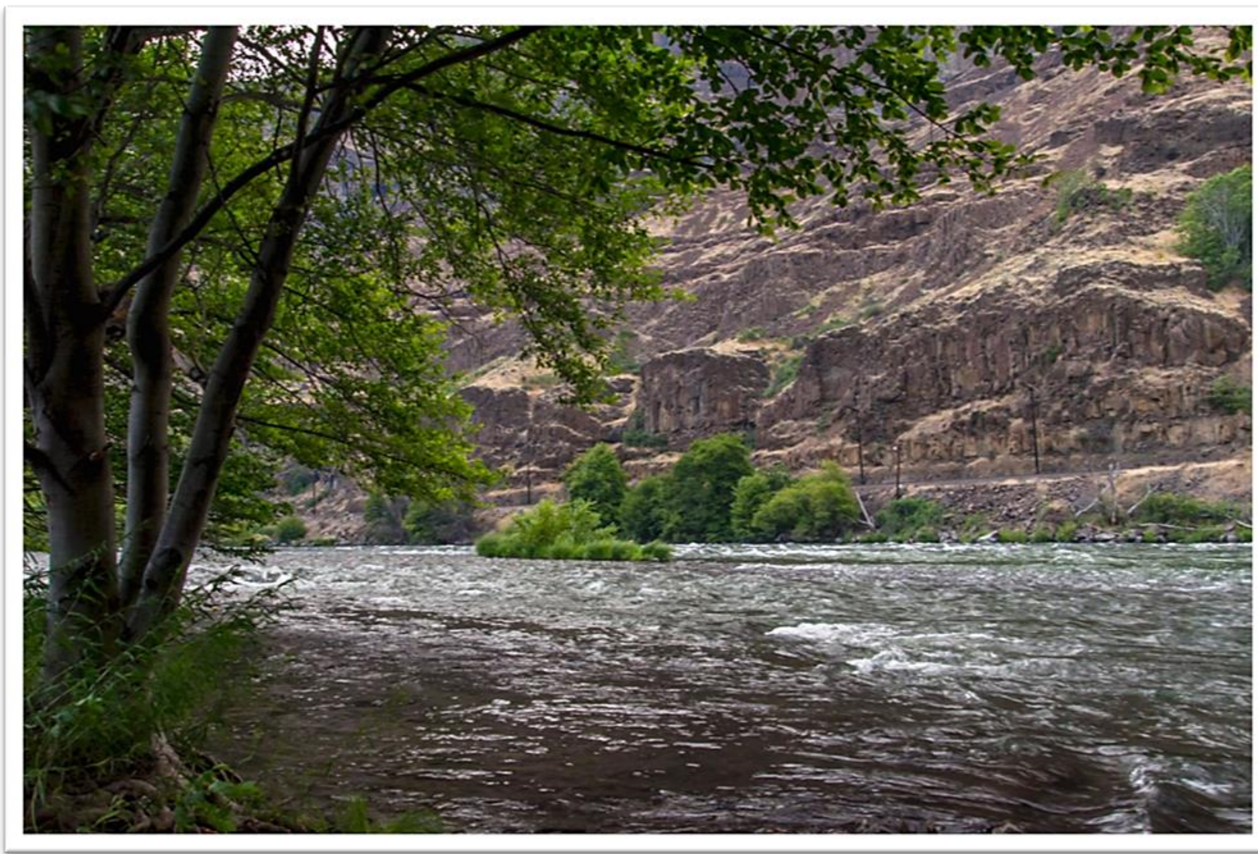
2020 LOWER DESCHUTES RIVER WATER QUALITY REPORT



Deschutes River Alliance
June 2021

Key Findings

- Operation practices at the Selective Water Withdrawal Tower directly affect water quality and continue to cause increased violations of water quality standards in the lower Deschutes River.
- Dissolved oxygen concentration is not managed adequately to protect incubating trout eggs and fry throughout spawning and incubation periods.
- High pH levels continue to exceed the state water quality standard and large diel swings were recorded.
- Both large diel swings in pH and dissolved oxygen indicate excess nutrients from the lower Crooked River during surface draw, and contribute to well-documented nuisance algal growth and aquatic plant biomass accumulation in lower Deschutes River.
- Nutrient pollution from surface water in Lake Billy Chinook continues to be the primary contributor to the declining health of the lower Deschutes River and aquatic ecosystem.
- Salmon, steelhead, and bull trout were observed tending to redds in the immediate vicinity of the data sonde.

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Acknowledgments

The Deschutes River Alliance thanks Larry Marxer, Greg McMillan, and Rick Hafele for their assistance with this study. Larry Marxer deserves special thanks for his expertise with quality assurance and ensuring proper procedures were followed throughout this project.

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

DO - Dissolved Oxygen

DRA - Deschutes River Alliance

IGDO - Intergravel Dissolved Oxygen

OAR - Oregon Administrative Rules

ODEQ - Oregon Department of Environmental Quality

ODFW - Oregon Department of Fish and Wildlife

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 operation of the Selective Water Withdrawal (SWW) Tower at the Pelton-Round Butte Hydroelectric Project (hereafter Project) in late 2009 is the largest anthropogenic change imposed on the lower Deschutes River since the initial construction of the three dams (Round Butte, Pelton, and Pelton Reregulating dams) in 1964. Upon completion of the Tower, the Oregon Department of Environmental Quality mandated a Water Quality Management and Monitoring Plan (WQMMP) for continued monitoring of the impact the Tower has on the lower Deschutes River as part of the Project's Clean Water Act Section 401 Certification. A thorough discussion of the Tower's construction and operation was covered in the Deschutes River Alliance's 2016 water quality report (DRA 2017).

To monitor and model water quality affected by Project and Tower operations, licensees – Portland General Electric (PGE) and the Confederated Tribes of Warm Springs, Oregon (CTWSRO) - hired the consulting firm MaxDepth Aquatics Incorporated to conduct an in-depth water quality analysis. From 2015-2017, MaxDepth Aquatics collected data in the three tributaries of Lake Billy Chinook (the Crooked, Deschutes, and Metolius Rivers), the three reservoirs of the Project (Lake Billy Chinook, Lake Simtustus, Regulating Reservoir), and in multiple locations in 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).

From 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 on our website in annual reports available to the public. This report presents the results of continued water quality monitoring in the lower Deschutes River in 2020.

Questions and Objectives

The monitoring objectives of this study are:

1. To determine how water quality parameters for temperature, pH, and DO change on an hourly basis.
2. To determine if any of these parameters exceed Oregon's water quality standards for the Deschutes Basin and, if so, how frequently.
3. To assess how water quality varies seasonally and annually in the lower Deschutes River.

Established Findings

Our 2020 results and prior years' data agree with several conclusions from the 2019 PGE Water Quality Study:

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. Operations at the SWW Tower discharge a disproportionate amount of surface water from Lake Billy Chinook into the lower Deschutes River. Surface water in Lake Billy Chinook is comprised primarily of "poor" water quality from the lower Crooked River.[2] Nutrient pollution from the Crooked River into Lake Billy Chinook is higher for nitrates (NO3) compared to the nitrate contributions from the Metolius and Deschutes rivers.[3] These differences in water quality reflect regional land use, with municipalities and agriculture the primary influences of water quality in the Crooked River Basin.[4] Agricultural pollutants, including the pesticide chlorpyrifos, were recently reported in the lower Deschutes River by the Oregon Department of Environmental Quality (ODEQ) at levels that exceed the toxicity limits for fish, other aquatic life forms, and humans set by the Environmental Protection Agency.[5]

   It should be noted that historically the lower Deschutes River water was a blend of nearly equal amounts of Crooked River water and Metolius River water prior to dam construction. After dam construction, and prior to Tower installation, water released from LBC was 100% bottom water, which is comprised almost entirely of the colder, cleaner water from the Metolius River.

3. Operations at the SWW Tower transports planktonic, free-floating algae and cyanobacteria not commonly found in streams from the surface of Lake Billy Chinook into the lower Deschutes River. This causes a murky appearance in the lower Deschutes River.

4. Increased water temperature (compared to pre-SWW Tower averages) now occurs from winter through early summer in the lower Deschutes River.

5. Both increased water temperature and nutrient pollution from Lake Billy Chinook cause excessive algal growth including the growth of nuisance diatom species forming felt-like mats of algae on stream substrate in the lower Deschutes River.[6]

[1]DRA Lower Deschutes River Water Quality Reports (DRA 2015, 2017, 2018, 2019c)
[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 2020, the DRA continued water quality monitoring at the DRA Monitoring Site (RM 99) in the lower Deschutes River (Figure 1). As in previous years a multi-parameter YSI EXO2 data sonde was used to collect hourly measurements for dissolved oxygen, pH, temperature, and turbidity.

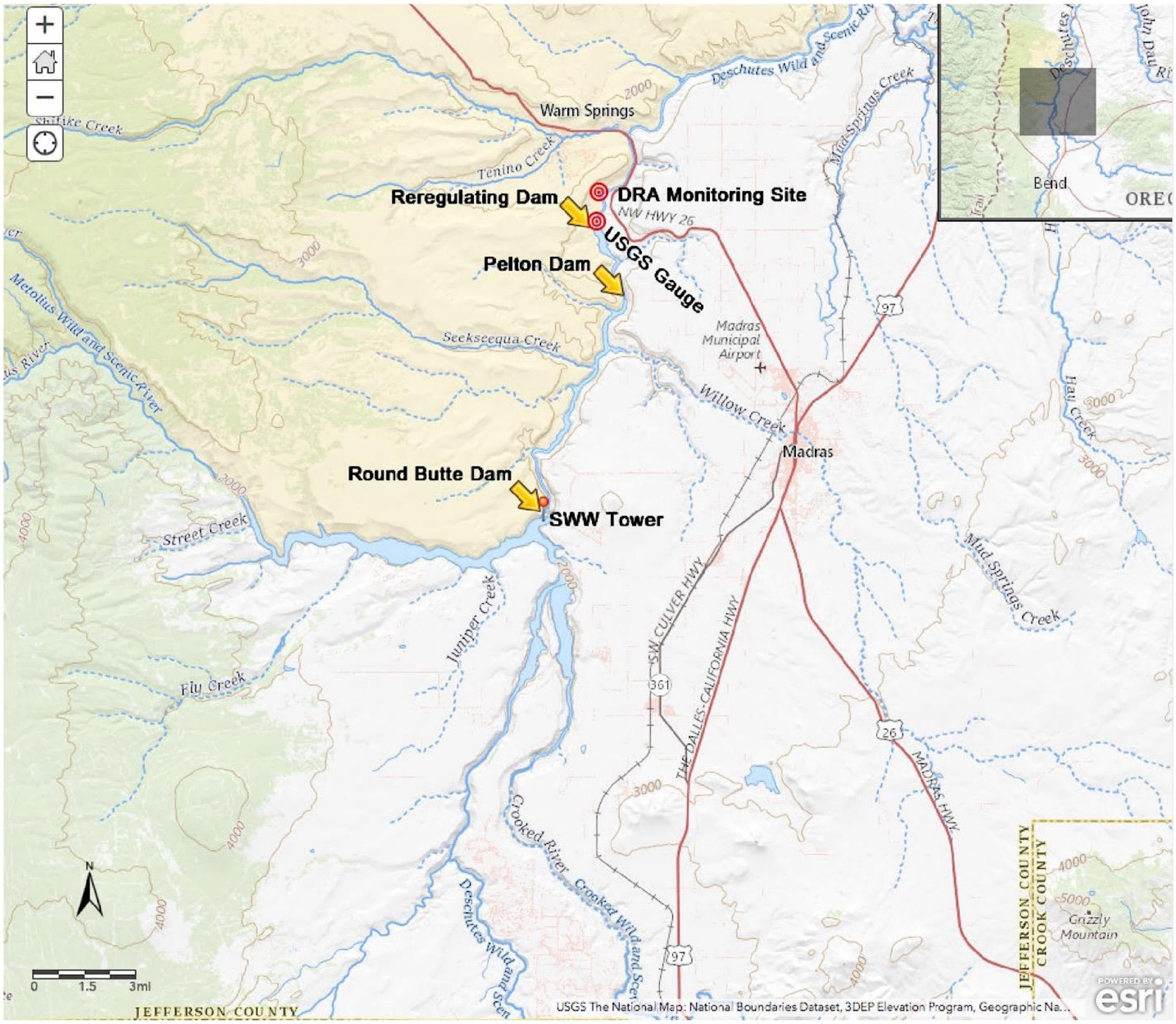

Figure 1. The three dams jointly owned by Portland General Electric and Confederated Tribes of Warm Springs, Oregon: Round Butte Dam (creates Lake Billy Chinook reservoir), Pelton Dam (creates Lake Simtustus reservoir), and the Reregulating Dam (creates the Reregulating reservoir). The USGS gauging station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

Operation of the SWW Tower and the release of surface water from Lake Billy Chinook continued throughout 2020. As in previous years, 100% surface water was released from winter through spring.

Operational changes at the Tower have occurred from 2017-2020, with the primary change being the release of surface water at night (PGE: Our Story…). "Night blend" operations typically occur from March-June (during the downstream migration of juvenile fish) in an attempt to increase capture rates for out-migrating juvenile salmonids at the Tower; a primary objective of the SWW Tower (PGE & CTWSRO 2019). Modeling from the PGE Water Quality Study (Eilers & Vache 2019) indicated slight improvements to multiple water quality parameters in the lower Deschutes when using the "night blend."

Releasing various blends of surface and bottom water downstream from Lake Billy Chinook may occur during any given part of the year. In general, blending of surface and bottom water occurs from June-October to manage water temperature in the lower Deschutes River. However, surface water, or any blend of surface and bottom water, is released only during periods of power production at the Round Butte Dam. When the turbines at the dam are not running, water is not released from Lake Billy Chinook. Streamflow in the lower Deschutes River is maintained at consistent levels 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).

Temperature stratification in Lake Billy Chinook is prevalent. Surface water is composed primarily of warmer, nutrient-laden water from the lower Crooked River, and generally 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 much colder and cleaner Metolius River water. Surface nutrient concentrations, however, are in a dynamic relationship with algal growth and density, and when algal blooms occur during the summer most of the available nutrients are consumed by the algae. The algae is then released downstream into the lower Deschutes where the algal cells breakdown and release nutrients back into the water. It is no surprise then, that the DRA advocates for consistently releasing a higher percentage of bottom water into the lower Deschutes River from Lake Billy Chinook. Blending a higher percentage of bottom water would provide an immediate benefit to the declining water quality in the lower Deschutes River. However, for the long-term health of the entire basin, the water quality and quantity from the lower Crooked River ultimately needs attention because of its effects on Lake Billy Chinook and lower Deschutes River. Unfortunately, even under the most optimistic scenarios, large-scale improvements in the Crooked River watershed to significantly improve water quality will take decades. Changes to Tower operations, however, will immediately benefit the lower Deschutes River. The DRA's monitoring work in the lower Crooked River is presented in a separate report found here: 2020 Crooked River Water Quality Report. See also DRA's Crooked River Basin GIS water quality report (Mapping Water Quality and Land Use in the Crooked River Basin).

Sampling Methods

One multi-parameter YSI EXO2 data sonde (Figure 2) was deployed with the YSI EXO Handheld Display at the DRA monitoring site approximately one mile below the Reregulating Dam tailrace at river mile (RM) 99 of the lower Deschutes River on April 29, 2020 (Figure 1). The monitoring site is the same location the DRA has sampled in prior years (2016-present) and is close enough to the Reregulating Dam tailrace to eliminate external influences on water quality, yet far enough downstream to allow the river to stabilize after its release from the Project.

Figure 2. YSI EXO 2 multi-parameter data sonde (left) and YSI EXO Handheld Display (right).

The YSI data sonde was calibrated to lab standards and programmed to record hourly readings before deployment. The following water quality parameters were measured every hour: temperature, DO, pH, conductivity, and turbidity. Field installation occurred after high flow conditions subsided and the sonde was successfully deployed from April 29, 2020 1600 hours through December 9, 2020 1200 hours. The data sonde was deployed in approximately three feet of laminar flow with probes positioned four to six inches above the stream bottom.

A central self-cleaning wiper was installed to avoid inaccurate results due to bio-fouling. Data audits of the data sonde sensors were conducted at the time of initial deployment and repeated once a month during field audits with field probes 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 9, 2020. Quality control and assurance procedures were followed throughout the study (APPENDIX B).

In addition to monitoring water quality, the DRA uses 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. Stream flows in 2020 had the lowest peak flows for all comparable dates (2016-2020) and reflect how flow-blending managed at the Project in Lake Billy Chinook can influence overall water quality in the lower Deschutes River. Snow water equivalent in 2020 was 13% less than 2019 when compared to 2020 on March 31.

Results

Temperature:

Hourly temperature measurements from April 29, 2020 to December 9, 2020 are shown in Figure 3. The graph shows the seasonal changes and daily range in temperature over a 24-hour period. The average difference between the daily minimum (occurs just before sunrise) and daily maximum (typically around 3pm) was 0.73°C (~1.3°F). The maximum daily temperature range was 1.46°C (~2.6°F) on May 27. The minimum daily temperature range was 0.1°C (~0.2°F) on December 7.

The seasonal pattern showed temperature increasing from initial deployment in April through mid-June, followed by a brief decline and then increasing until early July. The maximum recorded water temperature was 15.18°C (59.3°F) on July 3, 2020 at 1700 hours. The minimum recorded temperature was 8.70°C (47.6°F) on December 9, 2020 at 0900 hours. After declining from the early July peak, water temperature remained relatively consistent (12.5°to 14°C ~55-57°F) from mid-July through September. By early October water temperature and daily fluctuation began to decrease significantly until monitoring ended in December.

7-Day Average Daily Maximum Temperature:

Oregon's temperature standard is based on a maximum 7-day moving average of the daily maximum water temperatures or "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 (see red line in Figure 3; APPENDIX D for maps and criteria). A lower water temperature standard (13°C; 55.4°F) is applied during periods identified as having salmon and steelhead spawning use (Figure 12). Further discussion of temperature criteria and the time periods in which they apply follow in the Discussion section.

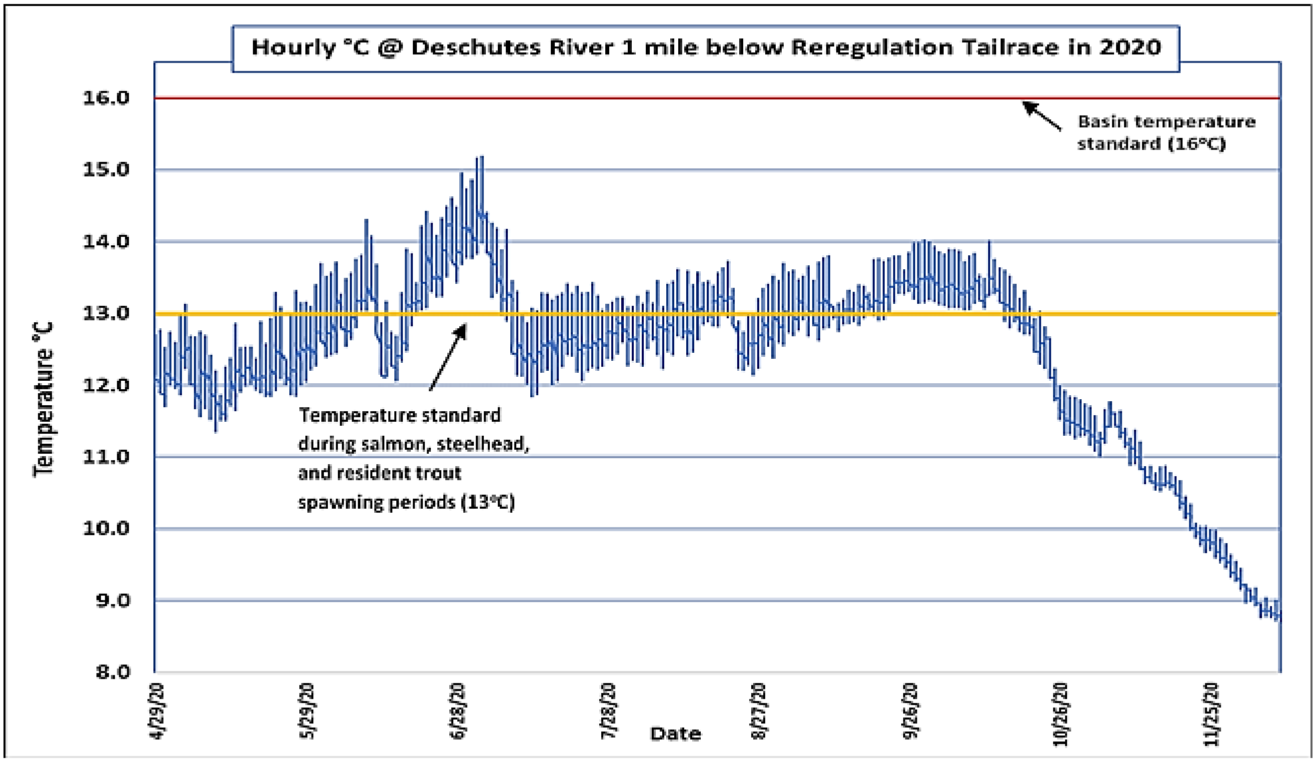

Figure 3. 2020 Hourly water temperature at River Mile 99 of the lower Deschutes River with the basin core-cold water habitat maximum temperature standard (16°C) show with a red line. Maximum temperature during spawning periods (January 1st – June 15th for salmon and steelhead), is shown with a yellow line.

Dissolved Oxygen:

Dissolved oxygen (DO) is measured and recorded in two ways: 1) the concentration in milligrams per liter (mg/L), and 2) the percent of oxygen dissolved in the water (% saturation) based on the locality (i.e. 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 met.

Oregon's water quality standard for DO is higher during the salmonid spawning season than during salmonid rearing season. The DO standard enforced by ODEQ 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 adequate intergravel dissolved oxygen (IGDO) is available. This same standard also applies during resident trout spawning through incubation, which has been observed as early as February and as late as December in the lower Deschutes. A three-way DO minimum standard is applied by ODEQ to days outside the designated period and the resident trout spawning and incubation period: a 30-day mean minimum of 8.0 mg/L, a 7-day minimum mean of 6.5 mg/L, and a 6.0 mg/L absolute minimum value (APPENDIX D). Further explanation of Oregon's DO standard and its application to the lower Deschutes River below the Project is covered in the Discussion.

Figures 4 and 5 show the daily DO levels as mg/L and % saturation, respectively, from April 29 to December 9, 2020. The two red lines in Figure 4 show the DO criteria and standards applied during salmon and steelhead spawning. The area highlighted in pink indicates the designated salmon and steelhead spawning period, and the area highlighted in blue indicates trout spawning through fry emergence.

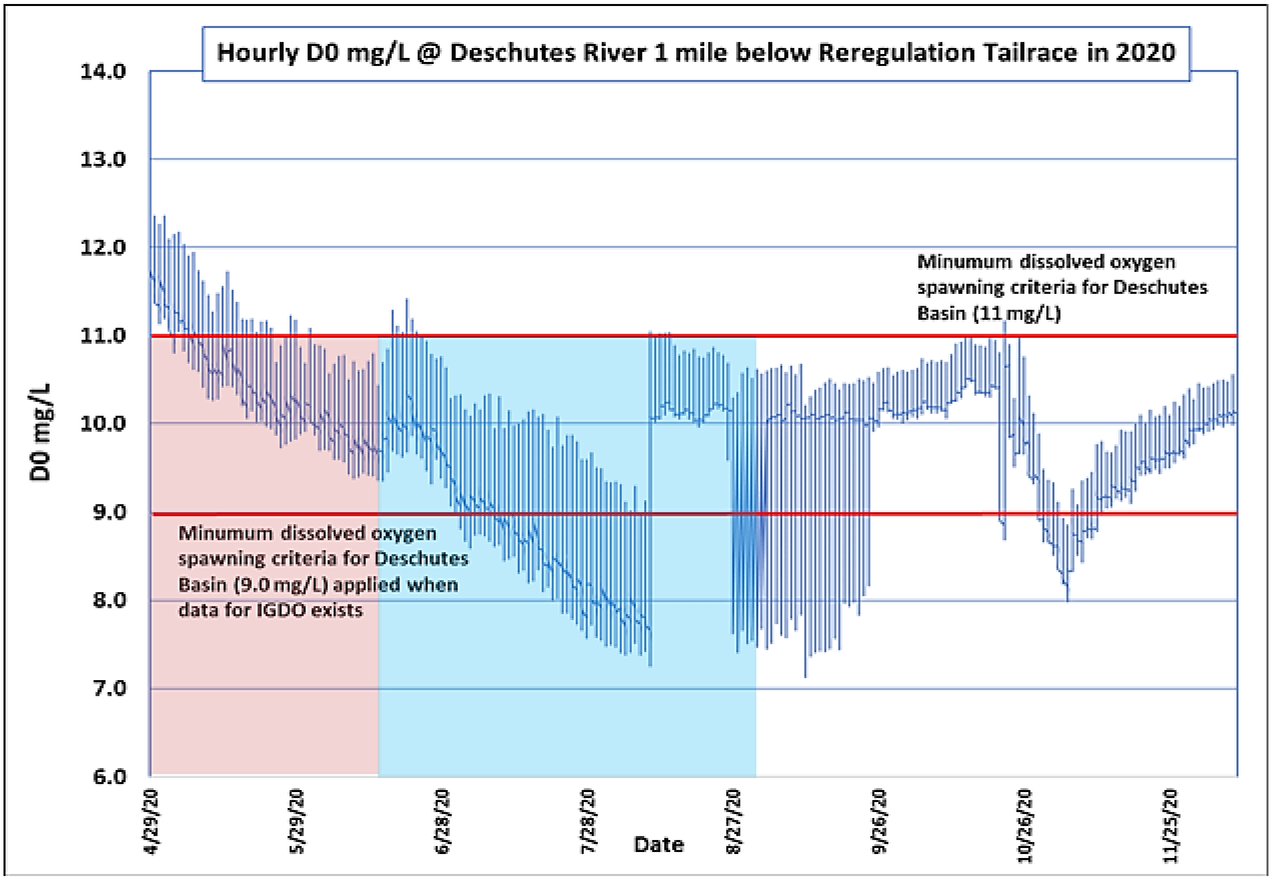

Figure 4. 2020 Hourly dissolved oxygen concentration (mg/L) at River Mile 99 of the lower Deschutes River. The red lines show the minimum dissolved oxygen basin standards based on two separate criteria. Designated salmon and steelhead spawning period highlighted in pink until June 15th, with residential trout spawning highlighted through September 1st in blue.

A large diel swing in DO occurred over most of the sampling period: 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. From initial deployment on April 29, to August 8, 2020 the daily swing in dissolved oxygen concentration increased while the maximum daily concentration decreased (Figures 4 & 5). Inter-day DO concentrations first dropped below the minimum standard of 9.0 mg/L on July 1 and continued until August 10 at 0800 when the next hourly reading at 0900 jumped from 7.65 mg/L to 10.66. The largest, consistent diel swings in DO were approximately 3.5 mg/L and occurred from August 27-September 23, 2020 (Figure 4). A period of noticeably lower DO diel range (approximately 0.5 mg/L) occurred from September 25 until the end of the monitoring on December 9, 2020.

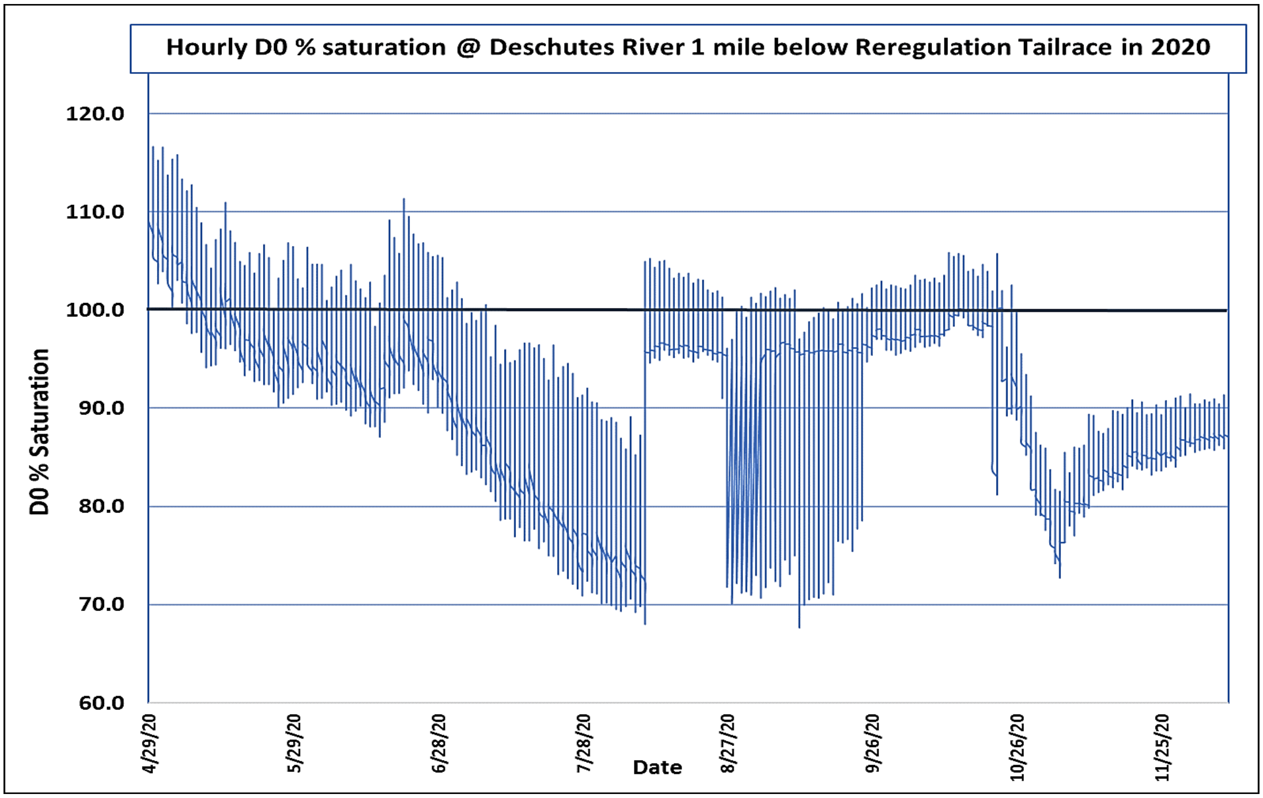

Figure 5. 2020 Hourly dissolved oxygen percent saturation (%Sat) at River Mile 99 of the lower Deschutes River.

DO % saturation was primarily within 90-110% from May-June, 2020 (Figure 5). The daily maximum dissolved oxygen % saturation fell below 100% first on June 15, and then consistently declined after July 4 until August 8. Minimum daily DO levels fell to a low of 67.7% on September 11, 2020. As seen with DO concentration (mg/L), large diel swings in DO % saturation (range: 70-100%) occurred from July-September 23 with the exception of the dates August 11-26. From September 25 through October 20, DO % saturation was within a range of 95-105% until it quickly declined to a stable range in the upper 80%'s for the rest of the monitoring period.

pH:

Figure 6 shows the hourly pH measurements recorded from April 29 - December 9, 2020. As with temperature and DO, the amplitude of the line shows the daily swing in pH over a 24-hour period. The red line shows the basin standard upper limit (8.5 standard units). Maximum daily pH levels typically occur mid-afternoon between 1400 and 1600 hours, while minimum pH occurs early in the morning (just before sunrise) due to daily changes in photosynthetic activity of aquatic plants and algae: pH rises with increased photosynthesis and drops when photosynthesis declines. 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 exposure, resulting in more photosynthesis.

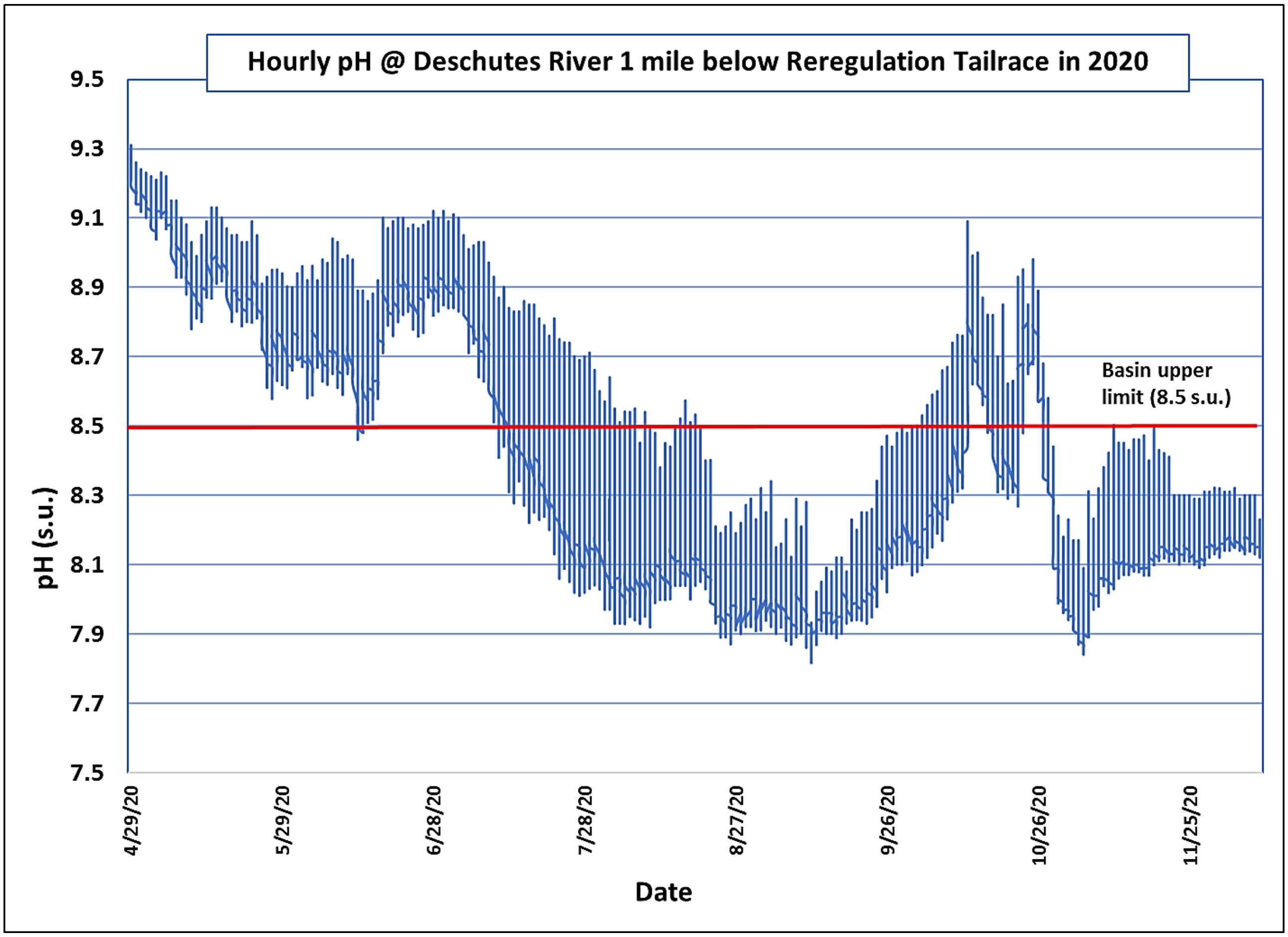

Figure 6. 2020 Hourly pH (standard units) at River Mile 99 of the lower Deschutes River with basin upper limit of 8.5 standard units shown with a red line**.**

From initial deployment on April 29 pH exceeded the basin pH standard consistently until early August (Figure 6). The maximum recorded pH was 9.31 standard units on April 29, 2020 at 1600 hours and the lowest recorded pH was 7.82 standard units on September 11, 2020 at 2000 hours. pH remained below the maximum basin standard from August 20 to October 3, 2020 when it again exceeded 8.5 standard units until October 29, 2020. From October 29 until the end of the monitoring period on December 9, 2020, pH remained within the basin standard.

Figure 7 shows the daily maximum pH measurements at RM 99 from 2016-2020, with Figure 8 containing only the daily maximums from 2020. 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. 2020 had stream flows even lower than those in 2018, yet pH levels first met the 8.5 s.u. standard in August 8th, but consistently stayed within the standard from August 20-September 29th.

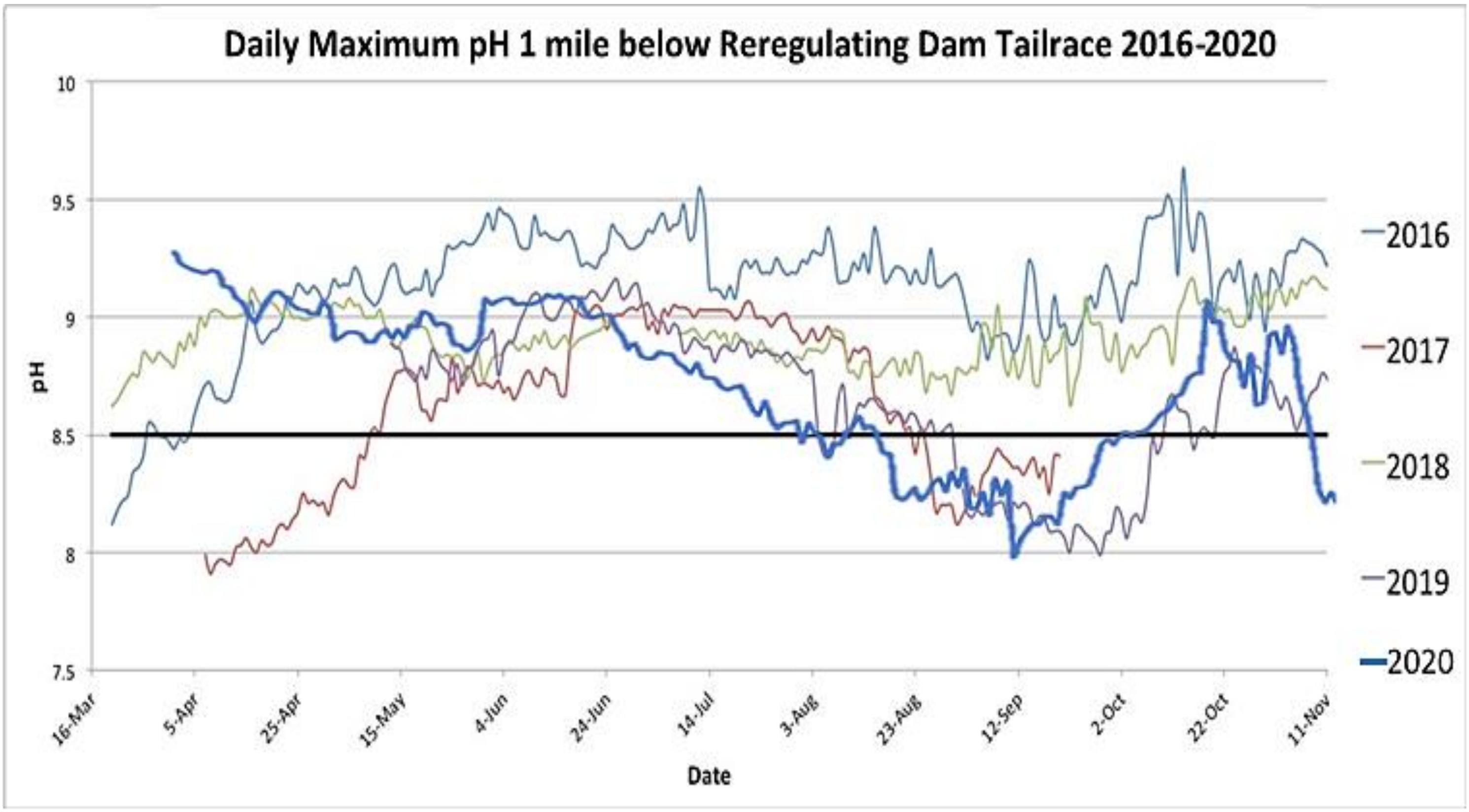

Figure 7. 2016-2020 Daily maximum pH records at River Mile 99 of the lower Deschutes River (DRA water quality reports).

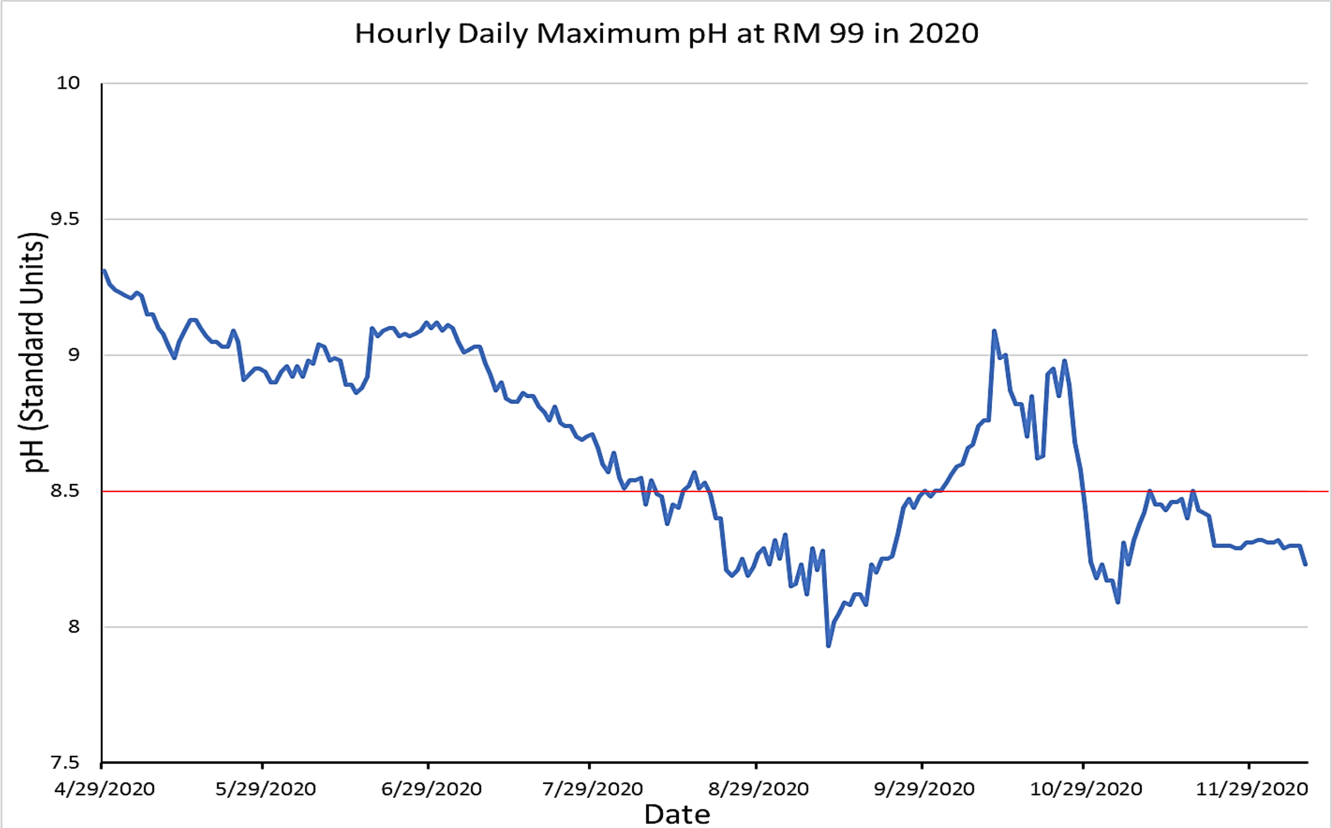

Figure 8. 2020 Hourly daily maximum pH at RM 99 with basin standard in red.

Streamflow/Precipitation:

Table 1 (on the next page) shows differences in streamflow of the lower Deschutes River from 2016 to 2020. 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 years 2016-2020. This year (2020) had the lowest peak flows for all comparable dates, and reflects how managed flow-blending at the Project in Lake Billy Chinook can influence to water quality in the lower Deschutes River.

Figure 9 shows the spring runoff event that occurred on April 9, 2019 in the lower Deschutes River next to the entire flow summary for 2020. High flows in the three tributaries of Lake Billy Chinook resulted in flows of 11,600 cfs at the Madras Gauge (RM 100; Figure 9). 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, much larger flows have occurred. Flows in the lower Deschutes River at its mouth (Moody Gauge) during the flood of 1996 reached 70,300 cfs (February 8, 1996; 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
	2020	4,250	4,280	4,280	5,040 on Dec. 21
Moody Gauge (RM 1)	**2016**	6,900	6,560 Apr. 2nd	4,860	9,380 on Jan. 20
Moody Gauge (RM 1)	**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
	2020	5,140	5,070	5,530	6,980 on Feb. 8

Table 1. Lower Deschutes River max daily stream discharge 2016-2020. (Source: USGS)

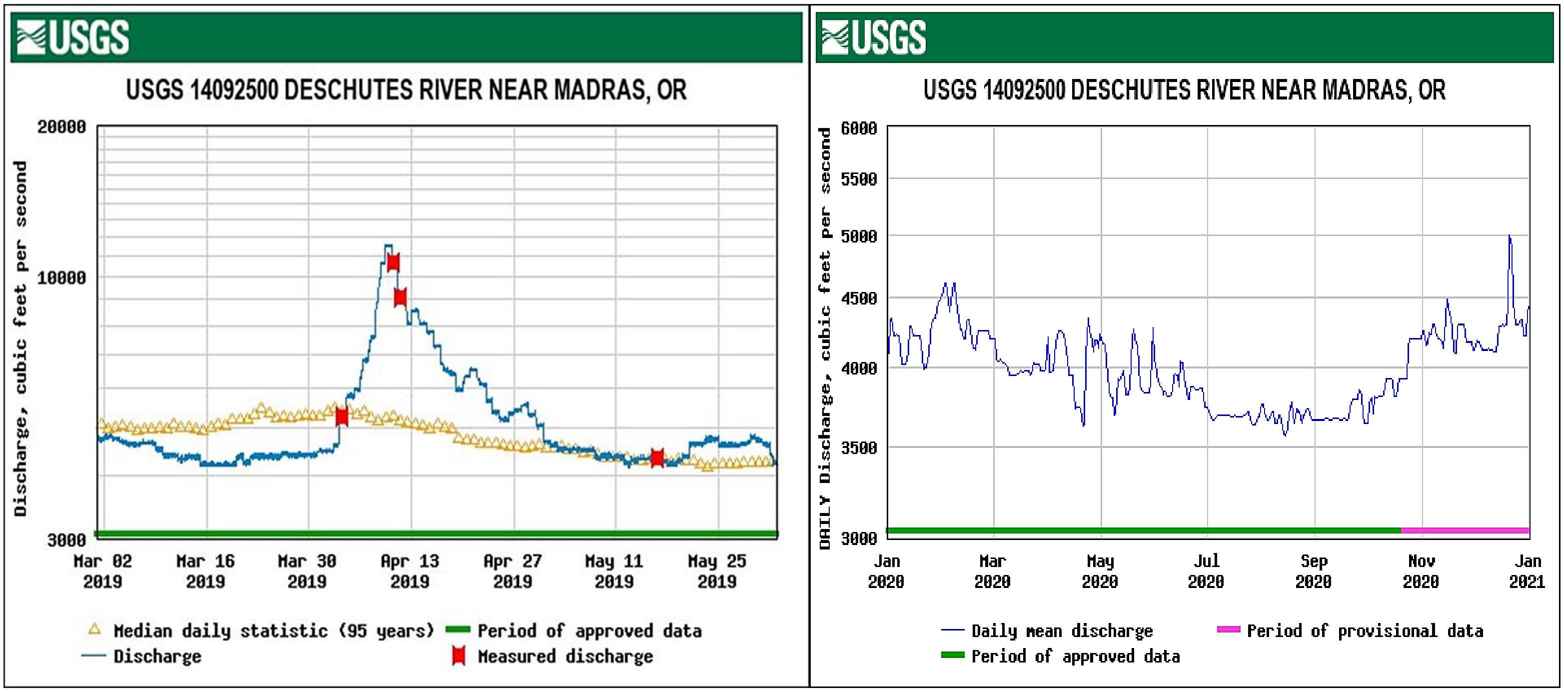

Figure 9. 2019 and 2020 lower Deschutes River hydrographs at RM 100. *Note change in date and scale between both graphs. (Source: USGS)

Figure 10 shows the hydrograph of the lower Crooked River from 2016-2020. 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. 2020 had no significant events throughout the entire year.

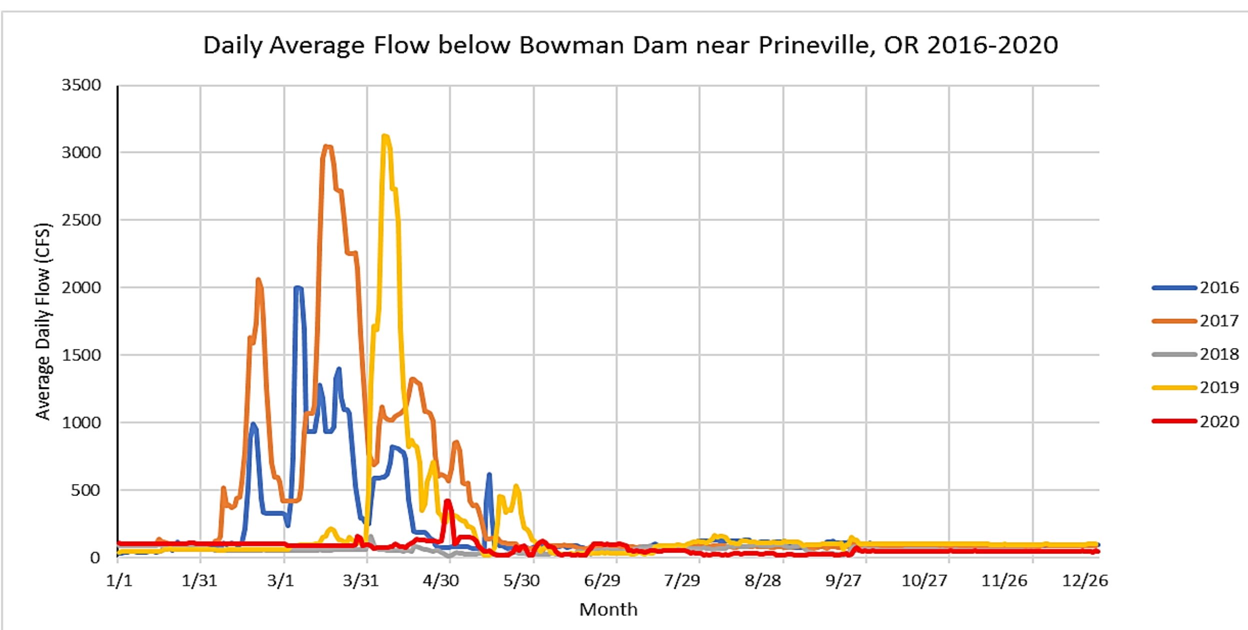

Figure 10. 2016-2020 Crooked River hydrograph measured below the Bowman Dam outflow. (Source: USBR)

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 stream flows of the Deschutes Basin. In 2020, snow water equivalent in the Deschutes Basin was 86% of normal in 2020, which was similar to 2016 (SNOWTEL Deschutes Basin Map—Appendix B). Both precipitation and snowpack in 2018 was significantly lower than other years (2016-2017, 2019, 2020) and contributed 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:

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

While the "night blend" brings some beneficial changes to water temperature in the river compared to prior years, the low percent of water drawn from the bottom port of the Tower (% Bottom Draw) has a significant influence. Figure 11 (next page) shows the % bottom draw at the Tower in 2020. The percent bottom draw gradually increased from

[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.

0% to 40% from May through July. From August 20-August 24, the SWW Tower was shut down due to wildfire concern (2020 PGE Blend notes) and the percent bottom draw increased to 60%. Following the wildfire concerns, percent bottom draw increased to 100% of maximum capacity (65% of total draw) on August 24 until November 2nd.

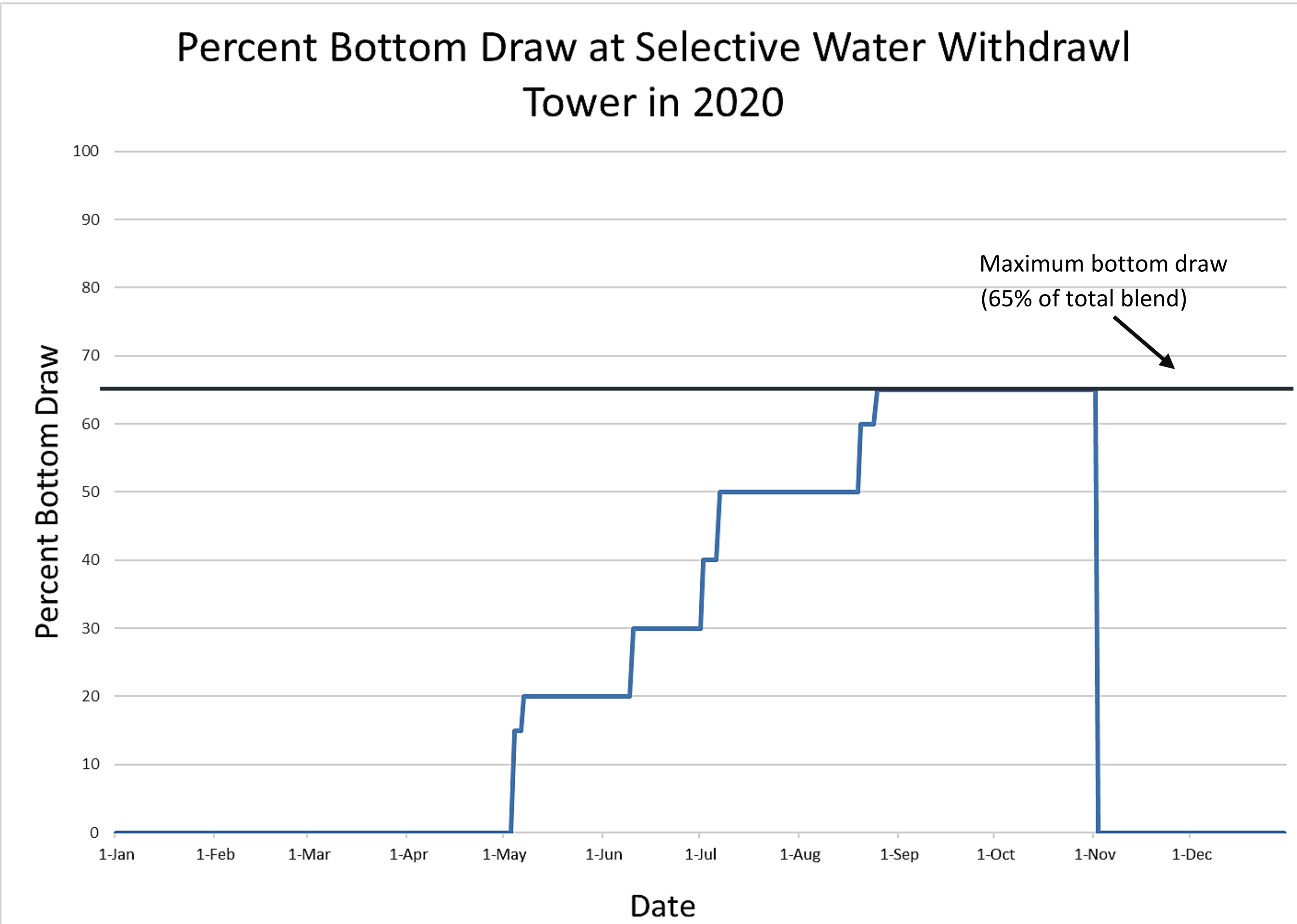

Figure 11. Percent (%) bottom draw at the Selective Water Withdrawal Tower in 2020. (Source: adapted from PGE report to ODEQ 2020). Maximum bottom draw is 65%.

When released into the lower Deschutes River, water from the bottom of Lake Billy Chinook results in changes to water quality throughout the lower river. Blending a higher percentage of bottom water with surface water reduces the temperature of water released from the Tower, and is the primary means for water temperature regulation at the Project. In addition to temperature management, a higher percentage of bottom release meets other water quality standards. In the following sections we discuss how changing the blend ratios at the Tower affected water quality parameters in 2020.

Temperature:

Figure 12 shows the 7-day average daily maximum temperature (7-DADM) at the DRA monitoring site in 2020. Pink highlights show the salmon and steelhead spawning/incubation period, and the blue highlights show that resident trout spawning/incubation period continues until at least early September (Zimmerman & Reeves 2000). The 13°C maximum temperature standard (OAR 340-041-0028) applies until the end of the salmon and steelhead spawning/incubation period on June 15. In 2020, the 7-DADM exceeded the applicable basin standard for salmon and steelhead spawning from May 22 through June 15. While Oregon's 13°C maximum temperature standard does not currently apply to resident trout spawning/incubation, water temperature should be held as low as possible during this time period to provide better survival of trout eggs and fry.

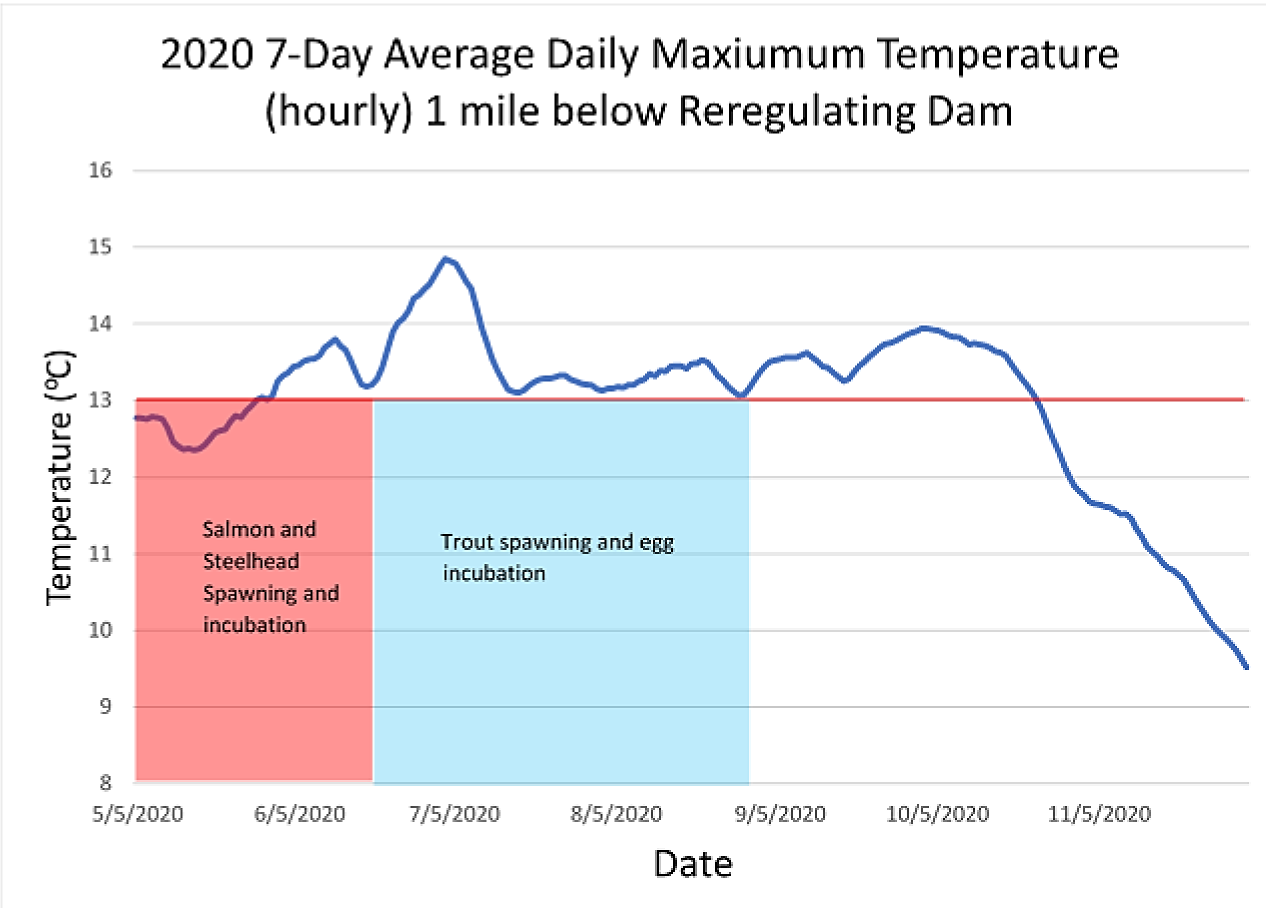

Figure 12. 2020 7-Day Average Daily Maximum water temperature (°C) at River Mile 99 of the lower Deschutes River. Shaded areas show spawning and egg incubation periods for salmon/steelhead and resident trout. Oregon's water temperature standard (13°C) during the designated spawning period for salmon and steelhead is shown with a red line.

A notable impact of current temperature management at the Tower is that peak annual water temperature of the lower Deschutes River now begins four to five weeks 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 occurred in early September (USGS Madras Gage; Eilers & Vache 2019). In the years 2016-2020 water temperatures peaked in late June and July (DRA 2017; DRA 2018; DRA 2019c). Effects from this shift in peak annual water temperature has led to early emergence (four to six weeks) of most major insect hatches on the river. Changes in trout spawning have also been observed and documented by the DRA, but currently there are no studies underway to discover the effects early hatching of aquatic insects has on the resident trout population.

Blending bottom water with surface water at the Tower is the primary means for the Project to meet temperature management targets outlined in their WQMMP.[8] The DRA stated 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 an average of the 7-day maximum 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 midafternoon high to a late night/early morning low (see for example Figure 3). Using only the maximum tributary temperatures, as is currently done, does not recognize the natural temperature regime and does not account for the diel temperature flux in the tributaries. There is no biological, or statistical justification for using maximum temperatures. This model does not create a "natural" temperature regime in the lower Deschutes River as stated 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, cold water can hold more DO than warmer water. When water and air mix due to turbulence (waterfalls, white water, release from dams, etc.) oxygen from the air entrains in the water, increasing its concentration. Photosynthetic activity from aquatic plants, and suspended oxygen attached to algae also increase oxygen concentrations.

The concentration of DO needed to support life functions of fish— feeding, spawning, predator avoidance, etc.—varies with among 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, 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 higher standards during the most sensitive times of year: salmonid

[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*.

spawning and egg incubation periods (APPENDIX D). Oregon's complete DO criteria for the Deschutes Basin are listed in Table 2.

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 ODEQ determines adequate data for DO exists, ODEQ 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.

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

In prior reports, the DRA expressed concerns about how the DO criterion is applied and how the designated spawning and incubation periods for species are 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 included. 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." 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 has 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 starting in July (Figure 4). Because trout spawning and incubation continue until early September, 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 every day starting in early-May through the end of the monitoring period on December 9th, 2020. Project operations can feasibly correct this by spilling water over the Reregulating Dam to entrain oxygen as it is released into the lower Deschutes River.

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 April 29, 2020 (Figure 6). Measurements were recorded above 9.0 starting at deployment. 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. A key question therefore is whether surface water withdrawal has made the pH problem worse. Bi-monthly water quality data collected by ODEQ 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). Such a significant increase in pH seen in ODEQ's pre- & post-tower data clearly demonstrates the negative effect the Tower has had on water quality in the lower Deschutes River.

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 CO_2 concentration in the water, which in turn reduces the carbonic acid concentration and raises pH. At night, photosynthesis stops and respiration releases CO_2 into the water. As a result, carbonic acid production increases and the pH drops. When algal biomass increases, the difference between the daily minimum and maximum pH increases and produces large diel 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 operating 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. Higher pH is the consequence. The DRA believes that data collected by ODEQ and the results of DRA water quality reports (DRA 2015-2019c) clearly establish that surface water releases have had a rapid and negative impact on pH in the lower Deschutes River.

Data collected in 2020 for pH continue to document violations of the basin standard throughout the monitoring period. Increases in the percent of bottom draw at the Tower in 2020 (Figure 11) improved pH levels in the lower Deschutes River (Figure 13) and illustrate how Tower operations could be managed in a way that improves pH in the lower Deschutes River. Figure 13 shows how pH in the lower Deschutes River continually decreased as the percent bottom draw at the Tower continually increased from its 0% on May 1st to its maximum (65% of the total blend) on August 24, 2020. Similar results were seen in 2019 when bottom draw had increased to 50% at the Tower.

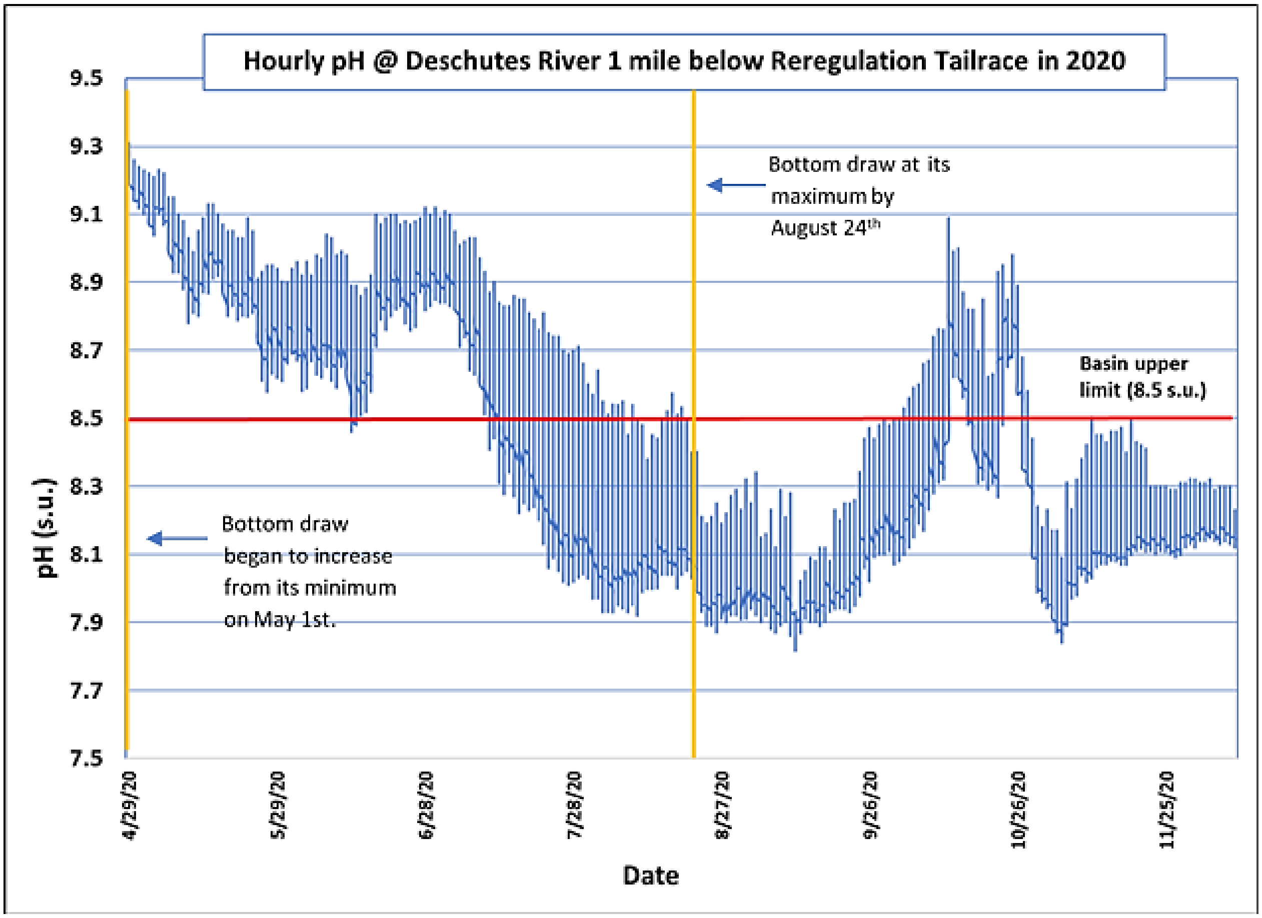

Figure 13. 2020 Hourly pH (standard units) at River Mile 99 of the lower Deschutes River with total period of increased percent bottom draw marked between the two yellow lines**.**

Conclusions

Water quality data collected and analyzed by the DRA in 2020 again document serious violations of Oregon's pH and DO water quality standards in the lower Deschutes River. Water quality management at the Project continues to negatively affect river conditions in the lower Deschutes and increase violations Oregon's water quality standards set to protect aquatic life. The DRA believes it is of utmost importance to the health of the lower Deschutes River's aquatic ecosystem that PGE manages water released from the SWW Tower to ensure water quality standards are met to the fullest extent possible. The WQMMP established, upon completion of the Tower, clear

management requirements for adhering to water quality standards for temperature, DO, and pH to adequately protect the aquatic life in the lower Deschutes River.
Data collected by ODEQ and the DRA clearly show that these problems are neither due to climate change nor do they reflect "regional" water quality problems, but rather, operational practices at the Tower. Solutions to improve water quality and protect aquatic life that do not hinder the reintroduction efforts of salmonids are readily available to manage water quality in the lower Deschutes River. In fact, as more data becomes available, improving lower Deschutes River water quality will be necessary for reintroduction efforts to succeed (e.g., C. shasta infection rates on salmonids; OSU 2019). Below, are the summarized water quality exceedances documented by the hourly water quality data collected by the DRA at RM 99 from 2016-2020 as well as from data reported in the PGE Water Quality Study (Eilers & Vache 2019).

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 "Without Project Temperature" equation used to set the temperature goals in the lower Deschutes River is flawed. By averaging the 7-day maximum temperatures of the three tributaries entering Lake Billy Chinook, the Project discharge allows for the maximum temperatures from the three tributaries to set the criteria. This does not recreate true or natural thermal conditions in the lower river that existed pre-dam construction.[9]

2. Releasing 100% surface water from Lake Billy Chinook from winter through May (or June) each year raises the water temperature in the lower Deschutes River throughout the late winter, spring, and early summer. This surface water temperature is greater than the pre-SWW Tower temperatures released into the lower Deschutes, and alters aquatic insect life cycles and abundance. It likely contributes to the widely observed earlier-in-the-year growth of nuisance algae that has further impacted aquatic invertebrate populations in the lower river. This is well supported by an independent statistical analysis of aquatic macroinvertebrate data collected by R2 Resource Consultants when their data showed 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).

3. Also of concern is the disturbing increase in abundance of the polychaete worm, *Manayunkia speciosa,* that is an obligate intermediate host for the parasite *Ceratonova*

[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-hightemperatures-in-the-lower-deschutes-river/

shasta that infects young, ocean-bound salmonids. DRA sampling of benthic invertebrates found over 8,000 *M. speciosa* per square meter in September 2016 at RM 99 (DRA 2019d).

4. Project operations under the rubric of temperature management caused water temperatures to exceed the temperature standard for spawning salmon and steelhead in June 2020 (7-day average daily maximum no greater than 13°C; Figure 12).

5. 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 encouraged smallmouth bass to migrate from the Columbia River, where they are abundant, up the Deschutes in search of the warm water they prefer. 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 impact of increased smallmouth bass numbers in the lower Deschutes River is currently unknown, but an increased predation of native fish is a possibility.

6. 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 the cold-water refugium.

Dissolved Oxygen:

Water with adequate dissolved oxygen is critical for the survival and reproduction 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 observation / photo documentation of trout spawning at RM 99 on August 2, 2020 confirm that trout spawning continues through August (Zimmerman & Reeves 2000, Appendix D). It is clear that resident trout incubation continues through the end of August and/or early September, and observation suggests incubation extends even further into the year. 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) should be extended to sufficiently support actual resident trout spawning and resulting incubation periods. From the middle of May until the end of the monitoring period in 2020, DO was below the 11.0 mg/L protective standard, and fell below the less protective standard of 9.0 mg/L from July to the middle of August, and again in September (Figure 4).

Dense growths of aquatic plants and algae produce high DO concentrations during the day but result in low levels late at night and early morning resulting in large diel swings. Large diel swings in DO during 2020 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. 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 2020 show significant water quality exceedances of the pH standard, which are largely due to the release of nutrient polluted surface water from LBC:

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 April 29 through the end of July. The measurements recorded between August and September showed improved pH within basin standards, but elevated pH measurements above the basin standard again occurred throughout October.
2. No management plan for lowering pH has been developed by PGE, even though it is required by the WQMMP when pH measurements from the Project discharge exceed the weighted average pH of inflows into Lake Billy Chinook (PGE & CTWSRO 2002).
3. Based on ODEQ data, pH showed an immediate and sustained increase when SWW Tower operations began in 2009 (DRA 2019c).

Summary:

Data record since 2010 indicate that Project operations have frequently caused violations of Oregon's water quality standards for temperature, pH, and DO. While water quality standards are set for each parameter independently, interactions among parameters can exacerbate and increase their level of negative impact on aquatic life. When one water quality standard is exceeded, the potential for negative impacts by other parameters also increases. When multiple standards are exceeded together for any given periods of time (days and weeks as seen in this study), the negative effects on aquatic life increase substantially.

Water quality standards are essential to protect the beneficial uses of the water. Years of research in both laboratory and field studies have determined acceptable standards for a wide range of water quality parameters (EPA 1986). These standards are further evaluated by state water quality agencies before being adopted as state standards. As a result, years of research and public process ensure that the standards will adequately protect aquatic life in Oregon's waterways. Without adherence to these standards, the efforts taken to maintain acceptable river quality and reintroduce anadromous salmonids and steelhead to the upper tributaries of the lower Deschutes River, in particular the lower Crooked River, will be an up-hill battle and may even prove impossible in the long-term.

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Appendix A – 2020 Field Audit Data

Riffle Ranch 2020

Watershed Assessment Section Multiparameter Logger Monitoring Report

SITENAME **FILENAME** **CASE #**

NOTE: GRADE F is a manual grade for "exceptional event" level data only(See DQM for further explanation). GRADE D is a manual grade for "missing" data. Grade E is data of an quality or of known poor quality. **GRADES D, E AND F REQUIRE AN EXPLAINATION IN THE RUN COMMENTS SECTION.**

ELEVATION (ft) unknown

TEMPERATURE AUDIT RESULTS

# Audit		DS Value		Status
1	12.35	12.419	-0.07	A
2	13.6	13.513	0.09	A
3	12.9	12.824	0.08	A
4	13.3	13.208	0.09	A
5	11.5	11.345	0.15	A
6	8.85	8.775	0.07	A

Criteria:

GRADE A	GRADE B	GRADE C
=<+1.5	=<+1.51 - 2.00	=>+2.01

pH AUDIT RESULTS

# Audit		DS Value	Abs. Difference	Status
1	9.25	9.28	-0.03	A
2	8.91	8.97	-0.06	A
3	8.54	8.57	-0.03	A
4	8.1	8.07	0.03	A
5	8.12	8.05	0.07	A
6	8.23	8.23	0.00	A

Criteria:

GRADE A	GRADE B	GRADE C
=<+0.3	=<+0.31 -0.5	=>+0.5

CONDUCTIVITY AUDIT RESULTS

# Audit		DS Value	Abs % Difference	Status
1				
2				
3				
4				
5				
6				

Criteria:

GRADE A	GRADE B	Grade D or E
=<+10%	=<+10.1% - 15%	=>+15%

DO AUDIT RESULTS

# Audit		DS Value	Abs. Difference	Status
1	12.51	12.63	-0.12	A
2	10.21	10.13	0.08	A
3	9.42	9.31	0.11	A
4	10.44	10.44	0.00	A
5	9.18	9	0.18	A
6	10.44	10.28	0.16	A

Criteria: units in **mg/L**

GRADE A	GRADE B	GRADE E	GRADE C
(<+ 0.3)	(<+ 0.31-1.0)	(<+1.01-2.0)	(≥+ 2.01)

AUDIT RESULTS:

IT #	LASAR #	DATE (mm/dd/yyyy)	TIME (hh:mm)	TEMP (deg C)	pH (SU)	CONDUCTIVITY (umhos/cm)	DO (mg/L)	DO SAT %	COMMENTS
1		4/29/2020	11:30	12.35	9.25		12.51		
2		6/9/2020	11:30	13.6	8.91		10.21		
3		8/1/2020	14:15	12.9	8.54		9.42		
4		9/20/2020	11:10	13.3	8.1		10.44		
5		11/1/2020	11:15	11.5	8.12		9.18		
6		12/8/2020	11:06	8.85	8.23		10.44		

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.

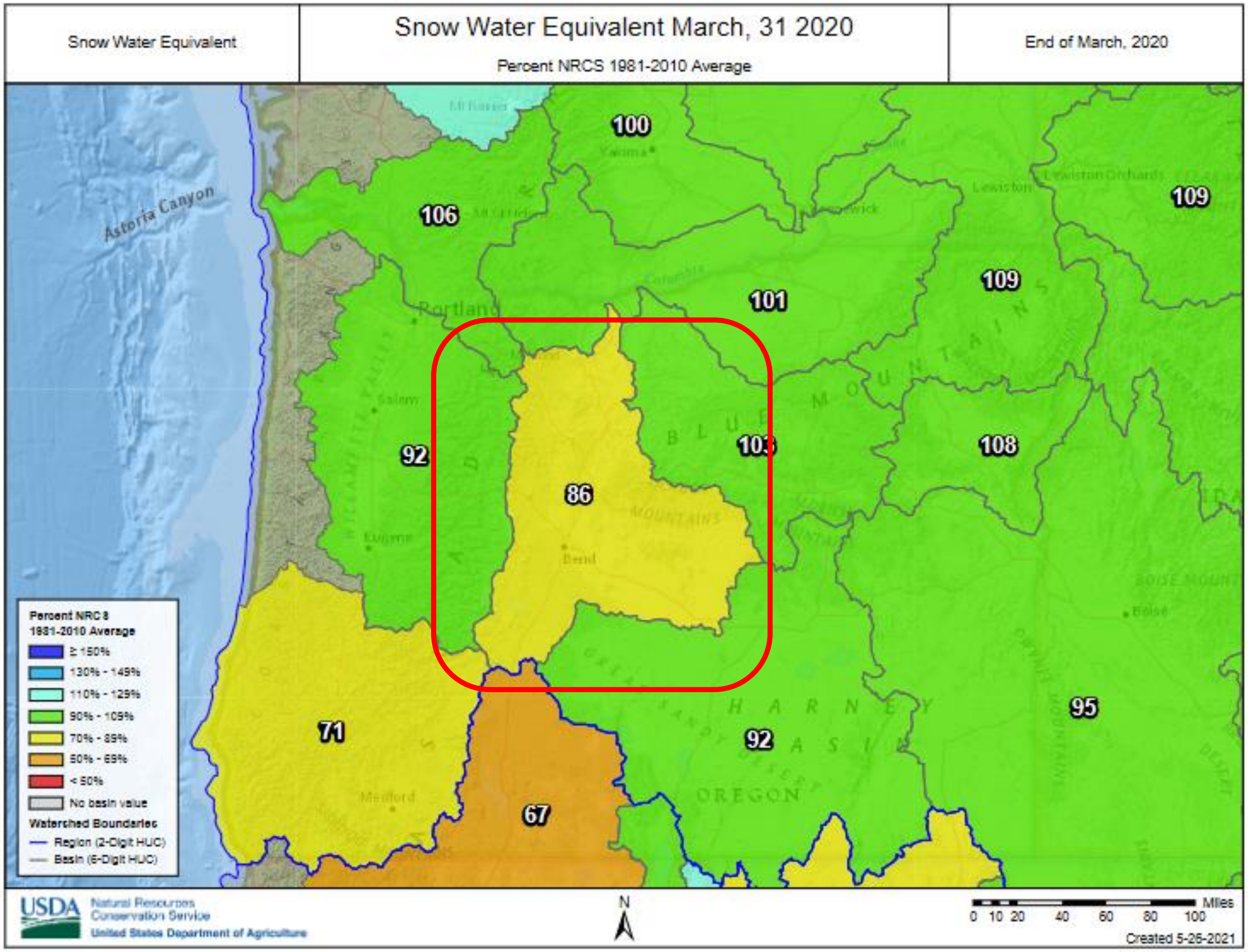
Use of Multiple Measures:

To ensure in-field accuracy, independent meters/instruments were used to measure temperature, pH and DO simultaneously with the YSI data sonde. 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



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

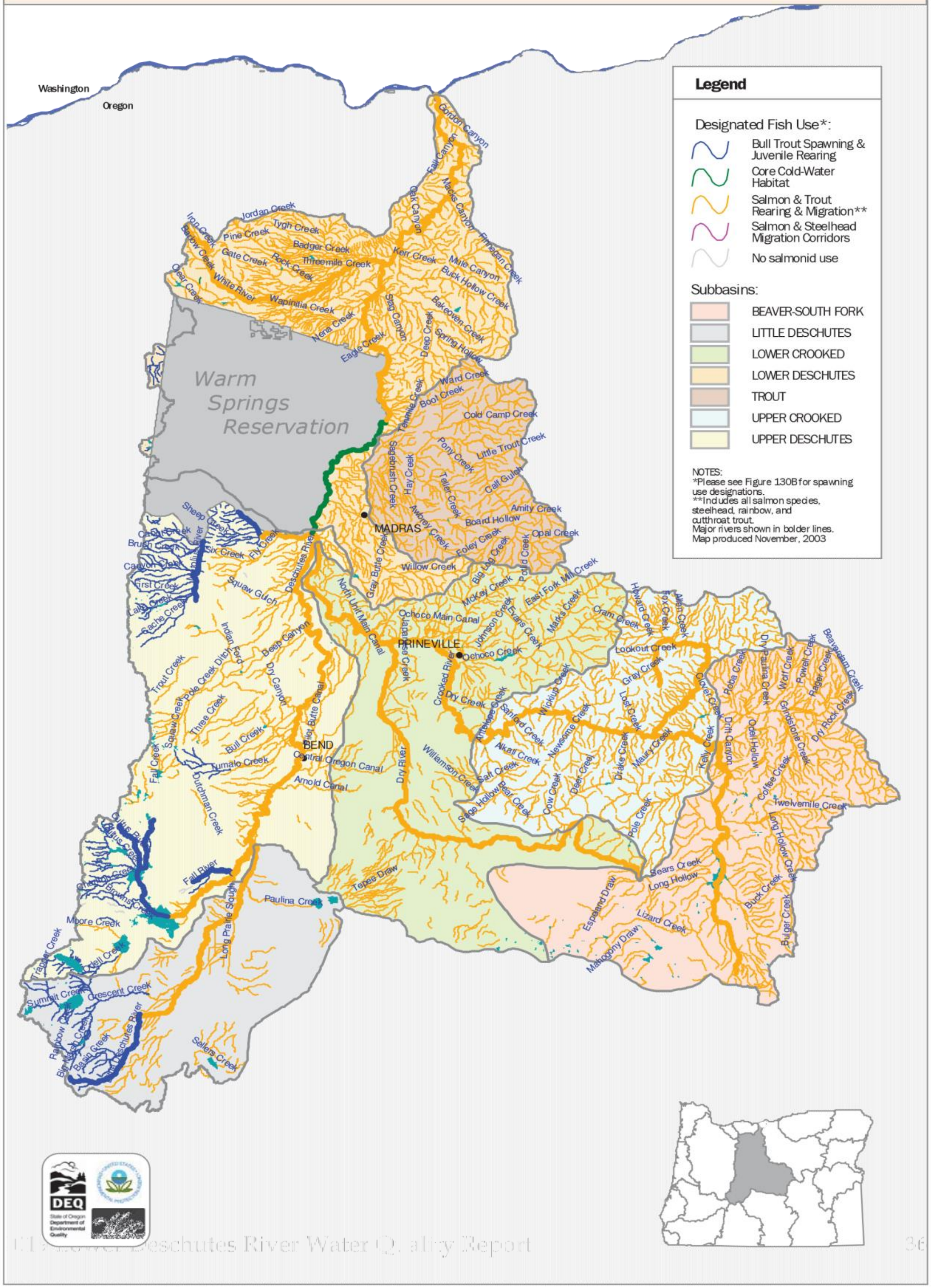
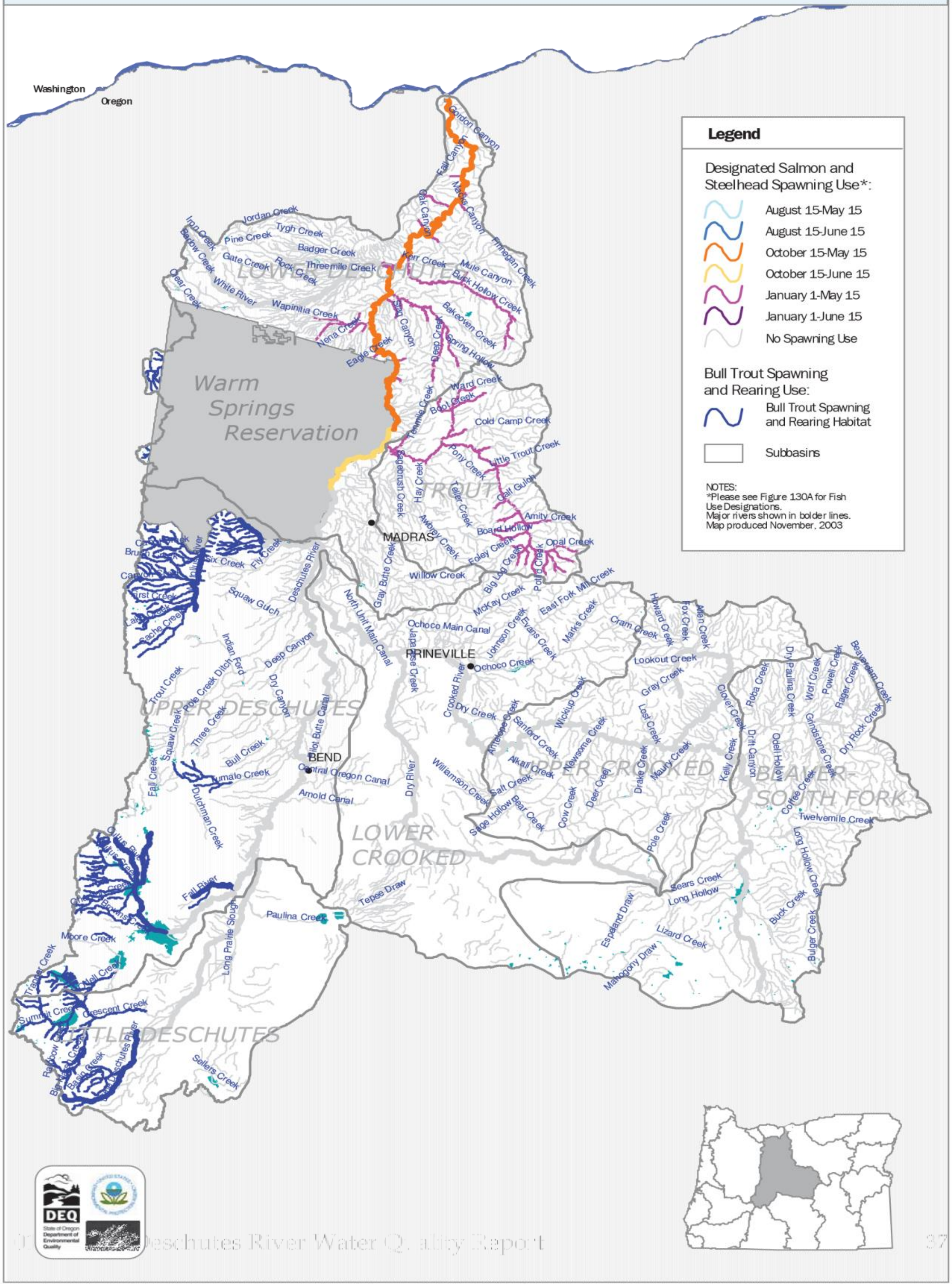
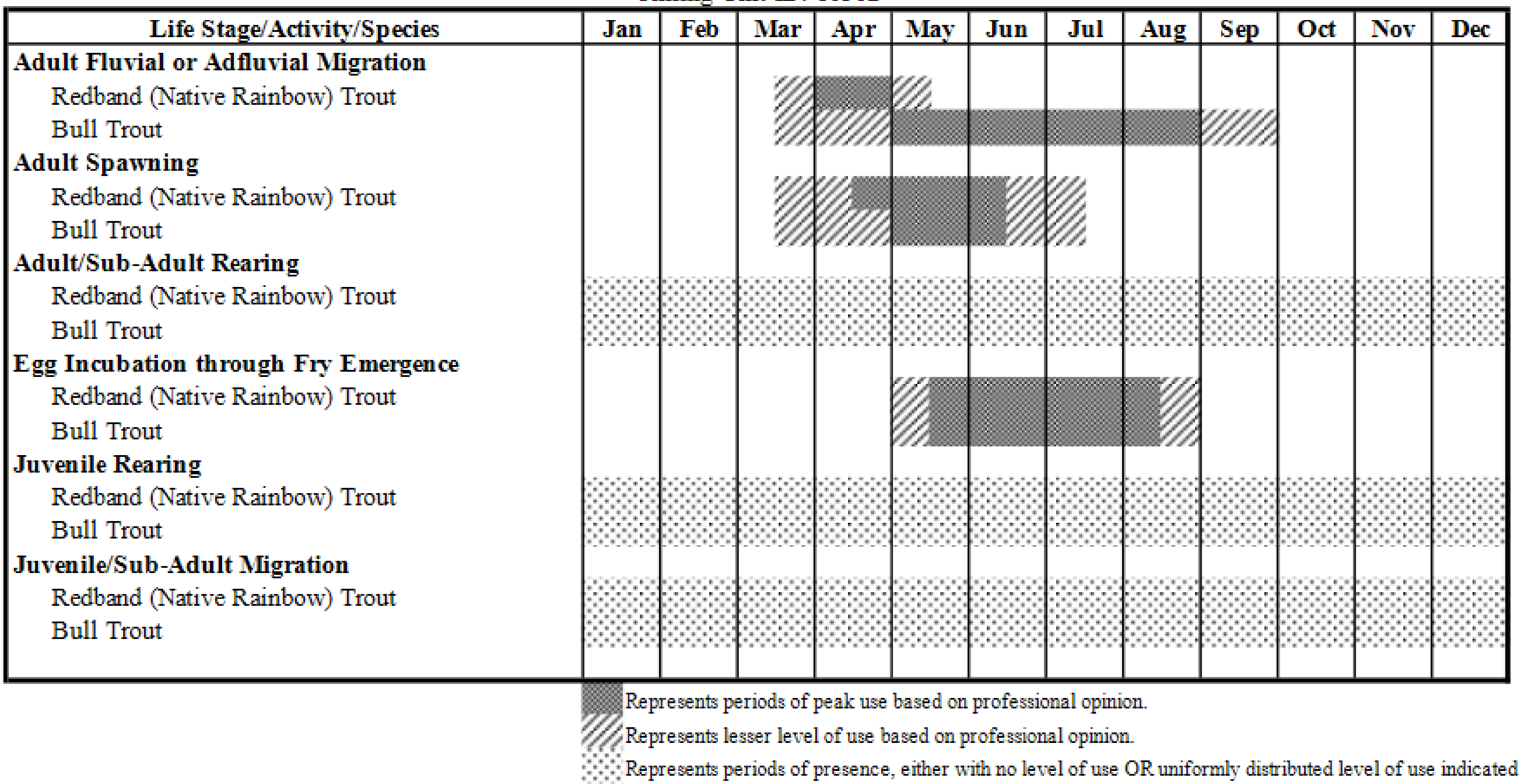


Figure 130B: Salmon and Steelhead Spawning Use Designations*
Deschutes Basin, Oregon



Deschutes R below Pelton Dam - Non-Anadromous Species

Timing Unit ID: 10362



Based on professional opinion, 90% of the life-stage activity occurs during the time frame shown as the peak use period.
Based on professional opinion, 10% of the life-stage activity occurs during the time frame shown as the lesser use period.