water quality, the DRA gathered weather data from the National Oceanic and Atmospheric Administration Climate Charts database for Redmond, OR to determine differences in annual precipitation and air temperature in the Deschutes Basin (APPENDIX C). The Natural Resources Conservation Service SNOWTEL basin report for the Deschutes Basin was used to determine differences in annual snowpack in the early spring (APPENDIX C). The United States Geological Survey (USGS) National Water Information System and United States Bureau of Reclamation (USBR) database were used to determine differences in streamflow between years.

RESULTS

Temperature:

Hourly temperature measurements from May 13, 2019 to December 12, 2019 are shown in Figure 3. The amplitude of the line shows the range in temperatures over a 24-hour period or diel temperature range. The average difference between the daily minimum (occurs just before sunrise) and daily maximum (typically around 3pm) was approximately 0.7°C (~1.3 °F). When monitoring began, diel temperature ranges were within approximately 0.5°C (~0.9°F). Diel temperature range increased rapidly to over 1.0 °C (~1.8°F) on May 21, 2019. The maximum diel temperature range was 1.5°C (~2.7°F) on June 4, 2019. As the days became shorter and the weather cooled in the fall the diel temperature range declined. The minimum diel temperature range was 0.1°C (~0.2°F) on December 12, 2019.

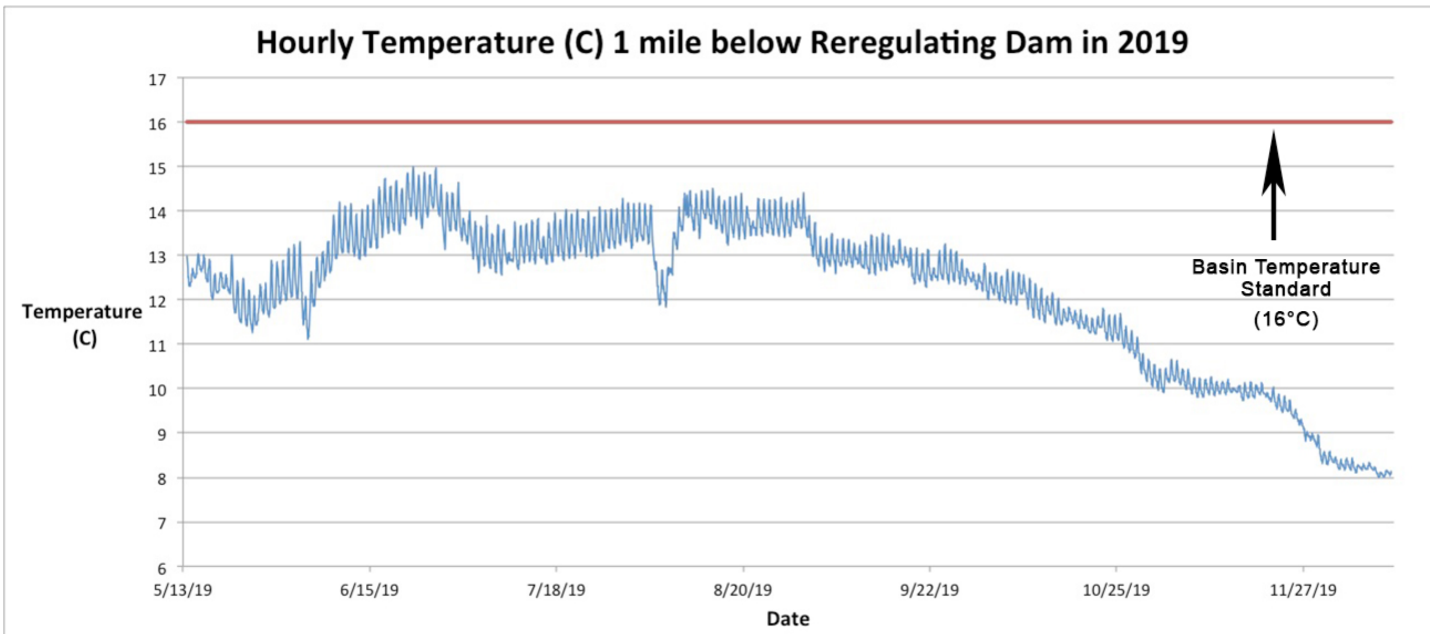

Figure 3. 2019 Hourly water temperature at River Mile 99 of the lower Deschutes River.

Water temperature followed a seasonal pattern and was within a range of 11-13°C (52-55°F) when monitoring began. Temperatures increased through mid-June and the maximum recorded water temperature of the study was 14.99 C (59°F) on June 22, 2019 at 1421 hours. From July through September, water temperature remained relatively constant between approximately 12.5°-14°C (55-57°F). A sudden drop in water temperature occurred on August 4-August 7. From late September through December a gradual decrease in water temperature occurred. The minimum recorded temperature of the study was 8.00°C (46.4°F) on December 10, 2019 at 0621 hours.

Oregon's stream temperature standard is based on a maximum 7-day moving average of the daily maximum water temperatures (7-DADM). The standard applied in the lower Deschutes River from below the Project downstream to the confluence with the Warm Springs River is 16°C (60.8 °F) for core cold-water habitat use (red line: Figure 3; see APPENDIX D for maps and criteria). A lower water temperature criterion (13°C; 55.4 °F) is applied during periods identified as having salmon and steelhead spawning use. More about these criteria and the time periods in which they apply will follow in the Discussion section.

Dissolved Oxygen:

Dissolved oxygen (DO) in water is measured and recorded in two ways: 1) as the concentration of DO in the water recorded in milligrams per liter (mg/L); and 2) as the percent of oxygen dissolved in the water (% saturation) given the temperature, elevation, and barometric pressure when the sample was collected. In most cases it is the concentration (mg/L) of DO that is applied to water quality standards. However, when the DO concentration (mg/L) standard cannot be achieved due to temperature, elevation, and barometric pressure conditions, the % saturation criteria is applied when evaluating whether DO water quality standards are being met.

Oregon's water quality standard for DO is higher during salmonid spawning season than during salmonid rearing season. The DO standard currently being applied by DEQ for the lower Deschutes River during steelhead and salmon spawning (designated as October 15-June 15 at the monitoring site) is a minimum of 11.0 mg/L with a lower acceptable limit of 9.0 mg/L when data showing adequate intergravel dissolved oxygen (IGDO) is available. A multiple standard of 8.0 mg/L as a 30-day mean minimum; 6.5 mg/L as a 7-day minimum mean; and 6.0 mg/L as an absolute minimum are the minimum requirements applied during the period DEQ has identified as outside the spawning and incubation period (APPENDIX D). More explanation of Oregon's DO standard and its application to the Project is covered in the Discussion section.

Figures 4 and 5 show the DO levels as mg/L and % saturation, respectively, from May 13 to December 12, 2019. The red lines in Figure 4 show the DO standards applied during steelhead and salmon spawning and the highlighted area indicates the time period that steelhead, salmon, and trout spawning through fry emergence occurs. These graphs also show a clear diel change in DO: minimum concentrations (and saturation) occurred an hour or two before sunrise, while maximum concentrations (and saturation) were recorded mid-afternoon. The greatest range from daily low to daily high occurred during the summer months.

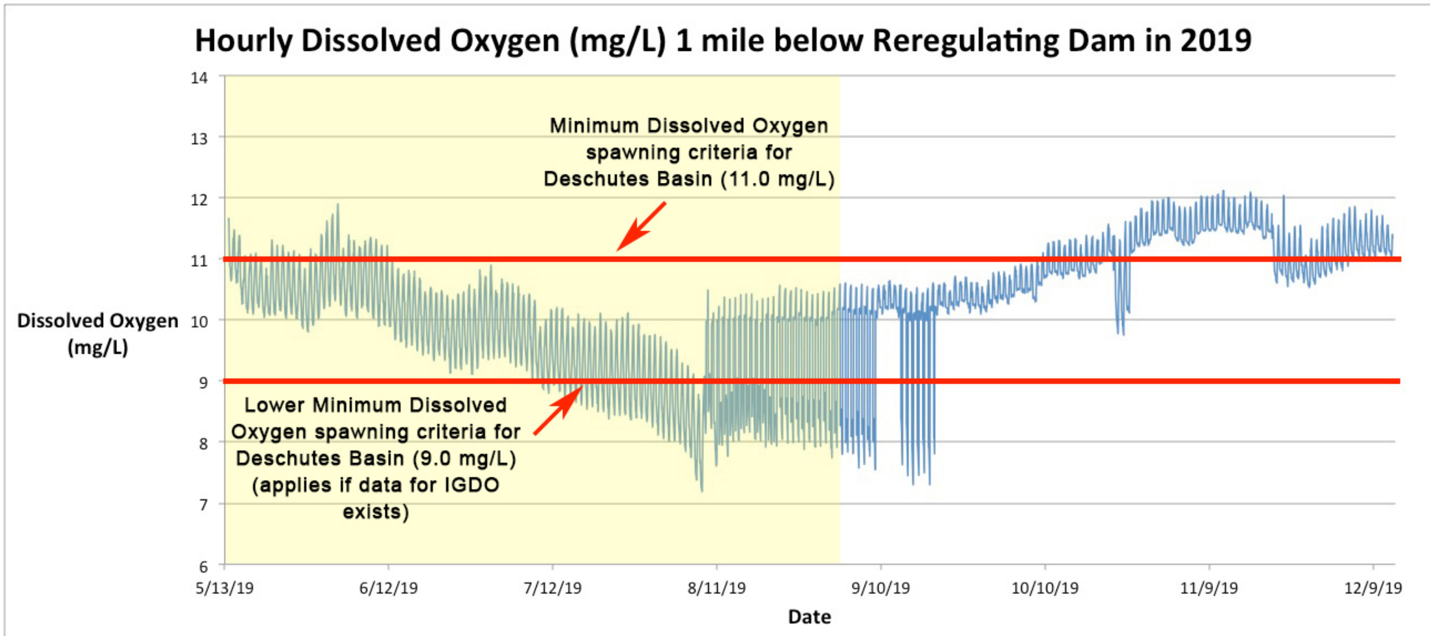

Figure 4. 2019 Hourly dissolved oxygen concentration (mg/L) at River Mile 99 of the lower Deschutes River. Criteria for dissolved oxygen concentration are shown during salmon, steelhead, and trout spawning period (highlighted).

Dissolved oxygen measurements were recorded within the range of 10.0-12.0 mg/L when monitoring began on May 13, 2019 (Figure 4). A gradual decline in DO concentration levels began in mid-June. The decline dropped below the lower minimum standard of 9.0 mg/L on July 8, 2019, and a sudden drop in DO occurred on August 4-August 7. All hourly measurements for DO on August 7 were below 9.0 mg/L. The daily maximum DO readings increased suddenly on August 8 as well as a sudden increase in the diel range in both DO concentration (Figure 4) and % saturation (Figure 5).

The diel range for DO was moderate when monitoring began and gradually increased as summer progressed. This is shown with a gradual increase in the amplitude of the lines in Figure 4 and Figure 5. The largest diel ranges in DO were approximately 2.5 mg/L and occurred from August 9-September 19, 2019 (Figure 4). A period of noticeably lower DO diel range (approximately 0.5 mg/L) occurred from September 9-September 12 followed by large diel swings until September 19, 2019 (Figure 4). On September 20, 2019 DO diel range returned to approximately 0.5- 1.0 mg/L for the remainder of the monitoring period.

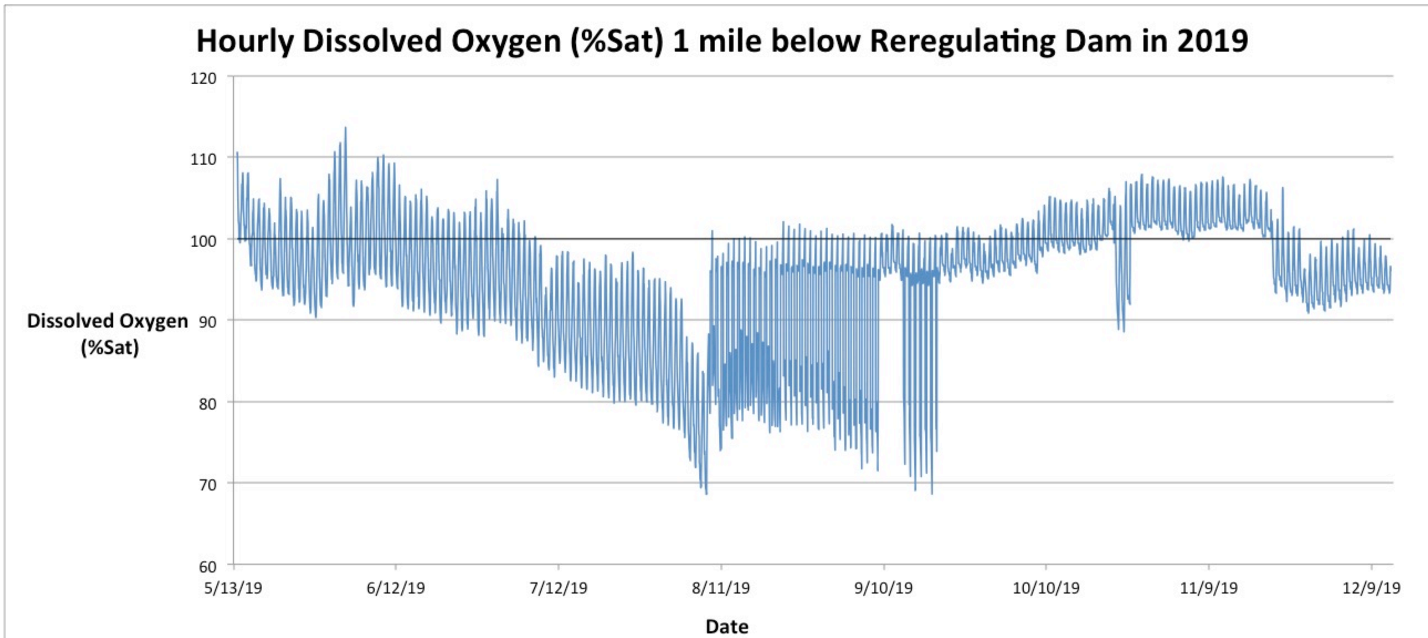

Figure 5. 2019 Hourly dissolved oxygen percent saturation (%Sat) at River Mile 99 of the lower Deschutes River.

Figure 5 shows that DO % saturation was within a range of approximately 90-110% from May-June. Dissolved oxygen % saturation fell below 100% on July 5, 2019 and continued to decline until August 8. Minimum daily DO levels fell to a low of 69% on August 8, 2019. As seen with DO concentration (mg/L), large diel swings in DO % saturation (range: 70-100%) occurred from August 9-September 19 with the exception of the dates September 9-12, 2019. From September 20, 2019 through the remainder of the monitoring period DO % saturation was within a range of 90-110%.

pH:

Figure 6 shows the hourly pH measurements recorded from May 13-December 12, 2019. As with temperature and DO, the amplitude of the line shows the difference in pH over a 24-hour period. Daily changes in pH are driven by the photosynthetic activity of aquatic plants and algae: pH rises with increased photosynthesis and drops when photosynthesis declines. As a result, maximum daily pH levels typically occur mid-afternoon between 1400 and 1600 hours, while minimum pH occurs early in the morning, generally just before sunrise. An increase in the range of pH between early morning and mid-day (shown by the amplitude of the line) indicates greater plant biomass and sunlight, which results in more photosynthesis.

Oregon's water quality standards in the Deschutes Basin restrict pH to a range between 6.5-8.5 standard units (OAR 340-041-0135). Like other water quality standards, the pH standard was set to protect aquatic life. The upper pH limit of 8.5 standard units is shown with the red line in Figure 6.

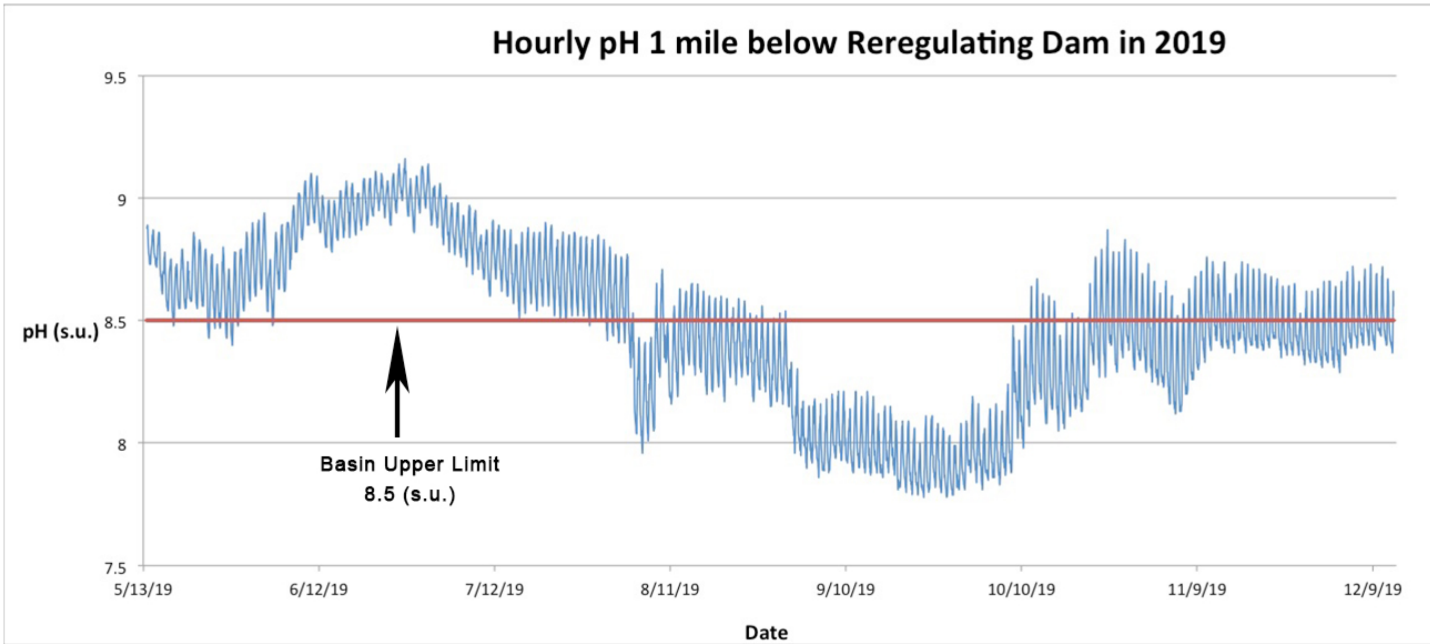

Figure 6. 2019 Hourly pH (standard units) at River Mile 99 of the lower Deschutes River**.**

From May 13-August 4, 2019 the hourly pH measurements were within a range of basic to highly basic (alkaline) and the majority of hourly measurements exceeded the basin pH standard (Figure 6). The maximum recorded pH of the study was 9.16 standard units on June 26, 2019 at 1721 hours. A sudden drop in pH occurred from August 5-7, 2019 and pH was within the basin standards. After this period, pH increased and daily maximum measurements exceeded 8.5 standard units from August 8-August 29, 2019. On August 30, pH dropped again and remained within the basin standards through October 10, 2019. The lowest recorded pH measurement of the study was 7.78 standard units on September 23, 2019 at 0721 hours. From October 11-December 12, 2019 pH was within a range of 8-9 standard units. Daily exceedances to the basin standard occurred from October 21-December 12, 2019.

Figure 7 shows the daily maximum pH measurements at RM 99 from 2016-2019. In 2016, a low flow year, the daily maximum pH exceeded 8.5 in April and remained above the basin standard throughout the monitoring period. In 2017, a moderately high flow year, the daily maximum pH exceeded 8.5 beginning in May and remained high until August. In 2018, a very low flow year, the daily maximum pH exceeded 8.5 when monitoring began in March and remained above the basin standard throughout the monitoring period. In 2019, a high flow year, the daily maximum pH exceeded 8.5 when monitoring began in May and remained high until the third week of August. In 2019 maximum pH levels rose above the basin standard again in October.

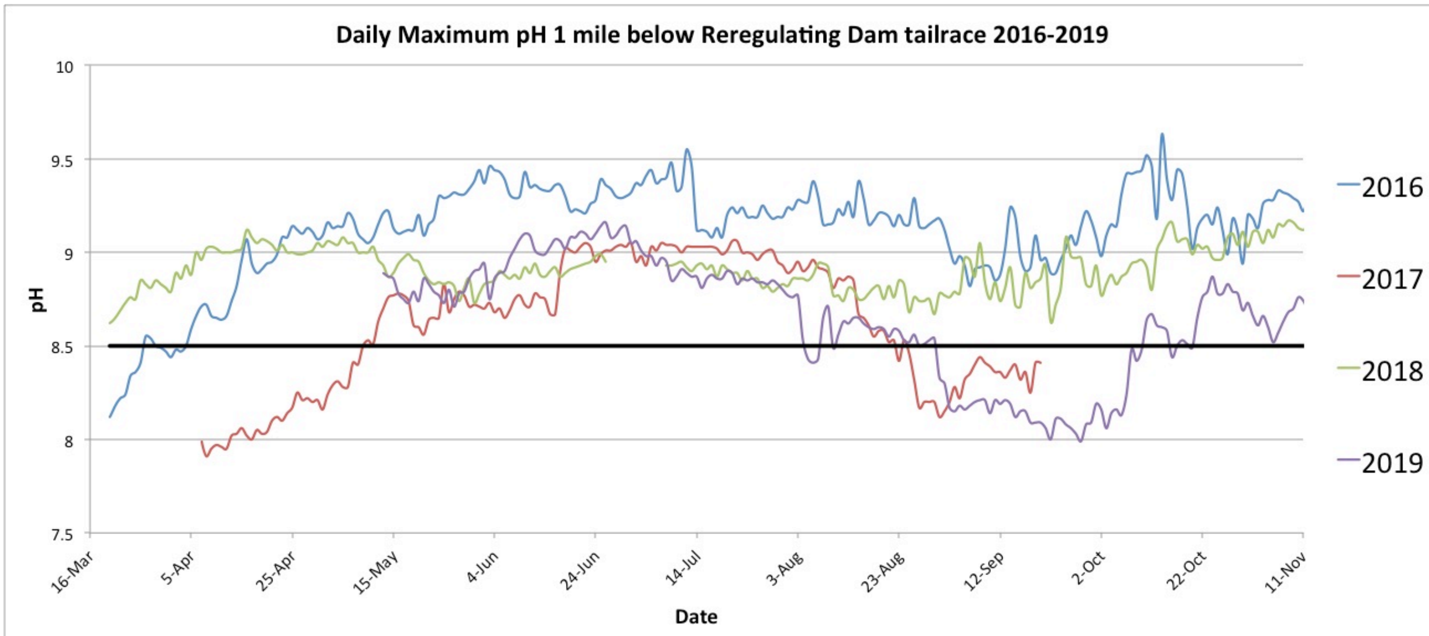

Figure 7. 2016-2019 Daily maximum pH records at River Mile 99 of the lower Deschutes River. (Source: DRA water quality reports)

Streamflow/Precipitation:

Table 1 shows differences in streamflow of the lower Deschutes River from 2016-2019. The Madras streamflow gauge (RM 100) is located below the Reregulating Dam tailrace and measures the flow being released from the Project into the lower Deschutes River (USGS Gauge in Figure 1). The Moody streamflow gauge is near the mouth of the Deschutes River confluence with the Columbia River (RM 1). Peak flow was highest in 2019 (25,100 cfs at RM 1 on April 9) compared to the years 2016-2018.

Table 1. Lower Deschutes River max daily stream discharge 2016-2019. (Source: USGS)

Max Daily Stream Discharge—cubic feet per second (cfs)					
Gauge Location	**Study Year**	March 1st	April 1st	May 1st	Peak Flow
Madras Gauge (RM 100)	**2016**	5,280	5,200	4,150	6,580 on Mar. 10
	2017	5,580	8,640	5,510	9,970 on Mar. 20
	2018	4,560	4,930	4,180	5,060 on Apr. 9
	2019	4,740	4,480	4,700	11,600 on Apr. 9-10
Moody Gauge (RM 1)	**2016**	6,900	6,560 Apr. 2nd	4,860	9,380 on Jan. 20
	2017	7,140	12,000	7,770	13,700 on Mar. 19
	2018	5,710	6,240	5,330	7,370 on Apr. 9
	2019	5,330	6,110	7,150	25,100 on Apr. 9

Figure 8 shows the spring runoff event that occurred on April 9, 2019 in the lower Deschutes River. High flows in the three tributaries of Lake Billy Chinook resulted in flows of 11,600 cfs at the Madras Gauge (RM 100; Figure 8). Flows at the Moody Gauge (RM 1) peaked at 25,100 cfs on April 9, 2019 (Table 1). These were the highest recorded flows at Moody since 2006 when peak flow reached 33,100 cfs (January 1, 2006; USGS). However, in the period of record much larger flows have occurred. Flows in the lower Deschutes River at its mouth (Moody Gague) during the flood of 1996 were 70,300 cfs (February 8, 1996; USGS).

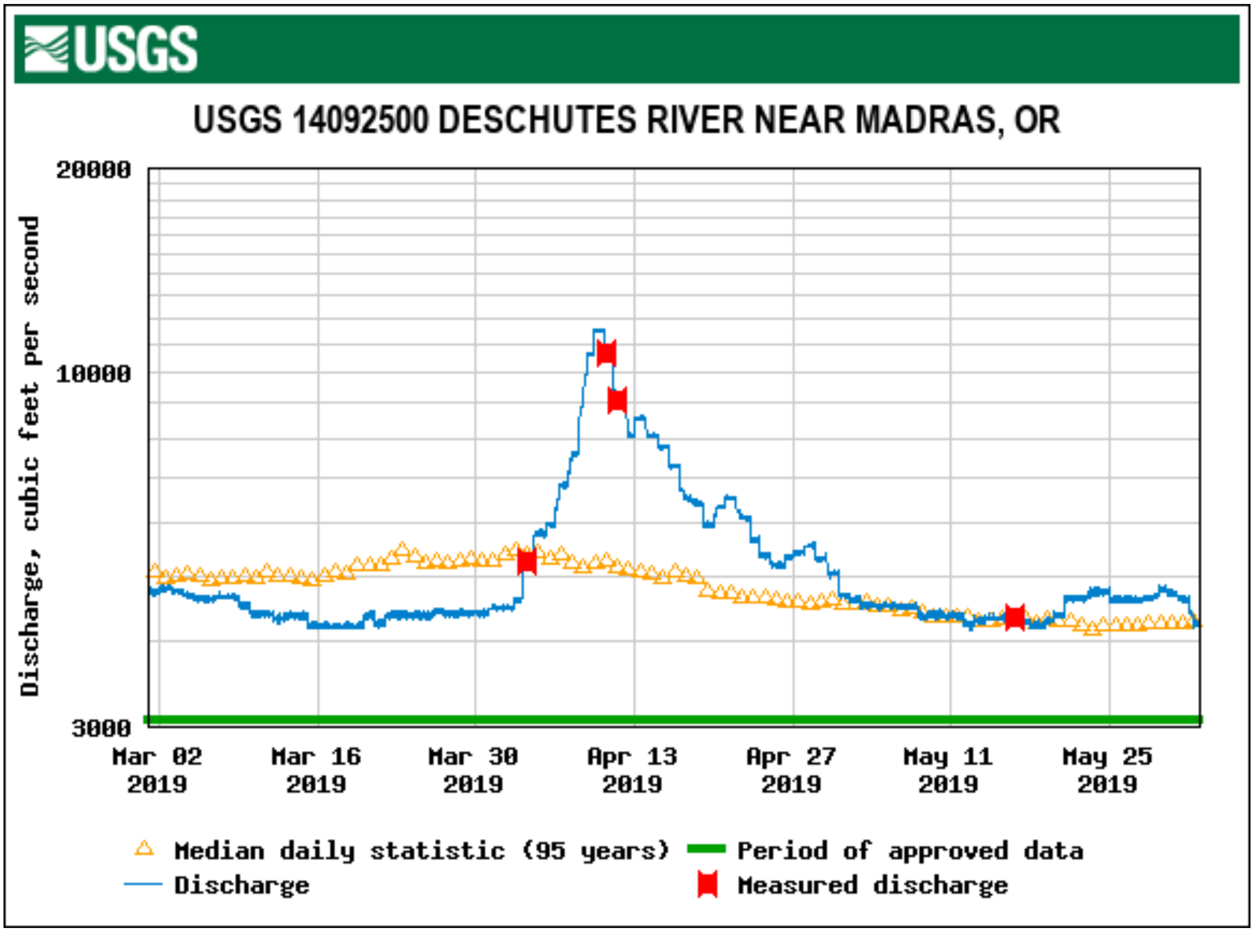

Figure 8. 2019 lower Deschutes River hydrograph at RM 100. (Source: USGS)

Figure 9 shows the hydrograph of the lower Crooked River from 2016-2019. In 2019, peak flow in the lower Crooked River occurred on April 10, 2019. Differences in Crooked River flows affect the water quantity, and to some degree the quality of water (i.e. nutrient loads and turbidity) entering Lake Billy Chinook and the lower Deschutes River. Three of the four years graphed for the lower Crooked River (2016-2017, 2019) had large spring runoff events.

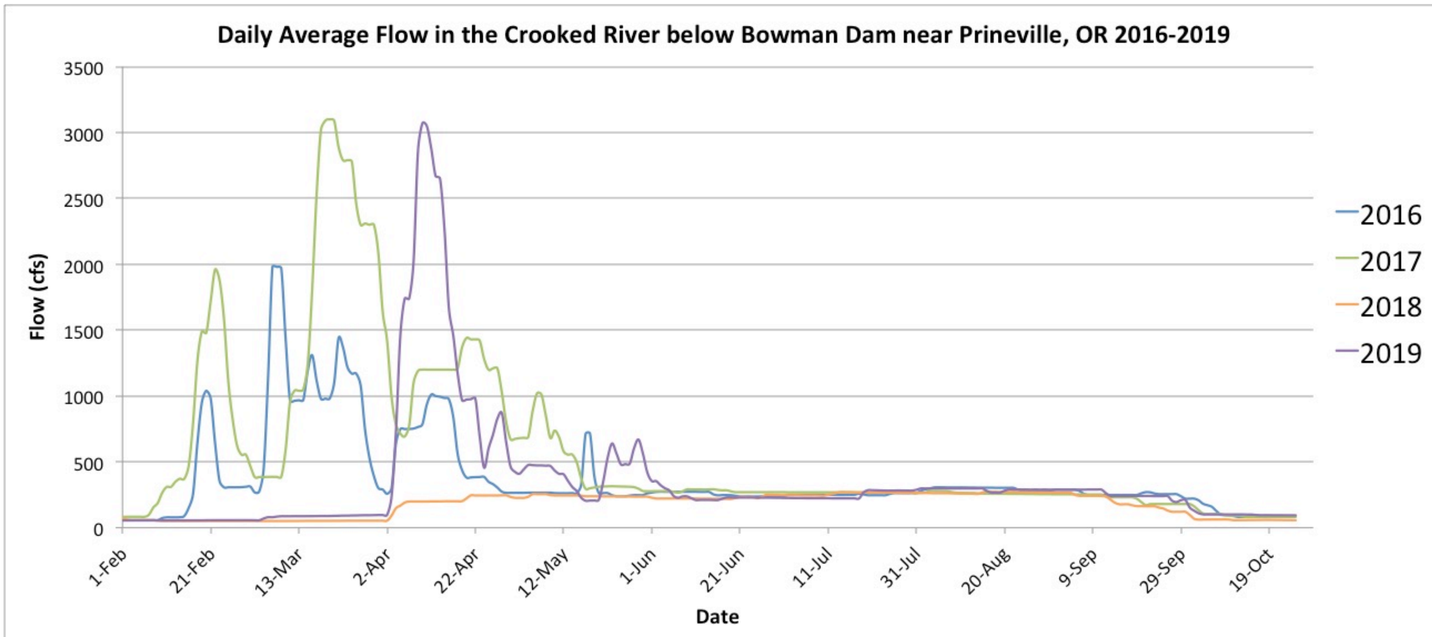

Figure 9. 2016-2019 Crooked River hydrograph measured below the Bowman Dam outflow. (Source: USBR)

Assessing the impact that large runoff events have on water quality is often not possible with the methods used in our studies due to concerns about equipment loss or damage. One expected result of these runoff events is an increase in erosion of stream banks and transportation of inorganic and organic material. These stream processes are natural and can have both beneficial and negative effects in stream ecosystems. For example, the movement of large wood and reduction in algae and periphyton growth on stream substrates can be beneficial while increases in total suspended solids can have negative effects on salmonids (Bash et al. 2001).

Precipitation, primarily in the form of snow, plays a key role in streamflows in the Deschutes Basin. In 2019, overall precipitation was above normal compared to the years 2016-2018 (NOAA Climate Charts—Appendix B). However, snow water equivalent in the Deschutes Basin was 99% of normal in 2019, which was similar to the years 2016 and 2017 (SNOWTEL Deschutes Basin Map—Appendix B). Both precipitation and snowpack in 2018 was significantly lower than other years (2016-2017 and 2019) and led to low-flow conditions in the lower Deschutes River and its tributaries. These annual differences in streamflow and precipitation play a large role in water *quantity* in the basin. However, assessing the degree of impact on water *quality* would also require an in depth understanding of groundwater in the basin. Such information is currently lacking and is beyond the scope of this report.

DISCUSSION

SWW Tower Blending:

Tower operations play a key role in the water quality of the lower Deschutes River. This is evident from the models developed as part of the PGE Water Quality Study (Eilers & Vache 2019). Of the models presented in the study, the "night blend" scenario[7] provided beneficial changes in multiple water quality parameters with only slight modifications to operations at the Project. Releasing water from the Tower at night has been used since 2017 in an attempt to improve the capture efficiency for out-migrating salmonid smolts at the Tower's fish collection facility (PGE: Our Story…).

The benefits to water quality from the "night blend" scenario are largely because the spring-summer surface waters of Lake Billy Chinook are less warm at night. Thus, if substantial surface water is released at night, the water released into the lower Deschutes River is cooler than if the water were released during the day. This water warms as it moves downstream, but because the water entered the river from the Project at a cooler temperature, it remains cooler than it otherwise would throughout the length of the river. Other water quality parameters are also influenced by the "night blend" including pH and DO (Eilers & Vache 2019).

While the "night blend" brings welcome changes to water quality in the river compared to prior years, the percent of water drawn from the bottom port of the Tower (% Bottom Draw) still has a significant influence. Figure 10 shows the % bottom draw at the Tower in 2019. The percent bottom draw gradually increased from 0% to 40% from May through July. On August 2-August 5, the SWW Tower was "shutdown due to communication issues" (2019 Blend notes) and the percent bottom draw increased to 60%. The percent bottom draw returned to 40% on August 5. On September 16, bottom draw increased to 60% when the Tower was, "shutdown for maintenance" (2019 Blend notes). On December 9 the Tower was, "moved to full surface withdrawal" (2019 Blend notes) and 0% bottom draw.

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[7] To attract smolts to the Tower's fish trap 100% surface water is released from the Tower to create attractive surface currents. However, water is only released from LBC when water is run through the dam's turbines to produce electricity, and power production only occurs during part of the day. The use of the "night blend" approach means all of the surface water released from the Tower takes place at night, and that power production also occurs at night.

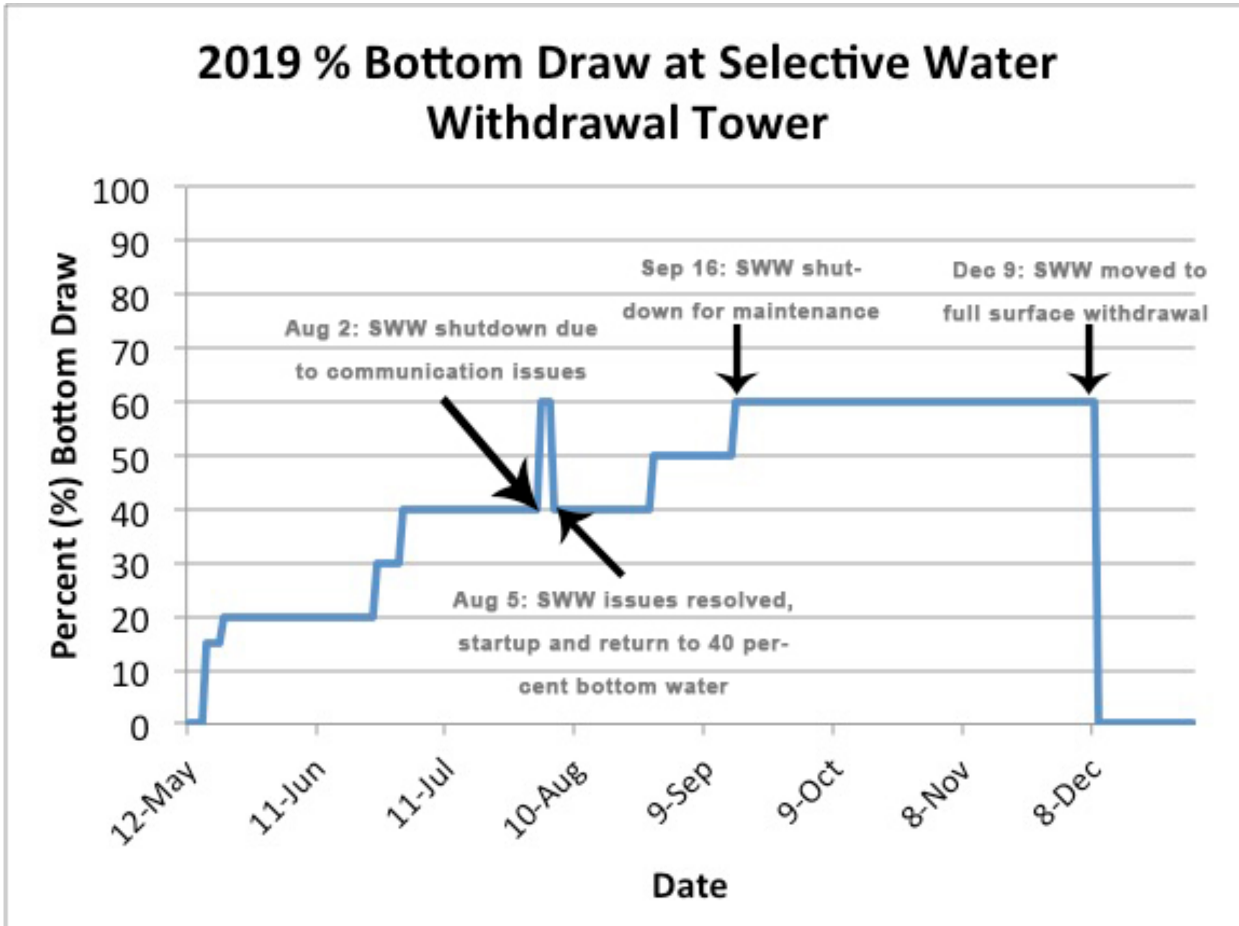

Figure 10. Percent (%) bottom draw at the Selective Water Withdrawal Tower in 2019. (Source: adapted from PGE report to ODEQ 2020)

The water at the bottom of Lake Billy Chinook, when released into the lower Deschutes River, results in changes to water quality throughout the lower river. Blending more bottom water with surface water reduces the temperature of water released from the Tower and is a primary means for water temperature management at the Project and meeting other water quality objectives. In the following sections we discuss the results of our study and how changing blends at the Tower affected water quality parameters in 2019.

Temperature:

Figure 11 shows the results of the temperature management blends used in 2019. In this graph the 7-day average daily maximum temperature (7-DADM) at the DRA monitoring site is shown with the blue line and the 13°C maximum temperature standard applied during salmon and steelhead spawning periods is highlighted in pink (OAR 340-041-0028). In 2019, the 7-DADM exceeded the applicable basin standard for salmon and steelhead spawning from June 6-June 15. The trout spawning and egg incubation period, however, is known to continue through the end of August (Zimmerman & Reeves 2000) and is highlighted in yellow. Oregon's temperature standard does not currently apply to trout spawning but water temperature should be held as low as possible during this time period to provide better survival of trout eggs and fry.

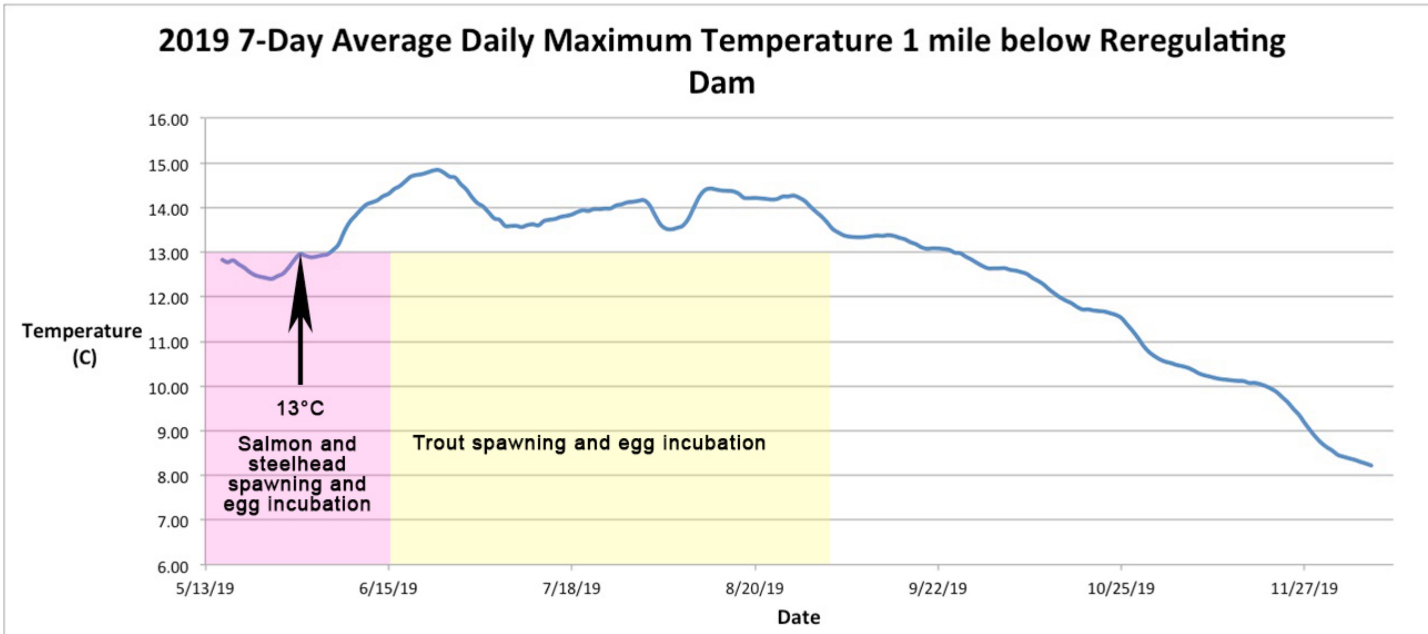

Figure 11. 2019 water temperature (degrees C) shown as the 7-day average daily maximum water temperature at River Mile 99 of the lower Deschutes River. Pink and yellow shaded areas show spawning and egg incubation periods. Oregon's water temperature standard (13°C) during the designated spawning period for salmon and steelhead is shown.

A notable impact of current temperature management at the Tower is that peak annual water temperature of the lower Deschutes River now occurs much earlier in the summer when compared to the pre-Tower period (prior to 2010). Water temperature data from 2006-2008 at RM 100.1 shows that pre-Tower peak water temperatures consistently occurred in early September (USGS Madras Gage; Eilers & Vache 2019). In the years 2016-2019 peak water temperatures occurred in June and July (DRA 2017; DRA 2018; DRA 2019c). The effect of this shift in peak annual water temperature has been an early emergence (four to six weeks) of most major insect hatches on the river. Changes in trout spawning have also been observed, but currently there are do data to document these changes or their possible effects on the trout population.

Blending bottom water with surface water at the Tower is a primary means for the Project to meet temperature management targets outlined in their WQMMP[8]. The DRA described concerns about the regression equation used to determine water temperature targets at the Tower in prior reports (temperature discussion section, DRA 2019c). The primary problem is that the equation used to determine the blending percentages of surface and bottom water uses the 7-day **maximum** average temperatures of the three tributaries entering Lake Billy Chinook. Streams in temperate regions of North America experience a natural diel or daily temperature flux (Hauer et al., 2006), meaning that water temperature changes over a 24-hour period from a mid-afternoon high to a late night/early morning low (see for example Figure 3). Using only the maximum tributary temperatures, as is currently done, cannot mimic a natural temperature regime and does not reflect the diel temperature flux in the tributaries. There is no biological justification for using these maximum temperatures, and this does not create a "natural" temperature regime in the lower Deschutes River as claimed by PGE.

Dissolved Oxygen:

Aquatic animals require adequate oxygen to survive. The amount of DO in water is affected by several factors, including temperature, turbulence, and photosynthetic activity. In particular, other things being equal, cold water can hold more DO than warmer water. Also, when water and air mix due to turbulence (think waterfalls, white water river sections, or spill from dams) oxygen from the air will be entrained in the water, increasing its concentration. Last, photosynthetic activity from aquatic plants including suspended and attached algae add oxygen to the water.

The concentration of DO needed to support the range of life functions of fish—feeding, spawning, predator avoidance, etc.—varies with different species and life stages. In cold-water streams of North America, salmon and trout are typically the most sensitive and least tolerant species to low levels of DO (Willers 1991). In addition, the oxygen requirements for developing salmonid eggs are greater than for juveniles and adults (ODFW 2000). For these reasons, Oregon's water quality standards for DO are set to protect the most sensitive use: salmonid spawning and egg incubation with higher standards applied during spawning and egg incubation periods (APPENDIX D).

[8] The method outlined in the WQMMP for calculating the maximum temperature allowed for water released into the lower Deschutes River is based on a regression equation developed by Huntington et al. (1999). This equation is defined as *the flow-weighted, 7-day rolling average daily maximum temperatures of the three major tributaries to LBC, and the 7-day average daily air temperature at Redmond Airport*.

Oregon's DO criteria for the Deschutes Basin are listed in Table 2.

Table 2. State of Oregon's dissolved oxygen criteria for the lower Deschutes River (OAR 340-041-0016).

Beneficial Use	Dissolved Oxygen Criteria
Salmonid Spawning, including where and when resident trout spawn through fry emergence.	1) Not less than 11.0 mg/L, or - 2) If intergravel DO (IGDO), as a spatial median, is 8.0 mg/L or greater, then DO criterion is not less than 9.0 mg/L
Cold-water Aquatic Life (includes salmon and trout rearing).	1) Not less than 8.0 mg/L. If DEQ determines *adequate data for DO exists, DEQ may allow: 2) 8.0 mg/L as a 30-day mean minimum, 6.5 mg/L as a 7-day minimum mean, and 6.0 mg/L as an absolute minimum. All three requirements must be met. *No definition for what constitutes "adequate" data is given.

In prior reports, the DRA explained our concerns about how the DO criterion is applied and the designated spawning and incubation periods and species covered (DO discussion section, DRA 2019c). In summary, Oregon's water quality standards for DO clearly mandate that, when determining the DO standard for a particular water body, resident trout spawning must be incorporated as well. Oregon Administrative Rules (OAR 340-041-0016) states "the following criteria apply during the applicable spawning through fry emergence periods set forth in the tables and figures **and, where resident trout spawning occurs, during the time trout spawning through fry emergence occurs**" (emphasis added). In other words, Oregon's DO standard requires that the DO criteria of 11.0 mg/L (or 9.0 mg/L when IGDO is above 8.0 mg/L) minimum concentration must be applied not just in the identified salmon and steelhead spawning time and place, but also during resident trout spawning through fry emergence.

As the DRA have seen in prior years, DO fell below the 11.0 mg/L standard in May and continued to decline below the 9.0 mg/L standard in July (Figure 4). Because trout spawning and incubation occurred during this time, the DO concentration fell below the applicable standard from early July through August. Additionally, if IGDO levels are not in fact above 8.0 mg/L, then DO should not fall below 11.0 mg/L. If the 11.0 mg/L standard were applied, then DO fell below the standard on every day starting in mid-May through August. Spilling water over the Reregulating Dam spillway entrains oxygen to the released water and can correct this problem.

pH:

Oregon's water quality standard for pH in the Deschutes Basin is a minimum of 6.5 and maximum of 8.5 standard units (OAR 340-041-0135). The pH standard is designed to protect aquatic life from the harmful effects of water that is too acidic or too alkaline. Hourly pH data show that pH was exceeding the basin standard of 8.5 when data collection began on May 13, 2019 (Figure 6). Measurements were recorded above 9.0 starting on June 8, 2019. Such a high level of sustained pH poses stress and health risks to aquatic life including salmon, steelhead, and trout (Robertson-Bryan 2004). Exceedances of the Deschutes Basin upper pH limit were known to occur before the SWW Tower went into operation. An important question, then, is whether surface water withdrawal has made the pH problem worse. Bi-monthly water quality data collected by DEQ at the Warm Springs bridge show that pH above 8.5 occurred in ~4% of measurements (n=28) from 2005-2009 (pre-SWW Tower) compared to 38% of measurements (n=58) above 8.5 from 2010-2019 (post-SWW Tower; DRA 2019c).

Like temperature and DO, pH also shows a daily range, with minimum values typically occurring just before sunrise, and maximum values reached in the mid to late afternoon. Mid-day peaks in pH are the result of increased photosynthetic activity by aquatic plants and algae due to maximum sunlight exposure. Photosynthesis lowers the dissolved CO2 concentration in the water, which in turn reduces the carbonic acid concentration and raises pH. At night photosynthesis stops—causing increased carbonic acid production and a decline in pH. As algal biomass increases, the difference between the daily minimum and maximum pH also increases—and that is reflected in large swings in pH. Thus, large diel swings in pH are a useful indicator of excessive algal and plant growth stimulated by excess nutrients in polluted water (EPA 2014).

Observed increases in nuisance algae in the lower Deschutes River since the SWW Tower began operation indicate an increase in nutrient loads from surface water releases. Elevated water temperatures being discharged into the lower Deschutes River throughout the winter and spring may also be a factor in increased nuisance algae and aquatic plant growth, and higher pH as a consequence. The DRA believes that data collected by Oregon DEQ and the results of DRA water quality reports (DRA 2015-2019c) clearly establish that surface water releases have a rapid and negative impact on pH in the lower Deschutes River.

Figure 12 shows how pH in the lower Deschutes River was influenced by the percent of bottom water released at the Tower in 2019. From August 2-5 the Tower was, "shutdown due to communication issues," (2019 Blend Notes) resulting in hourly pH measurements at RM 99 that were within basin standards from August 5-7, 2019. These changes were only observed at the monitoring site about three days later due to the residency time of water in the impoundments of the Project (Eilers & Vache 2019). Similar results were seen beginning on August 30, 2019 when bottom draw had increased to 50% at the Tower.

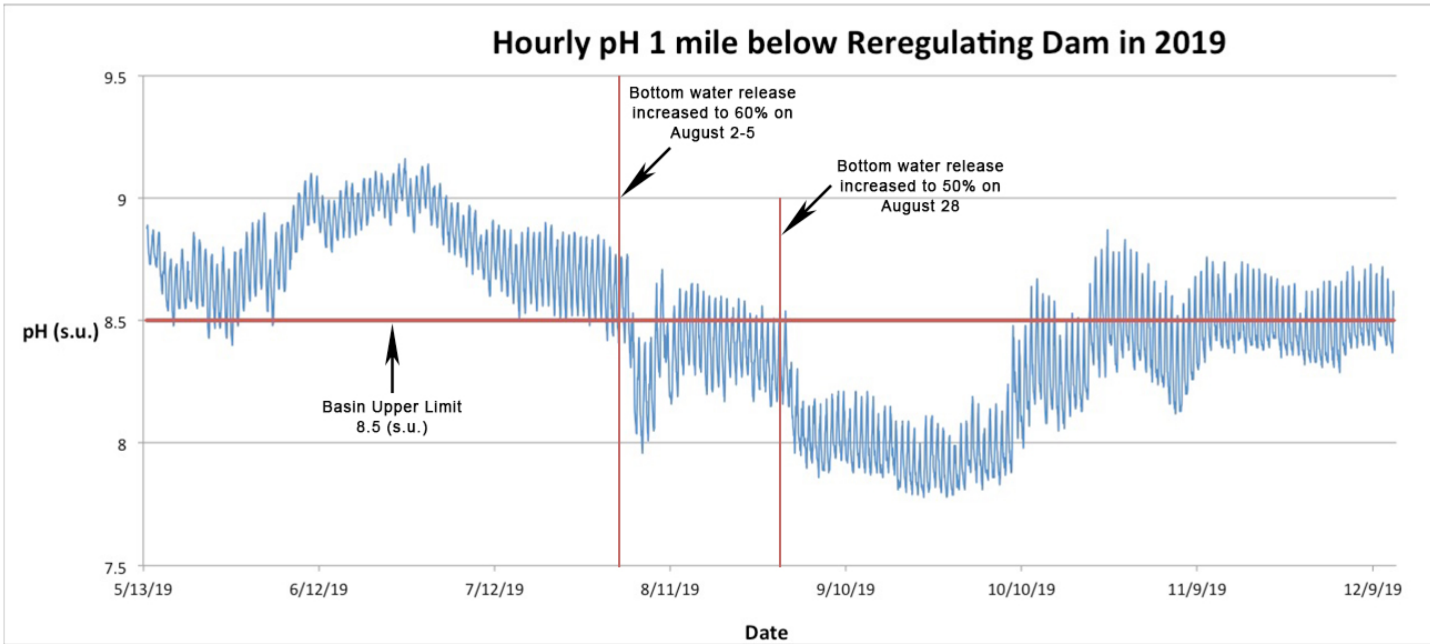

Figure 12. 2019 Hourly pH (standard units) at River Mile 99 of the lower Deschutes River with periods of increased % bottom draw marked**.**

The 2019 results for pH showed that exceedances to the basin standard are still an issue. In addition, the increases in the percent of bottom draw at the Tower in 2019 (Figure 10) improved pH levels in the lower Deschutes River (Figure 12) showing that Tower operations could be managed in a way that improves pH in the lower Deschutes River.

CONCLUSIONS

Oregon's water quality standards are set **to protect aquatic life**. Water quality data collected and analyzed by the DRA in 2019, again, show serious exceedances of Oregon's water quality standards. These exceedances occurred throughout the spring, summer, and fall months and continue to raise questions about water quality management at the Project. The DRA believes it is of utmost importance to the health of the lower Deschutes River's aquatic ecosystem that PGE manage water releases from the SWW Tower so that water quality standards are met. The WQMMP established clear management guidelines and water quality requirements for temperature, DO, and pH. These requirements were established to adequately protect the aquatic life in the lower Deschutes River.

The water quality exceedances summarized below have been documented by the hourly water quality data collected by the DRA at RM 99 from 2016-2019 as well as data reported in the PGE Water Quality Study (Eilers & Vache 2019). The DRA believes the data record clearly shows that these problems are neither due to climate change nor do they reflect "regional" water quality problems. Solutions to improve and protect water quality are readily available that would not negatively impact upstream salmonid reintroduction efforts. In fact, as more data becomes available (e.g., *C. shasta* infection rates; OSU 2019) improving lower Deschutes River water quality will be necessary for the reintroduction effort to succeed.

Temperature:

The current water temperature management approach with the SWW Tower has several serious impacts on aquatic life in the lower Deschutes River:

1. The so-called "Without Project Temperature" equation being used to set the temperature targets in the lower Deschutes River is flawed by averaging the 7-day **maximum** temperatures of the three tributaries entering Lake Billy Chinook. Project discharge targeting the maximum temperatures from the three tributaries does not create the true and natural thermal conditions in the lower river that would exist if the dams were not present.[9]
2. Releasing 100% surface water from Lake Billy Chinook from winter through May/June each year raises the water temperature in the lower Deschutes River throughout the late winter, spring, and early summer above pre-SWW Tower temperatures. This increase in water temperature has altered aquatic insect life cycles and abundance, and likely contributes to earlier growth of nuisance algae that has further impacted aquatic invertebrate populations in the lower river. An independent statistical analysis of aquatic macroinvertebrate data collected by R2

[9] See for example, DRA's blog post, "The Low Down on High Temperatures in the Lower Deschutes River" Available: https://deschutesriveralliance.wordpress.com/2015/08/12/the-low-down-on-high-temperatures-in-the-lower-deschutes-river/

Resource Consultants found significant increases in non-insect taxa (worms and snails), increases in pollution tolerant invertebrates, and declines in pollution sensitive taxa after the SWW Tower started operating (Edwards 2018).

One example is the disturbing increase in abundance of the polychaete worm, *Manayunkia speciosa*. DRA sampling of benthic invertebrates found over 8,000 *M. speciosa* per square meter in September 2016 at RM 99 (DRA 2019d).

3. Project operations under the rubric of temperature management caused water temperatures to exceed the temperature standard for spawning salmon and steelhead in June 2019 (7-day maximum average no greater than 13°C; Figure 11).
4. The capture of smallmouth bass *Micopterus dolumieu* by steelhead anglers in the lower 40 miles of the Deschutes River during the summers of 2016 and 2017 exceeded anything in recent memory (S. Pribyl, pers. comm.). In 2017 walleye *Sander vitreus* were also caught in the lower Deschutes River near its mouth for the first time. Subsequent investigations by the Oregon Department of Fish & Wildlife confirmed smallmouth bass presence in numbers never previously observed by them (ODFW 2019). Conditions that triggered this increase are not completely clear, but higher water temperatures in the lower Deschutes River from April-July compared to pre-SWW Tower temperatures are one explanation.

   The increase in spring temperatures have resulted in Deschutes River water temperatures near the Columbia River reaching 60°F earlier than in previous years. The warmer water earlier in the year likely encourage smallmouth bass to migrate from the Columbia River, where they are abundant, up the Deschutes in search of the warm water they prefer. Most of the smallmouth bass appeared to leave the Deschutes River in September and October, likely from a downstream migration back to the now-warmer Columbia River (ODFW 2019). The impact of increased smallmouth bass numbers in the lower Deschutes River is currently unknown, but increased predation on native fish is a possibility.
5. The lower Deschutes River is one of the more important cold-water refugium for Upper Columbia River Basin adult salmon and steelhead (Keefer et al. 2018). Increasing the water temperature is counterproductive to larger management goals for salmonids in the Columbia River Basin and potentially eliminates cold-water refugium.

Dissolved Oxygen:

Water with adequate dissolved oxygen is critical for the survival of aquatic life. Incubating salmon and trout eggs and developing fry are the most sensitive life stages to inadequate DO concentrations. For this reason, water quality standards for DO are higher during salmonid egg incubation and fry development (Table 2). Life history studies of resident trout in the lower Deschutes River, and direct observation of trout spawning at RM 99, confirm that trout spawning continues through August (Zimmerman & Reeves 2000). This means that resident trout incubation continues until the end of August and/or early September. Under current Oregon standards, a minimum DO concentration of 11.0 mg/L (lower minimum of 9.0 mg/L if IGDO data available and above 8.0 mg/L) is proper and should be applied throughout the resident trout spawning and incubation period. At the time of this writing no IGDO data were available for July or August 2019 and DO was below the 11.0 mg/L protective standard during this time, as well as the less protective standard of 9.0 mg/L (Figure 4).

Dense growths of aquatic plants and algae produce high DO concentrations during the day and low levels late at night and early morning, resulting in large diel swings. Large diel swings in DO during 2019 can be seen on Figure 4. These large diel swings are indicative of nutrient enrichment in water (EPA 2014). Exceedances to the basin standards for DO during trout spawning and large diel swings continue to raise concern about water quality management at the Project.

pH:

It is well established that pH provides a useful indicator of nutrient enrichment problems, since high nutrient loads stimulate excessive algae and aquatic plant growth, which in turn causes large diel swings in pH (EPA 2014). The pH levels measured at RM 99 in the lower Deschutes River in 2019 showed significant water quality exceedances of the pH standard:

1. Hourly pH measurements exceeded the upper limit for the Deschutes Basin pH standard (8.5 s.u.) from the start of data collection on May 13 until August 4. The measurements recorded between August and September showed improved pH within basin standards. Elevated pH measurements above the basin standard again occurred from mid-October through December.
2. No management plan for lowering pH has been developed by PGE. Even though such is required in the WQMMP when pH measurements from Project discharge exceed the weighted average pH of inflows into Lake Billy Chinook (PGE & CTWSRO 2002).
3. Based on Oregon DEQ data, pH showed an immediate and sustained increase when SWW Tower operations began (DRA 2019c).

The data record since 2010 indicate that Project operations frequently caused exceedances of Oregon's water quality standards for temperature, pH, and DO. It is important to remember that water quality standards are set at levels deemed necessary to protect the beneficial uses of the waters in question. In the lower Deschutes River, the most sensitive beneficial uses are salmon and trout spawning and egg incubation through fry emergence, and core habitat for cold-water aquatic life such as bull trout and aquatic invertebrates. Years of research, based on both laboratory and field studies, have been evaluated to determine safe levels for a wide range of parameters (EPA 1986). These levels are further evaluated by state water quality agencies before being adopted as state standards. The result is that Oregon's water quality standards have been set based on years of research and public process to ensure aquatic life is adequately protected.

While water quality standards are set for each parameter separately, interactions among parameters can increase their level of impact on aquatic life. Therefore, whenever water quality standards are exceeded the potential for negative impacts from other parameters also increases. When multiple standards are exceeded at the same time and over long periods of time, days and weeks as seen in this study, the negative effects on aquatic life increase substantially.

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APPENDIX A- Field Audit Data

Data Sonde Instantaneous Measurements

Date/Time	Riffle Ranch 5-13-19 15:10	Riffle Ranch 5-23-19 11:21	Riffle Ranch 7-2-19 11:15	Riffle Ranch 8-20-19 10:30	Riffle Ranch 9-20-19 10:30	Riffle Ranch 10-10-19 11:05	Riffle Ranch 11-15-19 10:25	Riffle Ranch 12-12-19 11:30
Temperature (C)	12.93 C		13.79 C	13.60 C	12.92 C	11.90 C	9.98 C	8.14 C
pH	8.78		9.01	8.42	8.04	8.25	8.54	8.62
Conductivity	127.4		126.6	128.3	119.6	122.1	123.4	123.0
Turbidity (NTU)	1.50		1.40	1.15	1.08	1.71	2.06	1.84
Dissolved Oxygen (mg/dl)	11.56	10.92	10.30	8.21	10.56	11.21	11.90	11.40
Oxygen Saturation (%)	108.8%		111.29%	88.5%	112.0%	116.3%	118%	108.2%
Battery (volts)	6.70		6.00	5.84	5.81	6.08	5.88	5.59

Audit Measurements

Date/Time	Riffle Ranch 5-13-19 15:10	Riffle Ranch 5-23-19 11:21	Riffle Ranch 7-2-19 11:15	Riffle Ranch 8-20-19 10:30	Riffle Ranch 9-20-19 10:30	Riffle Ranch 10-10-19 11:05	Riffle Ranch 11-15-19 10:25	Riffle Ranch 12-12-19 11:30
Temperature (C)	12.8 C	11.9 C	13.8 C	13.6 C	12.9 C	12.0 C	10.0 C	8.1 C
pH	8.8		9.16	8.66	8.19	8.45	8.81	8.69
Turbidity (NTU)	2.32		1.55	1.56	1.29	1.64	2.00	0.97
Dissolved Oxygen (mg/dl)	9.80	11.48	10.64	8.45	10.83	13.20	11.74	11.67

APPENDIX B- Water Quality Sampling Quality Assurance/Quality Control Program and Methods

Instrument Calibration:

All instruments were calibrated per manufacturer instructions. A log of calibrations has been kept on all instruments. Calibration and/or accuracy checks on handheld instruments were done within 24 hours of each use event. Calibration on in-dwelling instruments (YSI data sonde) was done prior to initial placement and again after battery replacement.

Instruments were calibrated using name brand pre-formulated calibration standard solutions.

Instrument Data Audits:

The YSI data sonde was audited as often as possible using handheld instruments to determine temperature, pH, dissolved oxygen, oxygen saturation and turbidity. Use of multiple measures was employed as described below.

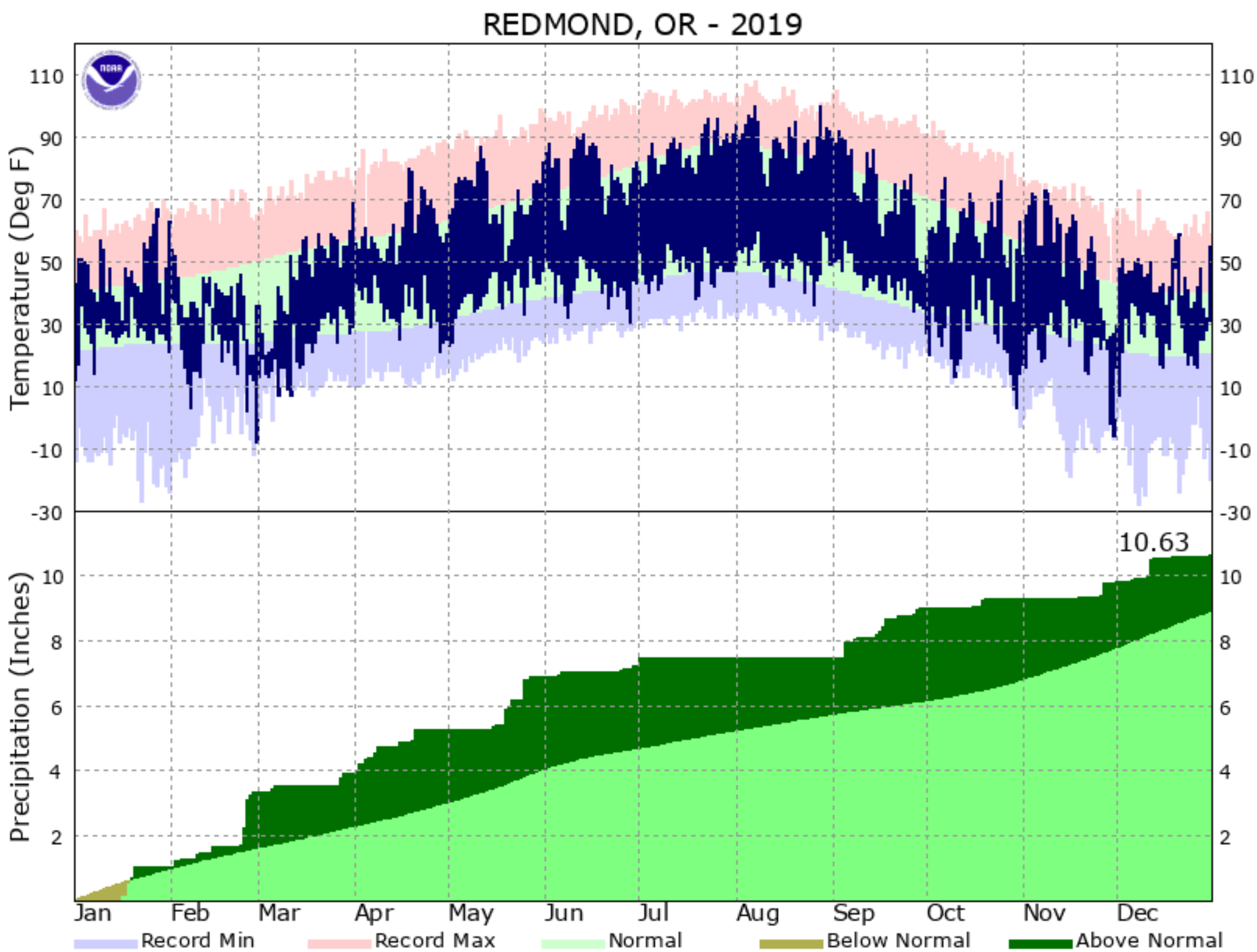
Use of Multiple Measures:

To ensure in-field accuracy, independent meters/instruments were used to measure temperature, pH and DO simultaneously with the YSI datasonde. Re-calibration and/or probe replacements were done when necessary.

Instrument Storage:

Instruments were stored in a secure and temperature controlled environment when not in use.

APPENDIX C- Supplemental Figures


REDMOND, OR - 2019
Temperature (Deg F)
Precipitation (Inches)
110
90
70
50
30
10
-10
-30
10
8
6
4
2
10.63
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Record Min
Record Max
Normal
Below Normal
Above Normal

APPENDIX D- Oregon Administrative Rules for Temperature & Maps

The seven-day-average maximum temperature of a stream identified as having salmon and steelhead spawning use on sub-basin maps and tables set out in OAR 340-041-0101 to 340-041-0340: Tables 101B, and 121B, and Figures 130B, 151B, 160B, 170B, 220B, 230B, 271B, 286B, 300B, 310B, 320B, and 340B, may not exceed 13.0 degrees Celsius (55.4 degrees Fahrenheit) at the times indicated on these maps and tables;

The seven-day-average maximum temperature of a stream identified as having core cold water habitat use on sub-basin maps set out in OAR 340-041-101 to 340-041-340: Figures 130A, 151A, 160A, 170A, 180A, 201A, 220A, 230A, 271A, 286A, 300A, 310A, 320A, and 340A, may not exceed 16.0 degrees Celsius (60.8 degrees Fahrenheit);

The seven-day-average maximum temperature of a stream identified as having salmon and trout rearing and migration use on sub-basin maps set out at OAR 340-041-0101 to 340-041-0340: Figures 130A, 151A, 160A, 170A, 220A, 230A, 271A, 286A, 300A, 310A, 320A, and 340A, may not exceed 18.0 degrees Celsius (64.4 degrees Fahrenheit)

*Figure 130A: Fish Use Designations**
Deschutes Basin, Oregon

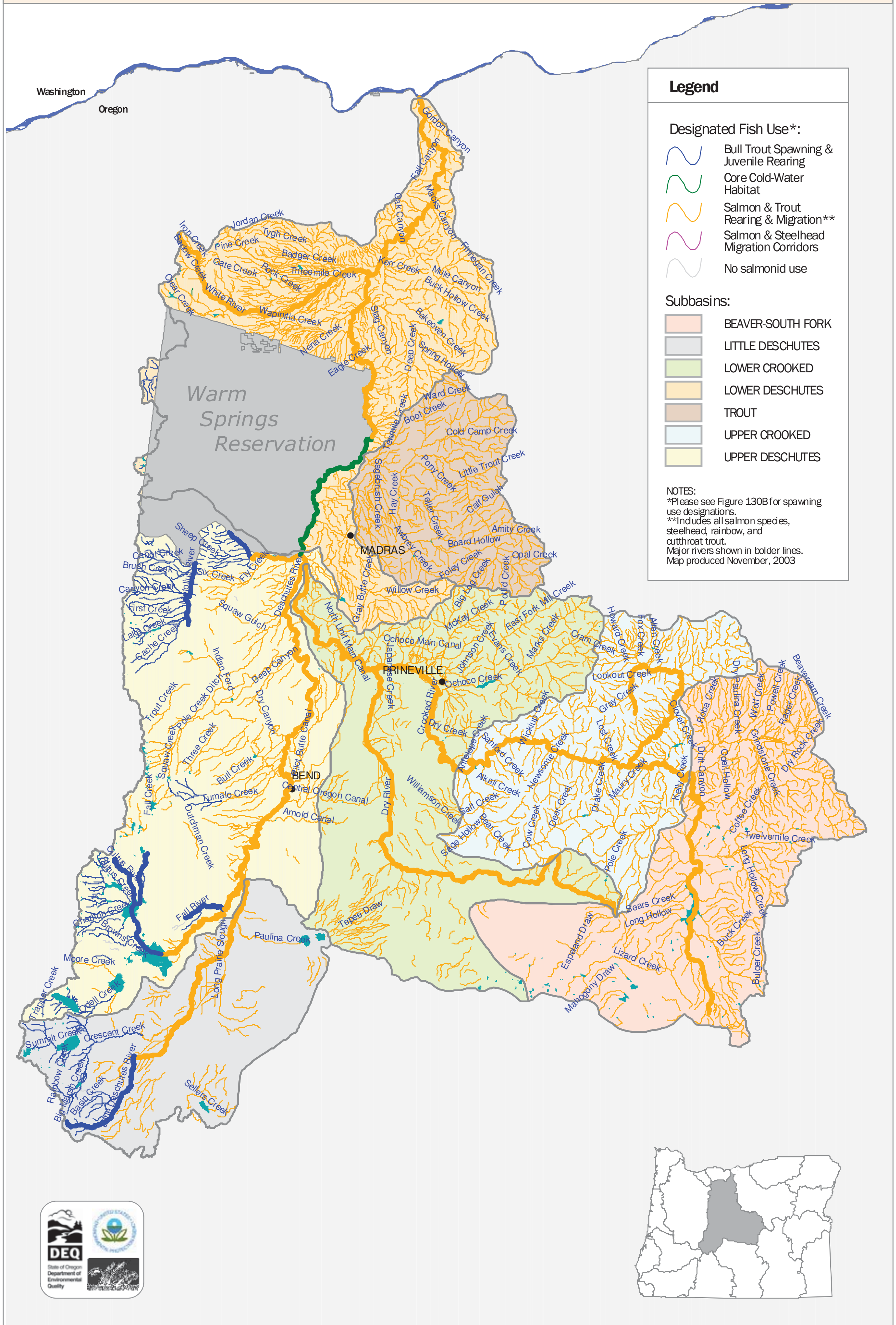


*Figure 130B: Salmon and Steelhead Spawning Use Designations**
Deschutes Basin, Oregon