2018 LOWER DESCHUTES RIVER WATER QUALITY STUDY RESULTS

Prepared for Deschutes River Alliance
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Last, thanks to all those not mentioned here who care about the Deschutes River, have contributed hours of their time, and donated 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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INTRODUCTION

The effect of the Selective Water Withdrawal (SWW) tower on water quality in the 100 miles of the Deschutes River downstream from the Pelton Round Butte Hydroelectric Project (the Project) has been an ongoing concern since the SWW tower became operational in December 2009. A thorough discussion of the tower's construction and operation was covered in the Deschutes River Alliance's 2016 water quality report (DRA 2017). Operation of the SWW tower and resulting release of surface water from Lake Billy Chinook (LBC), the reservoir behind Round Butte Dam,

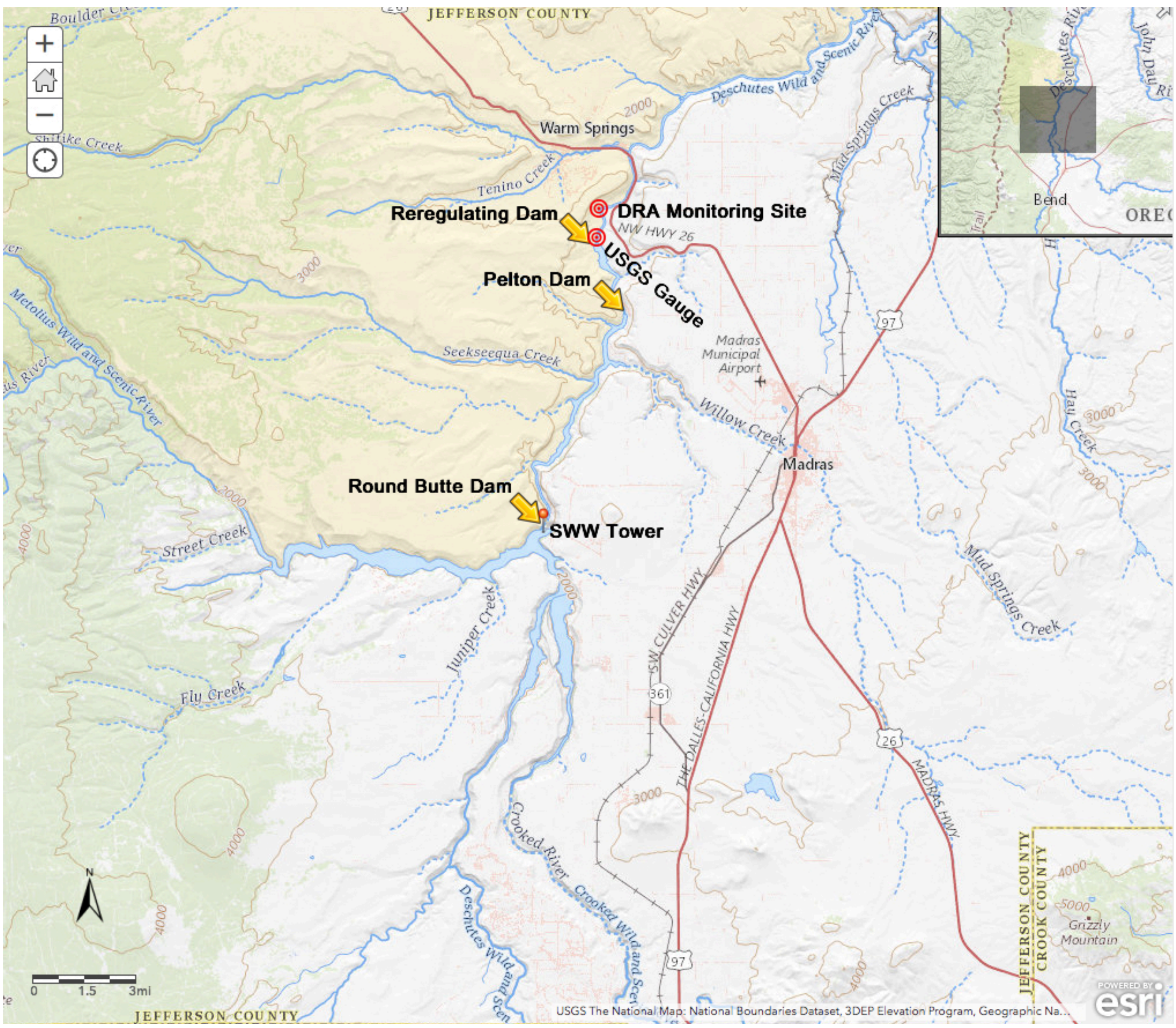


Figure 1. The three dams jointly owned and operated by Portland General Electric (PGE) and Confederated Tribes of Warm Springs (CTWS): Round Butte Dam (creates Lake Billy Chinook reservoir), Pelton Dam (creates Lake Simtustus reservoir), and the Reregulating Dam (creates the reregulation reservoir).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

continued with only minor operational changes throughout 2018. As in previous years, 100% surface water was released from early November 2017 through the winter and spring of 2018. From May 22, 2018 through the end of October 2018 various blends of surface and bottom water were mixed and released downstream from LBC. 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 LBC. Near constant streamflow in the lower Deschutes River is maintained by releasing 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).

Deschutes River Alliance (DRA) has described in detail, in previous reports, how the three tributaries entering LBC have different temperature and water quality characteristics (DRA 2017, 2016a, 2015). Crooked River water is the warmest and most nutrient laden, while Metolius River water is the coldest and has the lowest nutrient concentration. Because of the temperature differences between the tributaries the warmer water of the Crooked River remains at the surface of LBC while the colder water of the Metolius sinks to the bottom. As a result, when surface water is released from LBC, the Pelton Round Butte Hydroelectric Project is releasing the warmer and more polluted Crooked River water downstream into the lower Deschutes River. Water quality data collected by the DRA from 2015 through 2018 document how this change in the quality of water released from LBC is negatively impacting the water quality in the lower Deschutes River.

OBJECTIVES AND KEY QUESTIONS

In 2018 the Deschutes River Alliance Science Team continued to monitor water quality in the lower Deschutes River at river mile 99 (RM 99). The monitoring site, one mile below the Reregulating Dam tailrace, was the same location as DRA sampled in prior years. Hourly data for five water quality parameters (temperature, pH, dissolved oxygen, chlorophyll-a, and turbidity) were collected from March 20, 2018 through November 4, 2018. Monitoring objectives in 2018 remained unchanged from prior years:

1. To determine how water quality for the key parameters of temperature, pH, and dissolved oxygen 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 determine if the water released from the Pelton Round Butte (PRB) complex through the SWW tower contributes to violations of water quality standards in the lower Deschutes River?

To answer these questions a YSI Model 6600 V2 data sonde was installed at RM 99 (see methods section for details). This location is close enough to the Reregulating Dam tailrace to rule out other potential influences on water quality in the lower river, but far enough downstream to allow the river time to show a response to water released from the Pelton-Round Butte Dam (PRB) complex. Besides providing an excellent place to assess the effects of water released from the PRB complex on the lower Deschutes River, the sample site also includes spawning habitat actively used by trout and salmon.

A notable difference between 2017 and 2018 was that in 2018, the Deschutes basin received far below normal precipitation throughout the year (NOAA Climate Charts). In 2018 warm weather from January through mid-February combined with below normal precipitation resulted in lower overall snowpack and early snowmelt. On March 31^{st}, 2018 Snow Water Equivalent in the Deschutes basin was 59% of normal (NRCS SNOWTEL basin reports). Weather conditions in 2017 were nearly the exact opposite, with colder and wetter than normal weather throughout the late winter and spring. This resulted in a snowpack on March 31^{st}, 2017 in the Deschutes basin that was 110% of normal. These differences directly affected streamflow in the lower Deschutes River. Table 1 shows how streamflow differed between 2016, 2017, and 2018 at the Madras streamflow gauge, below the Reregulating Dam tailrace (USGS Gauge in Figure 1), and at the Moody gauge (mouth of the Deschutes River). These three years of data collection provide a unique picture of how water quality in the lower Deschutes River differed among years with varying amounts of precipitation.

Table 1. Comparison of max daily stream discharge (cubic feet per second) from 2016-2018 in the Lower Deschutes River. (USGS National Water Information System)

Max Daily Stream Discharge—cubic feet per second (cfs)					
Gauge Location	**Study Year**	March 1^{st}	April 1^{st}	May 1^{st}	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
Moody Gauge (RM 1)	**2016**	6,900	6,560 Apr. 2^{nd}	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

SAMPLING METHODS

Water quality was sampled with a YSI 6600 V2 data sonde with 4 optical ports in 2018 (same unit was also used in 2016 & 2017) (Figure 2). The data sonde recorded hourly water quality data for pH, dissolved oxygen, percent oxygen saturation, temperature, turbidity, and chlorophyll-a. Probes include self-cleaning optical sensors to avoid inaccurate results due to bio-fouling. More complete information about this YSI data sonde can be found at: https://www.ysi.com/6600-v2-4.

Figure 2. YSI 6600 V2 data sonde.

The YSI data sonde was calibrated against lab standards for all parameters before being deployed in the field and it was programmed to record hourly readings for each parameter. Field installation occurred on March 20, 2018, at RM 99. The data sonde was placed in an area of laminar flow near the east bank in three feet of water. The probes were positioned four to six inches above the stream bottom. Following field installation, field audits for all parameters, except chlorophyll-a, were completed periodically throughout the sampling season to ensure that the data sonde continued to collect accurate results (Appendix A). Data downloads were made during several field audits.

There is a break in the data after June 26, 2018 because the data sonde shut down due to a full memory bank. The file continues after July 8, 2018 through November 29, 2018. In November, the battery power began to run low and the sonde began to record data intermittently. The final field audit and data download was completed after the data sonde was removed from the river on November 29th. Quality control and assurance procedures were followed throughout the study (Appendix B).

RESULTS

Temperature:

Hourly temperature readings from March 21, 2018 to June 24th and from July 8th to November 1, 2018 are shown in Figure 3. Width of the line shows the range in temperatures over a 24-hr period (diel temperature range). The average difference between the daily minimum (occurs just before sunrise) and daily maximum (typically around 3pm) was around 0.9°C during the first ten days of April. Differences in daily minimum and maximum temperature gradually increased as the days grew longer and warmer. Maximum diel fluctuation occurred in the middle of the summer when the daily range increased to just over 2.3°C (~4.2°F). Diel fluctuations declined again in the fall as the days grew shorter and the weather cooled.

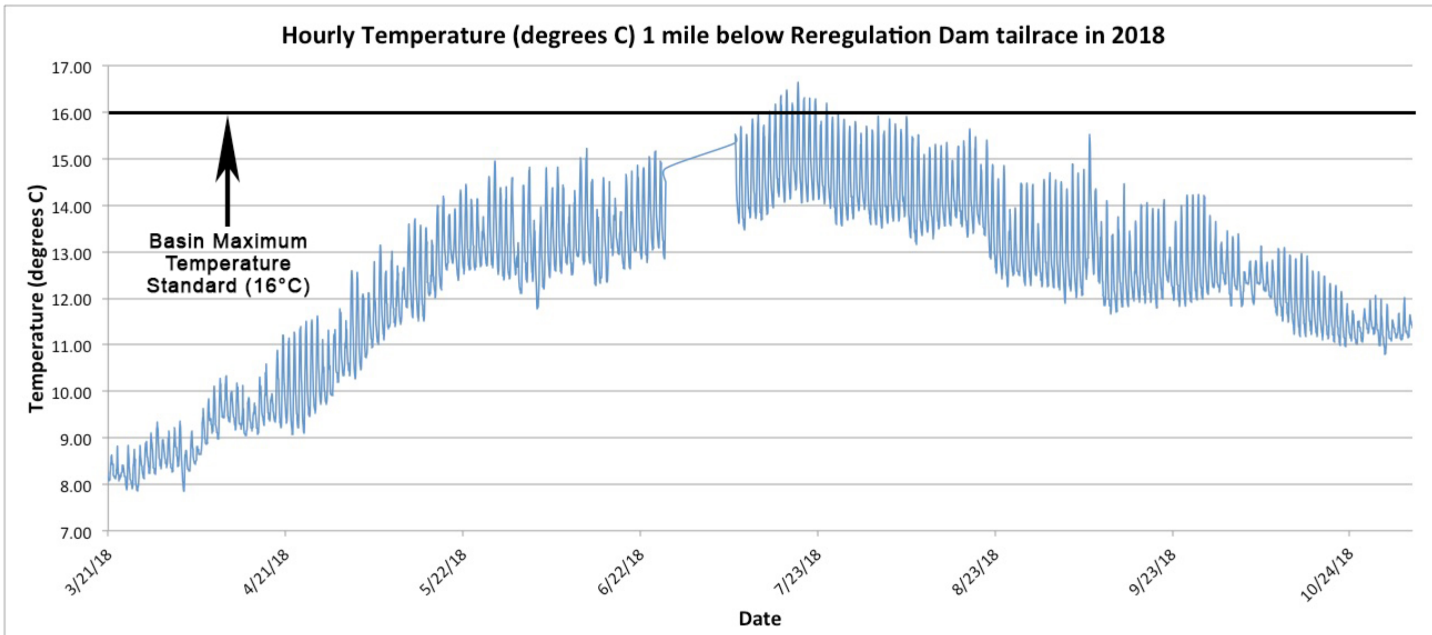


Figure 3. 2018 Hourly Water Temperature at RM 99.

The minimum recorded temperature at RM 99 during the 2018 monitoring season was 7.85°C (46°F) on April 4th at 0600 hours. Temperature exceeded the maximum temperature standard for the lower Deschutes River (16°C) on July 19th at 1400 hours with a recorded temperature of 16.65°C (62°F). Water temperature remained relatively constant between 14°C and 16°C throughout mid-July and early August followed by a gradual drop in temperatures through August and September. The break in temperature data from June 26, 2018 through July 8, 2018 was due to a full memory bank causing the data sonde to shut down.

Dissolved Oxygen:

Dissolved oxygen (DO) in water is measured and recorded in two ways: 1) as the concentration of dissolved oxygen 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 DO percent saturation criteria is applied when evaluating whether DO water quality standards are being met.

Oregon's water quality standard for dissolved oxygen is higher during salmonid spawning season than during salmonid rearing season. The DO standard currently being applied by Oregon Department of Environmental Quality (ODEQ) for the lower Deschutes River during steelhead and salmon spawning 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 is available (DRA 2017). 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 that must be applied during the period ODEQ identifies as outside the spawning and incubation period (DRA 2017). More explanation of Oregon's DO standard and its application to this Project is covered in the "Discussion" section of this report (see page 14).

Figures 4 and 5 show the dissolved oxygen levels as % saturation and mg/L, respectively, in 2018. Again, the break in the dissolved oxygen data from June 26th through July 8th was due to a full memory bank causing the data sonde to shut down. These graphs 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.

Daily changes in dissolved oxygen are driven by biological activity in the water. During daylight hours photosynthesis by algae and aquatic plants produces oxygen, increasing the DO levels. At night, when photosynthesis stops, respiration by plants and animals uses up the oxygen dissolved in the water, causing a decrease in DO concentration. The large difference between the daily low and daily high DO concentration during the summer months (indicated by the wider line on the graphs), reflects a higher level of photosynthetic activity (and hence oxygen production) due to a greater biomass of algae and longer days with more sunlight exposure. The effect of high algal biomass is clearly shown by the large swings in the daily DO concentration levels throughout June, mid-July, and August (Figure 4 and 5). In addition, daily periods of DO saturation well above 100% (i.e. supersaturation) were recorded as early as March and continued through October (Figure 4). These changes in DO saturation - large diel swings and supersaturation - often occur in response to nutrient enrichment (EPA 2013, Hynes 1972).

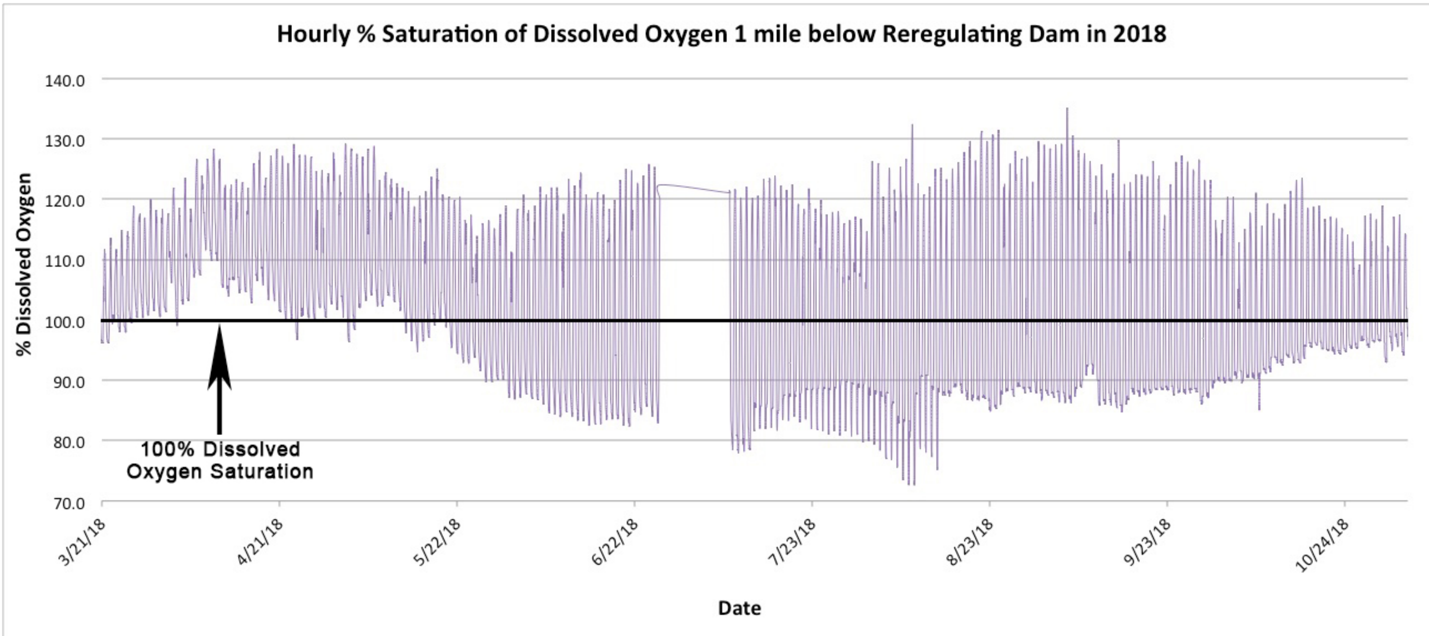


Figure 4. 2018 Hourly percent saturation of DO (%sat) at RM 99.

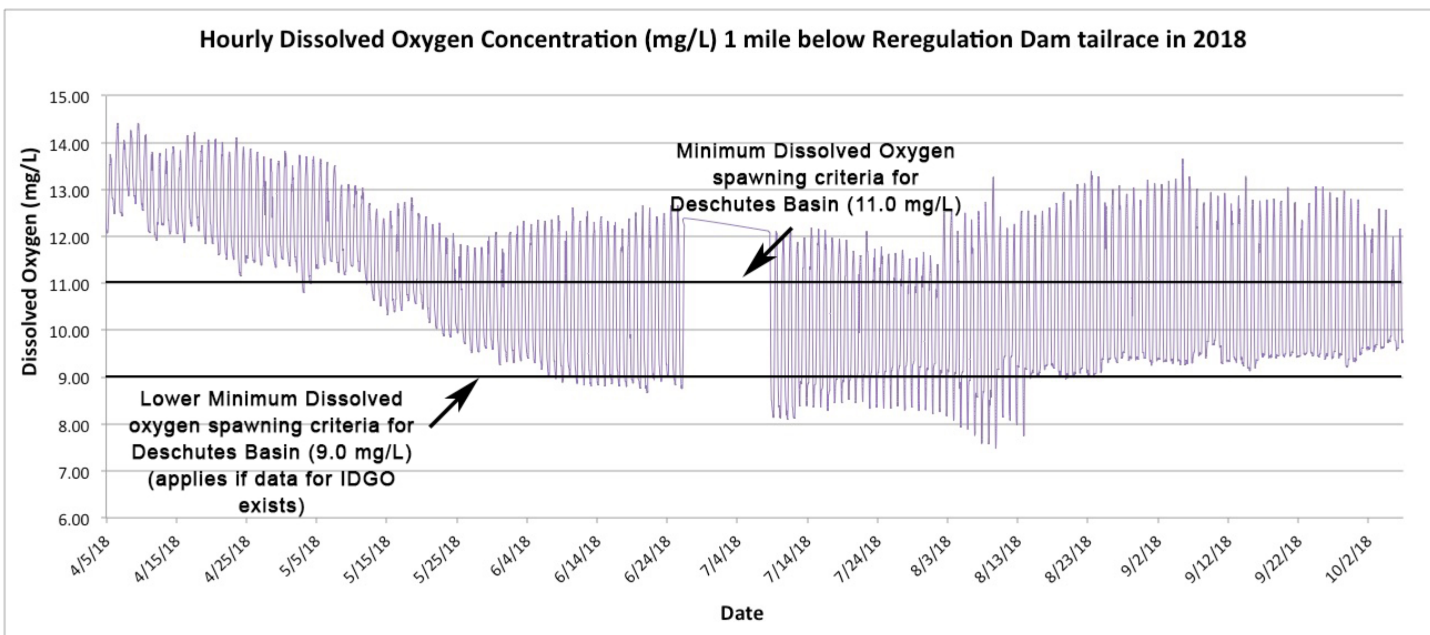


Figure 5. 2018 Hourly concentration of DO (mg/L) at RM 99.

Figure 5 shows the highest daily max value for DO concentration occurred on April 6, 2018 at 1600 with a reading of 14.42 mg/L. After May 13, 2018 daily minimum DO levels declined until August 9, 2018 at 2100 hrs. and reached an absolute minimum of 7.49 mg/L (Figure 5). Maximum daily DO concentrations remained above 11 mg/L, and daily minimums stayed above 8 mg/L with the exception of some minimum readings below 8 mg/L in August (Figure 5). Minimum DO values dropped below 9 mg/L in early June 2018. However, in prior years DO has remained above 9 mg/L until July (Figure 6).

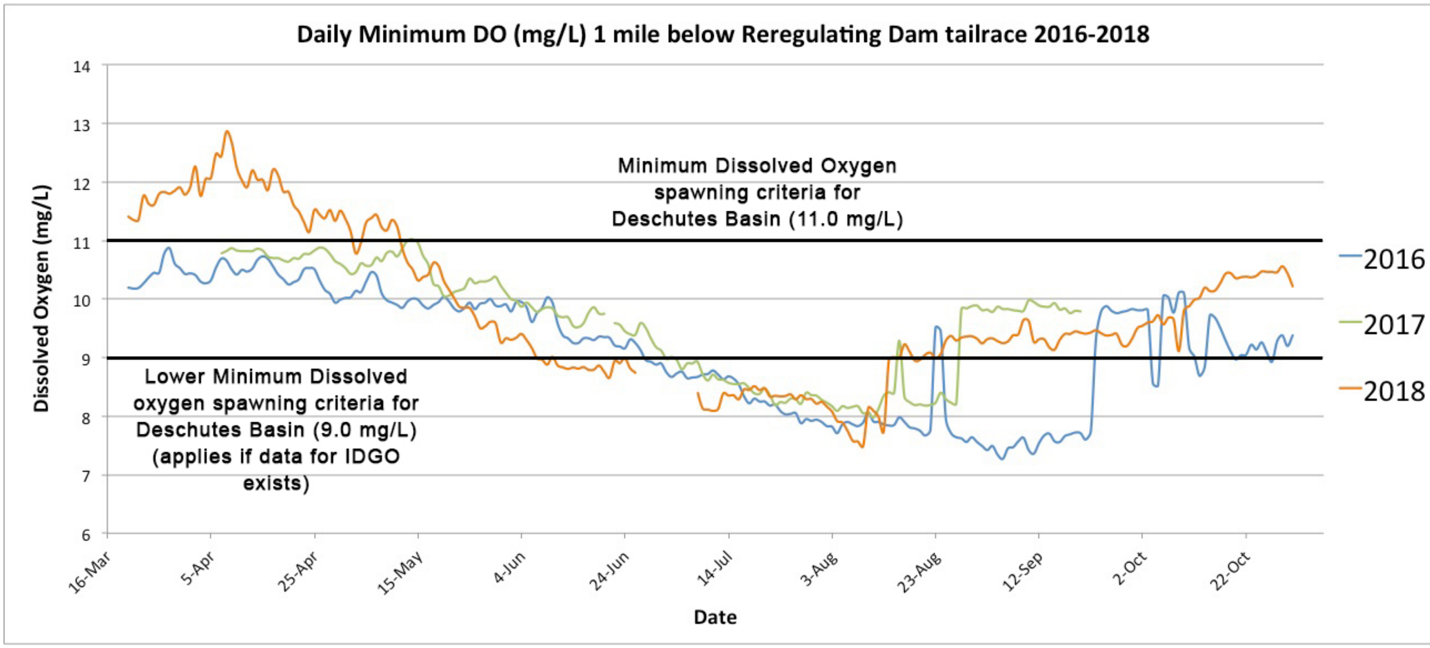


Figure 6. 2016-2018 Daily minimum DO concentration (mg/L) at RM 99 (DRA data). Minimum DO levels dropped below the lower minimum DO criteria, 9.0 mg/L (lower black line), during trout and salmonid spawning from June through mid-August.

Results for DO in 2018 are similar to results from 2016 and 2017, although, DO concentration is much higher in spring 2018 (Figure 6). In 2016, 2017, and 2018 minimum DO concentrations dropped below 9 mg/L between June and July and continued to drop below 9 mg/L on a daily basis until late August and early September (Figure 6). Because trout spawning continues until at least the end of July or early August, and thus intergravel egg/fry incubation occurs until early September (Zimmerman & Reeves 1995), any DO concentration below 9 mg/L during this time period is a failure to meet the basin water quality standards for salmonid spawning and incubation (Oregon Administrative Rules 340-041-0016).

pH:

Figure 7 shows the hourly pH measurements recorded from March 21, 2018 to November 1, 2018. Again, the break in the pH data from June 26th through July 8th was due to a full memory bank causing the data sonde to shut down. As with temperature and DO, the width 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: 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 width of the line) indicates greater plant biomass and sunlight, which results in more photosynthesis. Because pH changes in response to algal density, high pH levels are also a useful indicator of excess nutrients in contaminated water (EPA 2013).

Oregon's water quality standards for pH in the Deschutes Basin restricts pH to a range between 6.5-8.5 standard units (Oregon Division 41 Water Quality Standards 2016). Like other water quality standards, the pH standard was set to protect aquatic life. While a pH just above 8.5 is not lethal to aquatic life, such levels do not provide adequate protection (Robertson-Bryan 2004) and serve as an indicator of excessive algal growth.

Hourly pH readings above 8.5 were recorded as early as March 20, 2018 when the sonde was deployed and the daily maximum pH was recorded above 8.5 throughout the entire monitoring season (Figure 7). In 2016, a low flow year, the

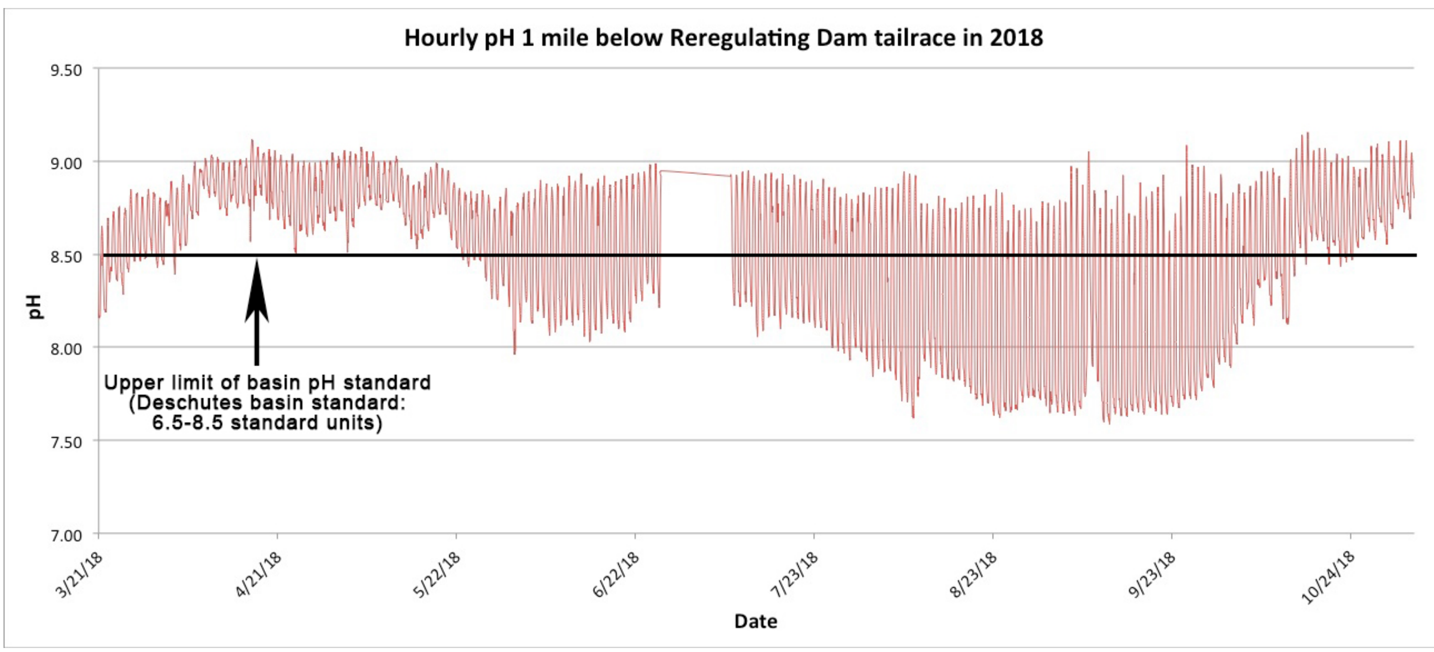


Figure 7. 2018 Hourly pH at RM 99.

recorded data show that hourly pH readings exceed 8.5 in late April and May and that maximum pH exceeded 9.5 in July and October (Figure 8). In 2017, a moderately high flow year, the first recorded pH reading above 8.5 occurred later—on May 10, 2017. During 2018 daily maximum pH levels exceeded 9.0 as early as April 8th and continued close to or above 9.0 until May 11, 2018 (Figure 8). The maximum recorded pH occurred on November 8, 2018 at 1400 hours with a reading of 9.17.

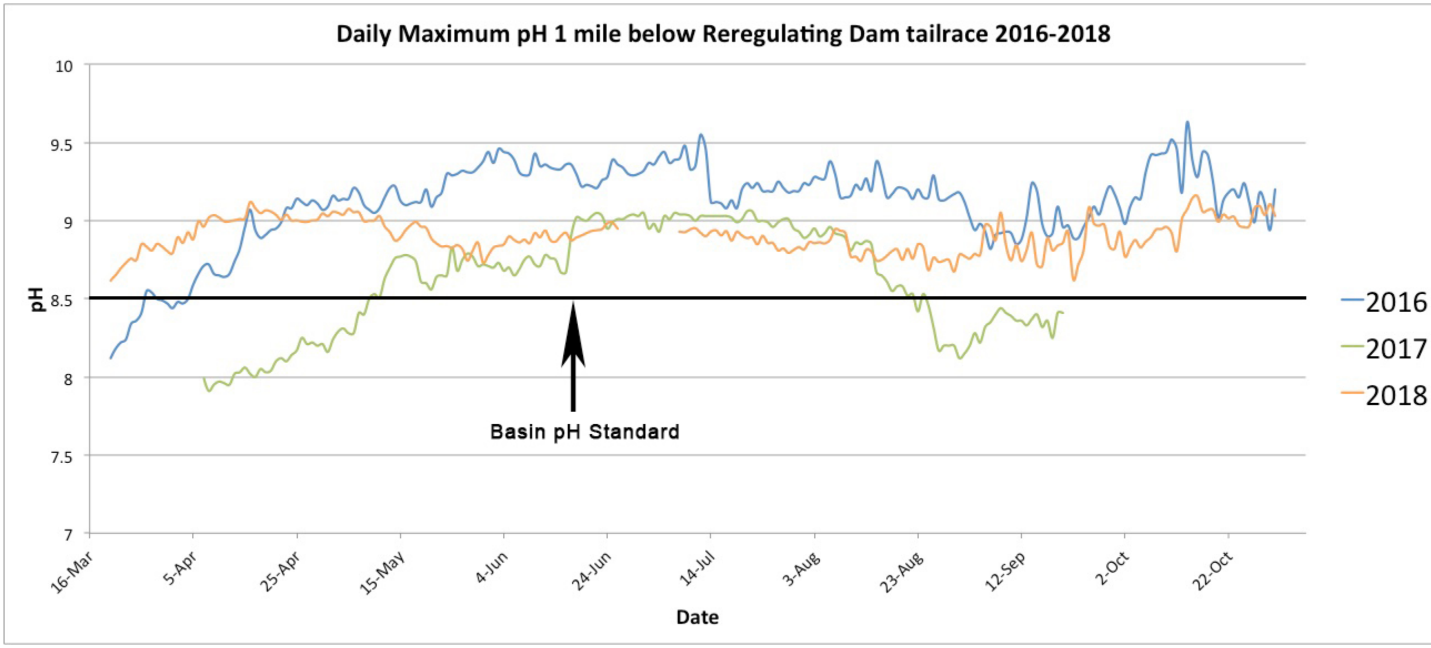


Figure 8. 2016-2018 Daily maximum pH at RM 99.

Compared to spring in 2016 and 2017, pH levels were higher in spring 2018 but pH did not remain as high as in 2016 (Figure 8: blue line). These annual differences in pH are not likely due to differences in flow alone but reflect different weather patterns year to year and timing of annual algal activity in Lake Billy Chinook, its tributaries, and the lower Deschutes River.

DISCUSSION

Temperature:

Temperature management has been cited by the Confederated Tribes of the Warms Springs Reservation and Portland General Electric (Joint Applicants) as one of the key objectives of the SWW tower and one of the main reasons for releasing surface water from Lake Billy Chinook (Water Quality Management & Monitoring Plan 2002). Specific temperature requirements for the Project have been set out in the Water Quality Management & Monitoring Plan (WQMMP). That document describes how water quality is to be managed as part of the Project's water quality permit (§ 401 Certification).

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* (CH2 Method). We believe this equation does not provide a sound biological basis for temperature management at the PRB complex and has caused water temperatures to exceed Oregon's water quality standards. The water temperature used in the equation is the 7-day rolling average of the **maximum** (bold added for emphasis) daily temperature of the three tributaries entering LBC. We submit that using only the maximum temperature of the three tributaries does not, and cannot, result in, quoting from the WQMMP: *conditions that would exist as if the dams were not present*.

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. The daily range in temperature recorded by DRA in 2018, in the Deschutes River at RM 99, is shown by the width of the graph line in Figure 3. A model that accurately predicts water temperature below the dams *as if the dams didn't exist*, should take into account the natural diel temperature range of the three tributaries entering LBC. Using only the maximum tributary temperatures, as is currently done, cannot mimic a natural temperature regime.

Figure 9 shows the result of the current temperature management scheme. In this graph the actual 7-day average maximum temperature at the Reregulating Dam tailrace (blue line), the calculated or modeled 7-day average maximum temperature (teal line), and the pre-SWW tower 7-day average maximum temperature averaged for the years 2006-2009 (black line) are compared. Comparing the actual observed average temperature at the Reregulating Dam to the average maximum temperature for 2006-2009, shows that surface water releases resulted in an increase in water temperature throughout the spring and early summer. Increased water temperatures in the spring and summer, compared to the 2006-2009 average, were also observed in 2016 and 2017.

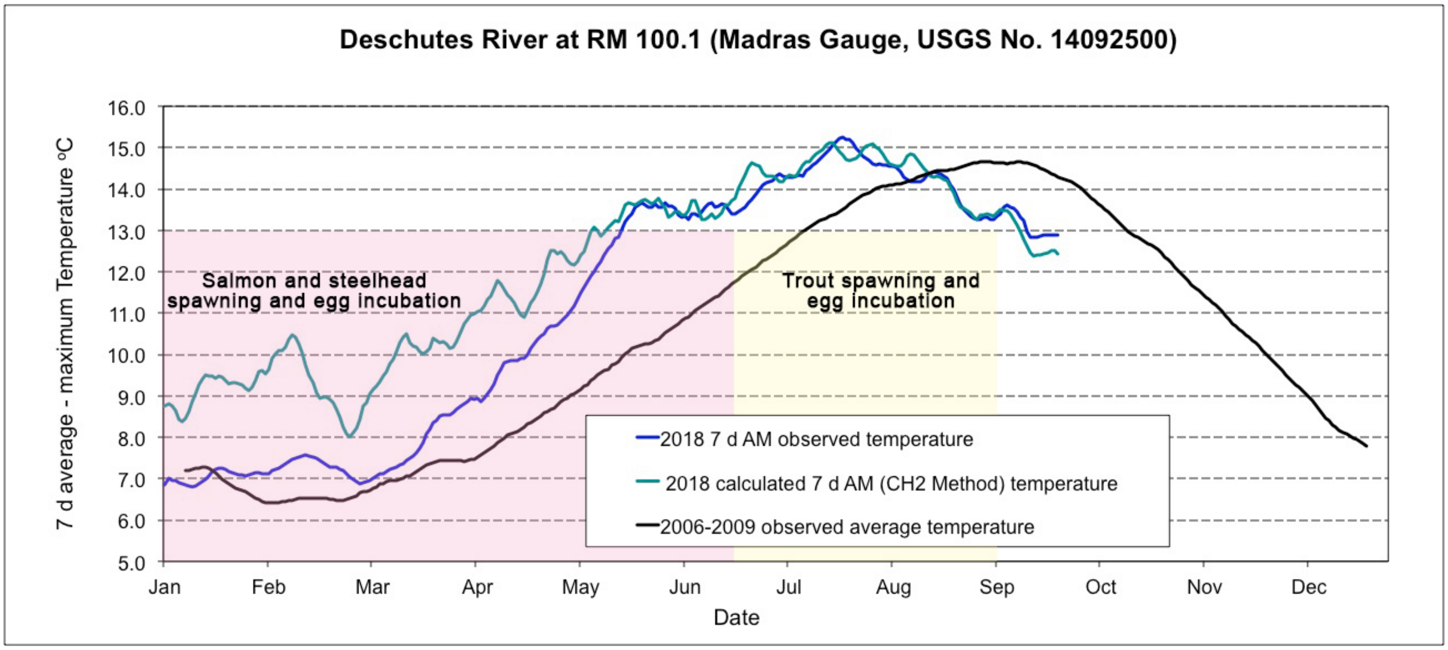


Figure 9. Comparison of the observed, modeled and pre-tower water temperature at the Reregulating Dam tailrace in 2018. Pink and yellow shaded areas show salmonid rearing period with Oregon's temperature standard of 13°C for streams supporting salmonid spawning.

As a result of PGE implementing the new temperature management approach in 2010, the maximum annual temperature now occurs about four to six weeks earlier (early to mid-July) than when 100% bottom water was released prior to 2010. However, while the annual peak temperatures occur earlier in the summer (one of the goals of the SWW tower), they are no cooler than pre-SWW tower maximum temperatures. In addition, the higher temperatures since 2010 in the late winter through early summer have had several important negative ecological impacts on the river, as we describe below.

1) DRA's guide hatch surveys have confirmed earlier emergence of the major insect hatches, and consistently low to moderate abundance of adult insects (Hafele 2014, 2015, 2016, 2018). Increased water temperature can affect aquatic invertebrates in several ways: 1) changes in egg development, 2) faster larval growth, 3) earlier adult emergence, and 4) smaller adults due to faster larval development and earlier emergence, which has been correlated with a decline in insect fecundity (Ward 1992).

2) Algal growth is accelerated by higher water temperature (Bellinger & Sigee 2010),

which, along with greater nutrients released with surface water, has resulted in nuisance levels of algae in Lake Billy Chinook and the lower Deschutes River. Two periphytic (attached) species that reduce suitable habitat for aquatic insect larvae have significantly increased in abundance since 2010. As discussed below, the increased algal growth negatively affects pH and dissolved oxygen concentrations in the river downstream from the Project.

3) Warmer water (and higher nutrients) has led to a shift in the aquatic invertebrate community with an increase in more pollution tolerant species (primarily worms and snails) and a decline in pollution sensitive species (mostly mayflies and stoneflies) in the lower Deschutes River (Edwards 2018).

   There has been a dramatic increase in numbers of the polychaete worm *Manayunkia speciosa* (Campbell 2013, Nightengale et al. 2017). *M. speciosa* is the intermediate host of *Ceratonova shasta*, a lethal parasite for Chinook Salmon *Oncorhynchus tshawytscha*. *C. shasta* infects both juvenile and adult Chinook Salmon with up to 90% mortality rates of infected fish (ODFW 2016). In 2014 the US Fish and Wildlife Service (USFWS) began investigating the increase in *C. shasta* induced mortality in Deschutes River spring Chinook Salmon. A news release on the USFWS website stated, "the work has shown that parasite numbers are driven by water temperatures and suggests that man made and climate driven temperature changes in the lower Deschutes are indeed the likely cause for the severe increase in, and severity of, *C. shasta* infections" (Link Last Updated: May 25, 2017)(Connolly & McLean 2016).

4) A 7-day average maximum of 13°C is the Deschutes basin moving temperature standard during salmon and steelhead spawning (Oregon Administrative Rules, 340-041-0028). The 7-day moving average maximum water temperature exceeded 13°C from May 17, 2018 to September 15, 2018. This exceeds the salmon/steelhead and the trout spawning use temperature standard (Figure 9).

5) The temperature of water released at the Reregulating Dam is the primary driver of water temperatures in the upper reaches of the lower Deschutes River and influences water temperatures throughout the lower 100 miles of the river (DRA 2016b).

   The Deschutes River mouth, at the Columbia River, is the only significant cold water refugium for upstream migrating adult salmonids between the Dalles Dam and Lower Monumental Dam (>155 miles) (Keefer et al. 2018). Cold water refugia are defined as, "portions of a water body where, or times during the diel cycle when, the water temperature is at least 2°C colder than the daily maximum temperature of the adjacent well mixed flow of the water body" (EPA 2016). Thermal refugia are commonly used by adult summer steelhead *Oncorhynchus mykiss* and Chinook Salmon when water temperatures in the Columbia are near or above thermal maxima, typically from July through August (20°C-22°C for steelhead and 21°C-22°C for Chinook Salmon) (EPA 2016). Presently, the impact of the SWW tower on summer thermal refugium in the Deschutes River is unknown but the Sockeye Salmon *Oncorhynchus nerka* die-off in the Deschutes River during spring of 2015 raised concern about temperature management at the Project (Link)(ODFW 2015).

Dissolved Oxygen:

Aquatic animals require adequate oxygen to survive. The amount of dissolved oxygen in water is affected by several factors. For example, cold water can hold more dissolved oxygen 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 absorbed by the water, increasing its concentration. Last, photosynthetic activity from aquatic plants, which include suspended and attached algae, add oxygen to the water.

The concentration of dissolved oxygen 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 dissolved oxygen(Willers 1991). In addition, the oxygen requirements for developing salmonid eggs are greater than for fry and adults (ODFW 2000). For these reasons, Oregon's water quality standards for DO are set to protect the most sensitive use: salmonid

Table 2. State of Oregon's dissolved oxygen criteria for the lower Deschutes River.

Beneficial Use	Dissolved Oxygen Criteria
Salmonid Spawning, including where and when resident trout spawn.	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.

spawning/rearing with higher standards applied during spawning and egg incubation periods than during non-spawning and incubation periods. Oregon's DO criteria for the Deschutes basin are listed in Table 2.

The criterion applied during spawning periods can depend on intergravel DO concentration (Table 2). Intergravel dissolved oxygen (IGDO) is the amount of oxygen dissolved in the water that flows within the stream substrate. Adequate oxygen within streambed gravels is critical for developing salmon and trout eggs and incubating fry. Through a series of interim agreements between PGE, the CTWS, and ODEQ the DO standard currently being applied by ODEQ for the lower Deschutes River during steelhead and salmon spawning is the lower standard of 9.0 mg/L minimum concentration (DRA 2017). Intergravel DO studies, completed by PGE, show that intergravel DO has been above 8.0 mg/L (Campbell 2013). While the DRA has concerns about the quality and accuracy of these intergravel DO studies, even when the 9.0 mg/L minimum is applied, serious departures from the DO standard have occurred— as we describe below.

Figure 10 shows the map, from Oregon's water quality standards and developed with input from the Oregon Department of Fish & Wildlife (ODFW), that identifies the location and time of year salmon and steelhead spawning occurs in the Deschutes Basin and thus when the DO standard for spawning should be applied to protect salmonid reproduction. The spawning season for the reach from the Reregulating Dam to Warm Springs River (RM 84) (shown in yellow) is October 15 - June 15, while the spawning period from Warm Springs River to the mouth of the Deschutes at the Columbia River (shown in orange) is October 15 - May 15.

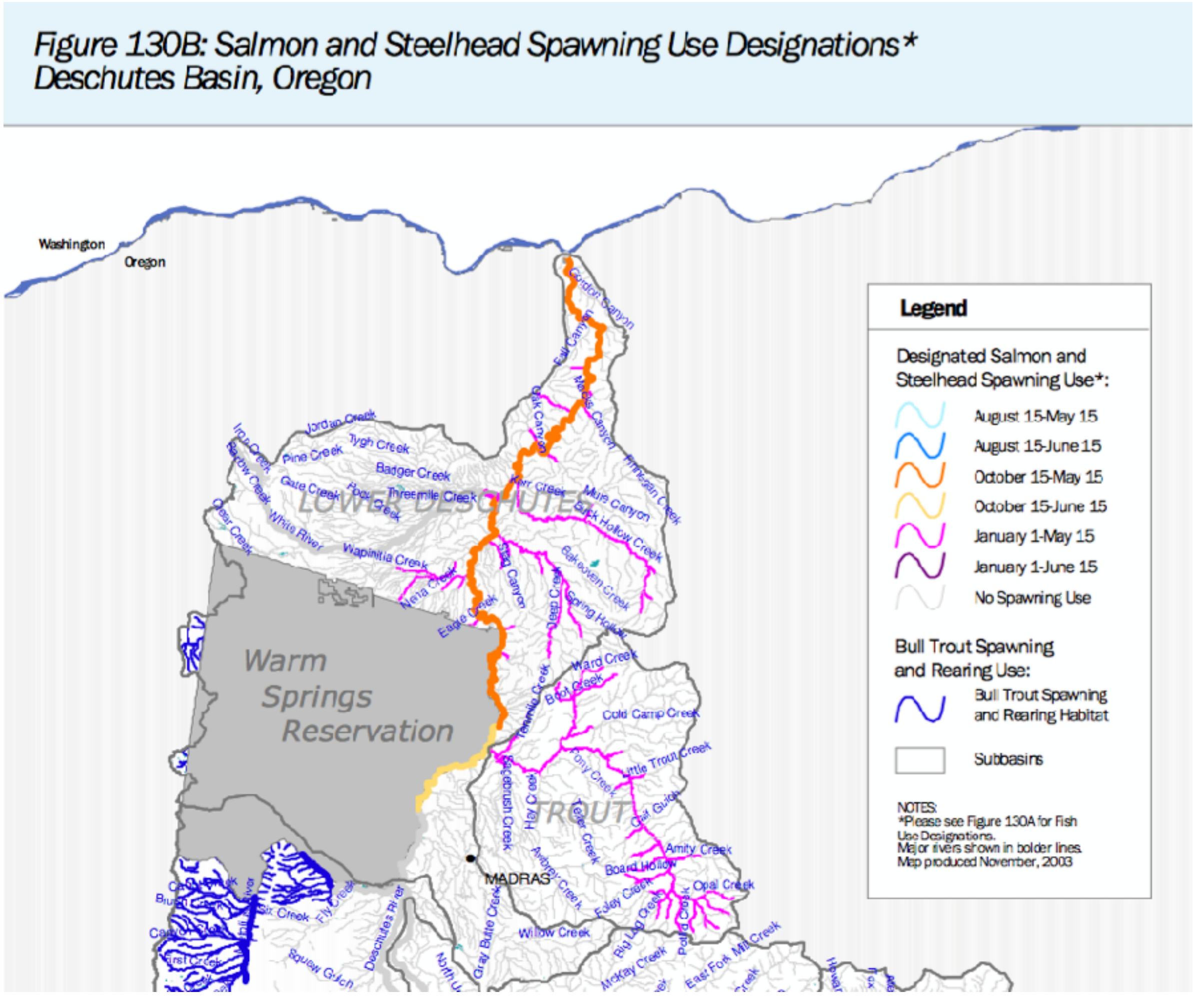


Figure 10. Map showing designated spawning periods for salmon and steelhead in Deschutes Basin. (Taken from Oregon OAR's section 340-041-0016)

It is important to note that this map identifies the time and place of spawning for only salmon and steelhead (and Bull Trout *Salvelinus confluentusin* in some watersheds), but not for resident trout spawning. However, 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*** (bold added for emphasis). In other words, Oregon's DO standard requires that the DO criteria of 11.0 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.

Studies have documented trout spawning in the lower Deschutes River until the end of July (Zimmerman & Reeves 1995). DRA volunteers have also documented, at RM 99, resident trout spawning in late July. Staff at ODFW, in a letter sent to the Deschutes River Alliance in 2019, confirmed observations of resident trout spawning in late July. As a result, the spawning/incubation criteria of 9.0 mg/L (11.0 mg/L if IGDO falls below 8.0 mg/L) is applicable until late August or early September to take into account all salmonid egg incubation through fry emergence, which continues for weeks after spawning is completed.

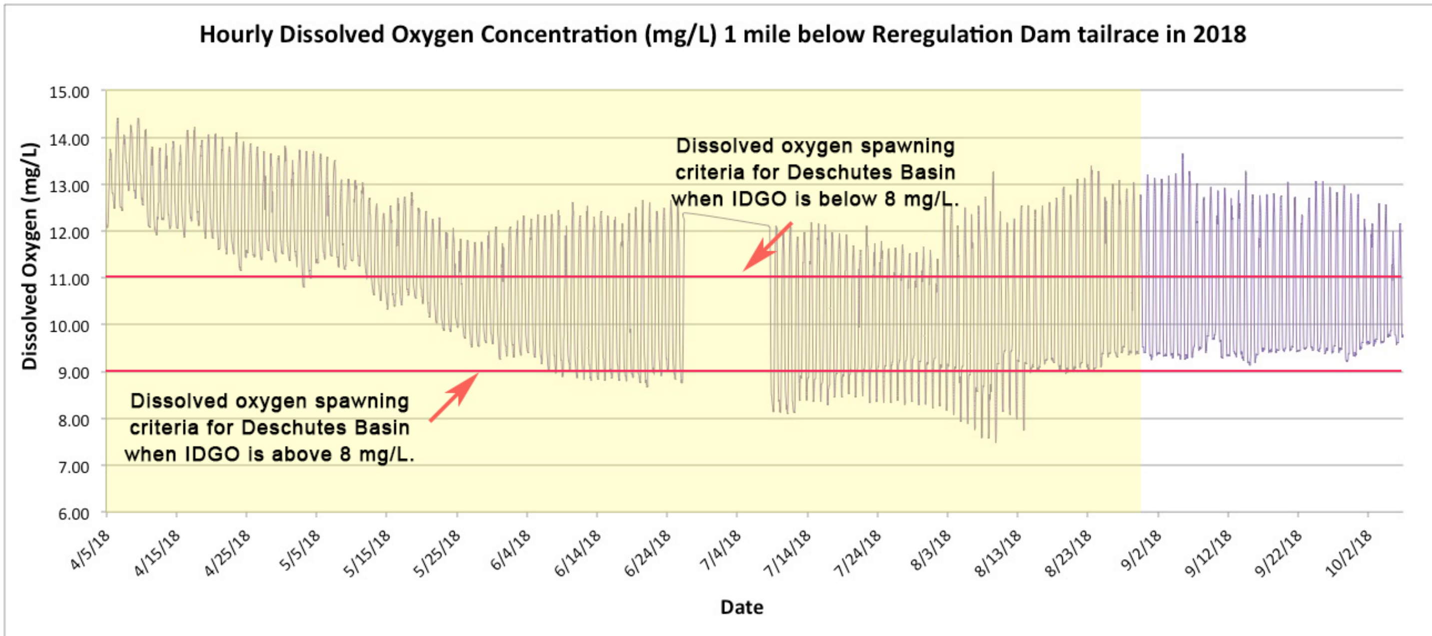


Figure 11. Hourly dissolved oxygen concentrations at RM 99 in 2018. **Shaded area shows spawning/incubation season through emergence for salmon, steelhead, and trout.**

Figure 11 shows that DO levels began dropping below the 9.0 mg/L minimum concentration in early June and continued to fall below 9.0 mg/L daily until August 14, 2018. Because trout spawning and incubation are occurring during this time, on each of these days DO concentration fell below the applicable basin standard. Plus, 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 (Figure 11).

This failure to protect trout spawning and egg incubation violates Oregon's water quality standards. Spilling water over the Reregulating Dam spillway introduces 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. The pH standard is designed to protect aquatic life from the harmful effects of water that is too acidic or too alkaline. Like temperature and DO, pH 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, including 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 and respiration continues, so that CO2 levels increase — causing increased carbonic acid production and a decline in pH.

Because both low (acidic) and high (alkaline) pH levels are harmful to aquatic life, the water quality standard includes both a minimum and a maximum pH value. Since high pH levels (>8.5) are often the result of increased photosynthetic activity, pH is also a useful indicator of excessive algal growth and excess nutrients in freshwater (EPA 2013). As algal biomass increases, the difference between the daily minimum and maximum pH also increases as evidenced by the large swings in daily pH noted in our data (Figure 7).

Hourly pH data collected at RM 99 showed that pH was exceeding the basin standard of 8.5 when data collection began on March 20, 2018 (Figure 7). Data from 2018 show that pH continued to exceed 8.5 throughout the entire monitoring period (data sonde was removed November 29, 2018). The fact that pH levels were elevated above the 8.5 standard from March through November is a strong indicator of excessive algal growth caused by nutrient contamination. Such a high level of sustained pH poses definite stress and health risks to aquatic life including salmon, steelhead, and resident native trout (Robertson-Bryan 2004). Algal blooms, or rapid increases in the abundance of algae, occur when environmental conditions are favorable. Favorable conditions include stagnant water, full sun, warm temperatures, and eutrophic conditions. In 2018 the Deschutes Basin had a mild winter with below average precipitation. This resulted in more days of sunlight during the spring and low spring flows from tributaries. These conditions likely led to algal blooms in LBC and the Crooked and Deschutes rivers earlier than in prior years. The DRA water quality data recorded from 2016 and 2017 identifies the Crooked River as the source of many water quality issues in the lower Deschutes River due to the release of surface water having water quality properties similar to Crooked River water. Water quality issues associated with the Crooked River are described in detail in DRA 2016a. In 2018 no spring runoff events occurred in the Crooked River below Bowman Dam as seen in the hydrograph (Figure 12). This should have resulted in less agricultural runoff into the river which is generally beneficial for water quality in the lower Deschutes River. Although agricultural runoff was likely less than in prior years, pH in the Crooked River remained high in 2018 as indicated by field measurements collected by Oregon Department of Environmental Quality taken once every other month (Figure 13).

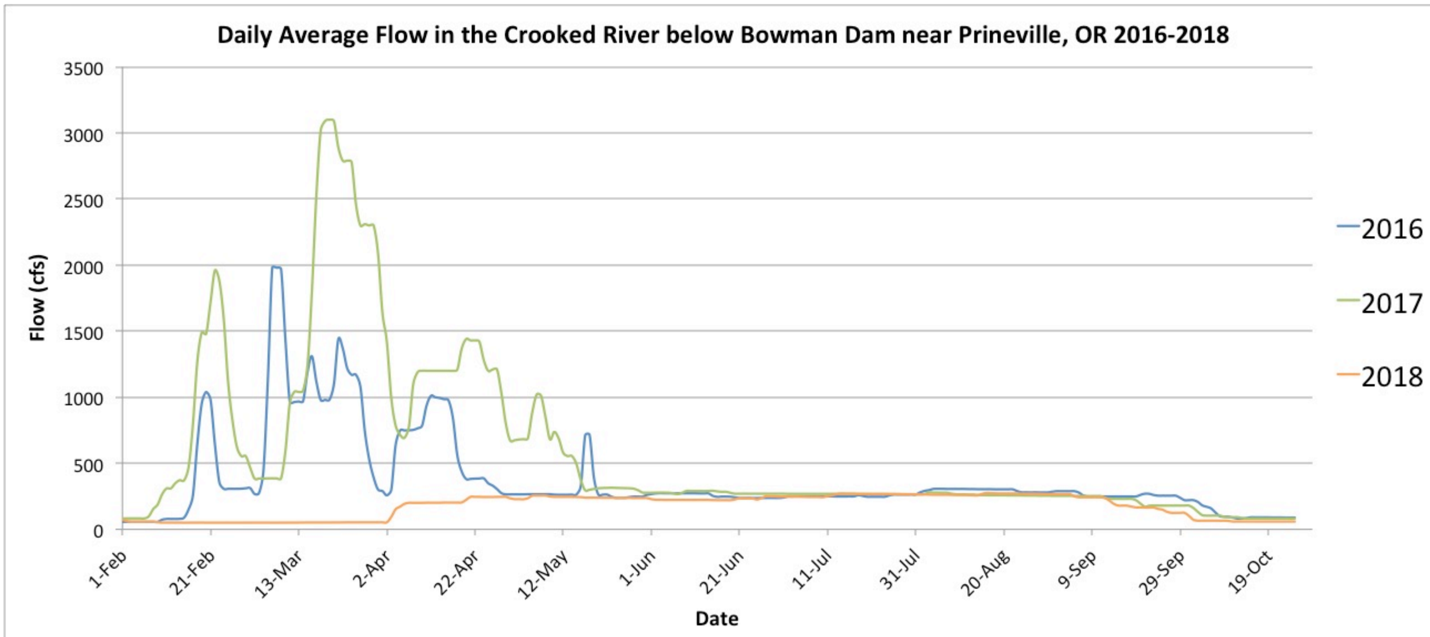


Figure 12. 2016-2018 Daily Average Flow in the Crooked River below Bowman Dam near Prineville Oregon. Spring runoff events are distinguished by peaks in the hydrograph. 2018 received far less precipitation than 2016 and 2017 and as a result had no spring runoff events.

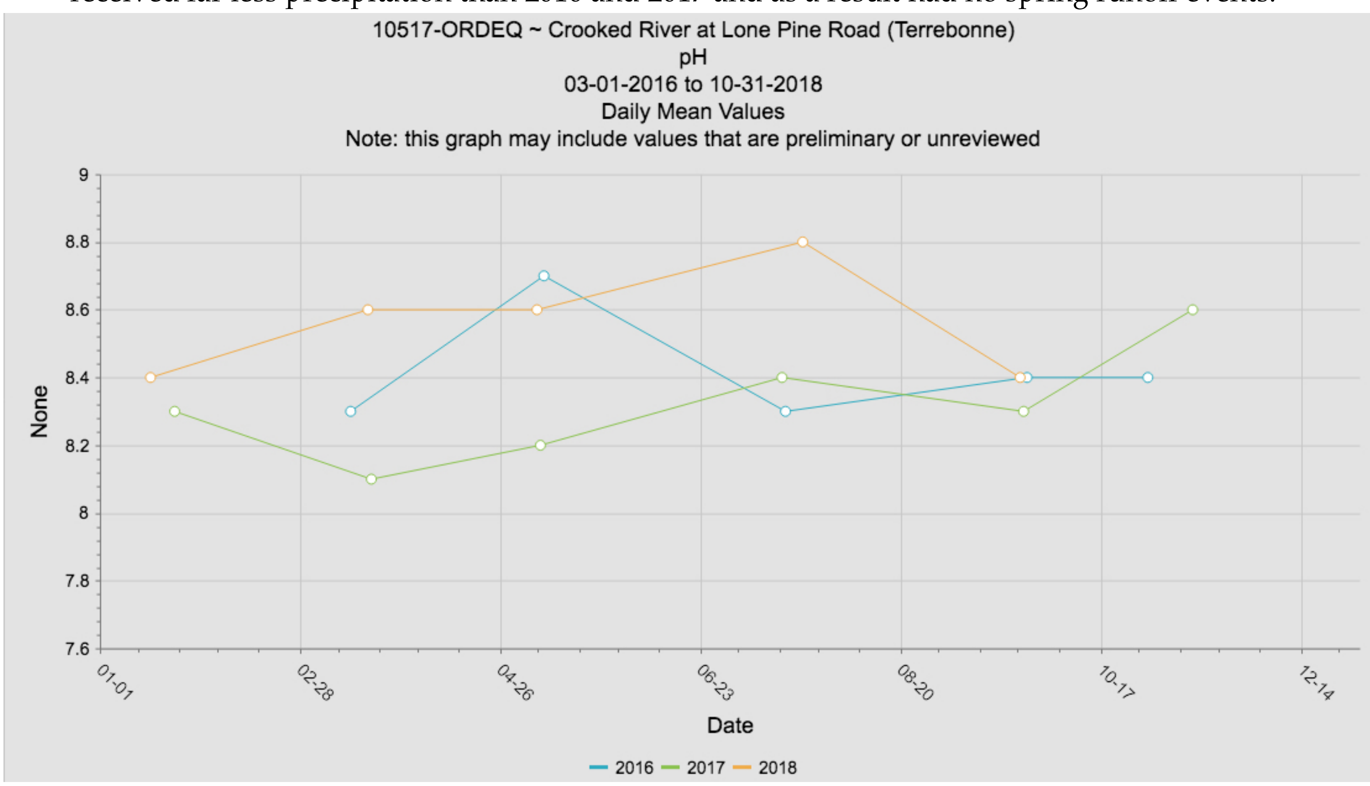
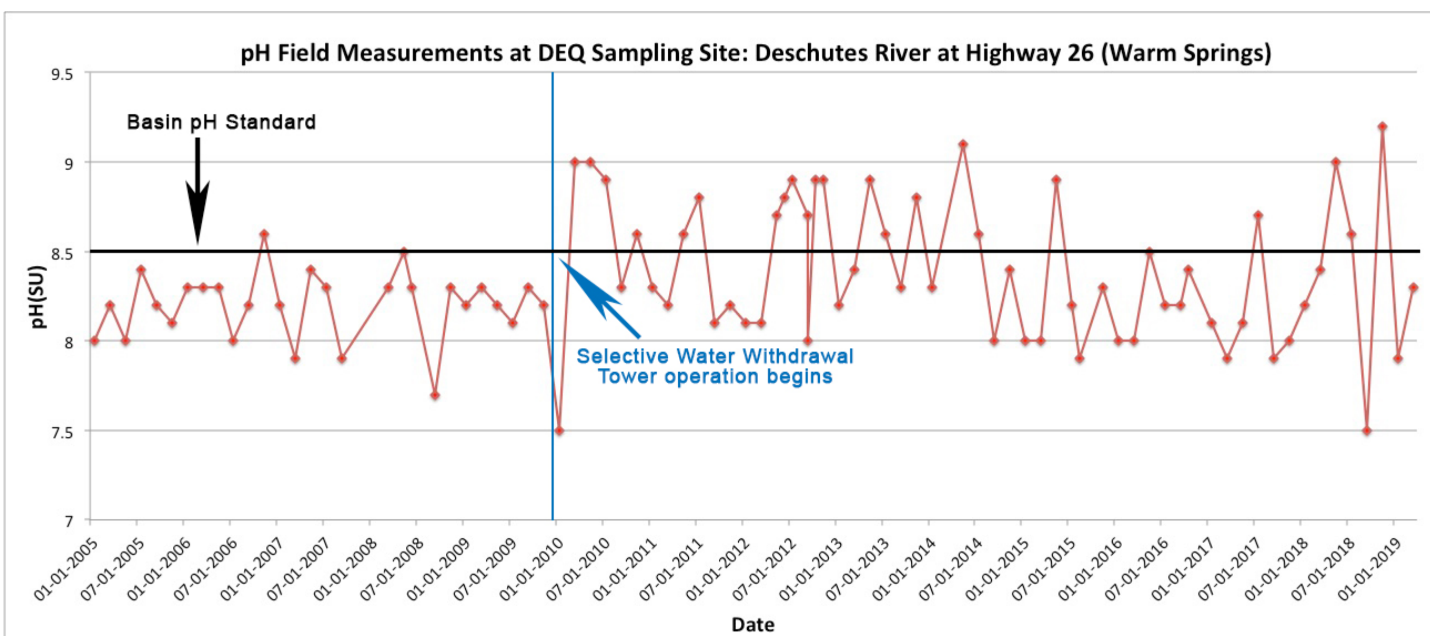


Figure 13. 2016-2018 pH field measurements at Lone Pine Road on the Crooked River. Data queried from the Oregon DEQ AWQMS (ODEQ 2016-2018).

Violations of the Deschutes Basin pH standard 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. Pre-SWW tower pH readings above 8.5 occurred in ~4% of measurements collected by DEQ from 2005-2009 (n=28) compared to post-SWW tower pH readings above 8.5 that occurred in ~38% of readings collected by DEQ from 2010-2019 (n=58) (percentages were calculated by DRA based on bi-monthly field measurements recorded by ODEQ at RM 97). Observed increases in nuisance algae in the lower river since the SWW tower began operation indicate that there has been an increase in nutrient loads to the lower river from surface water releases. The elevated water temperatures being discharged to the lower Deschutes River throughout the winter and spring may also be a factor. Increased algae in the river further raise the pH level of the water during photosynthesis. The DRA believes that data collected by Oregon Department of Environmental Quality (Figure 14), results of the DRA lower Deschutes River aquatic macroinvertebrate surveys (Hafele 2014-2016, 2018) and DRA water quality study reports (DRA 2015-2018) all clearly establish that surface water releases have a rapid and negative impact on water quality in the lower Deschutes River.

Figure 14. Bimonthly field measurements for pH collected by ODEQ from January 2005-March 2019 on the Deschutes River at HWY 26 (Warm Springs) River Mile 97. The data are divided into pre-SWW tower (before December 2009) and post-SWW tower (after December 1, 2009) categories. The range of pH values is much higher post-SWW tower operation, has a greater number of values above 8.5, and exceeds 9.0.



CONCLUSIONS

Oregon's water quality standards are set for one reason: **to protect aquatic life** (bold added for emphasis). Water quality data collected and analyzed by the Deschutes River Alliance in 2018 again show serious exceedances of Oregon's water quality standards throughout the spring, summer and fall months that continue to raise important questions about water quality management at the Pelton Round-Butte Hydroelectric Project. We believe 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 to the fullest extent possible. The WQMMP established clear management guidelines and water quality requirements for temperature, pH, and dissolved oxygen. These requirements were established to adequately protect the aquatic life in the lower Deschutes River.

The water quality exceedences summarized below have been documented by the hourly water quality data collected by the DRA at RM 99 from 2016 through 2018 as well as data reported in PGE's water quality reports to the Federal Energy Regulatory Commission. We believe the data record clearly show 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) improving lower Deschutes River water quality will be necessary for the reintroduction effort to succeed.

Temperature:

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

1) The equation (CH2 Method) being used to set the temperature targets in the lower Deschutes River is flawed by averaging the 7-day **maximum** (bold added for emphasis) temperatures of the three tributaries entering LBC. 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 Project did not exist.

2) Releasing 100% surface water from LBC from November through early June each year raises the temperature in the lower Deschutes River throughout the late winter, spring, and early summer above pre-SWW tower temperatures. This increase has altered aquatic insect life cycles 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 data collected by R2 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*. The number of individuals per square meter of stream substrate of this species increased from zero (data collected 2000-2001) pre-SWW tower to over 4,000 at sites post-SWW tower (Nightengale et al. 2016). DRA sampling of benthic invertebrates found over 8,000 *M. speciosa* per square meter in September 2016 at RM 99 (DRA 2019).

3) Temperature management in 2018 allowed water temperatures to exceed the temperature standard for spawning salmon and steelhead (7-day maximum average no greater than 13°C) from May 17th to June 15th and the temperature standard for spawning trout from May 17th until mid-September.

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 ODFW confirmed Smallmouth Bass presence in numbers never previously observed by them (R. French pers. comm. to S. Pribyl). Conditions in the lower Deschutes River that triggered this increase are not completely clear, but Figure 9 clearly shows higher water temperatures in the lower Deschutes River from April to July compared to pre-SWW tower temperatures. These increased spring temperatures are resulting 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 up the Deschutes River from the Columbia River, where they are abundant, 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. The impact of increased Smallmouth Bass numbers in the lower Deschutes River is currently unknown, but increased predation on native fishes is a definite possibility.

5) Increasing water temperature in the Deschutes River is counter-productive to larger management goals for salmonids in the Columbia basin and potentially eliminates one of the more important cold-water refugium for Upper Columbia River basin adult salmonids.

6) According to data reported to FERC by PGE, bottom water released from the SWW

tower increased from 30% on August 10, to 65% on August 12, 2017. The increase in bottom water quickly lowered the water temperature in the lower Deschutes River one mile below the Reregulating Dam by 2°C (DRA 2018). This corresponding drop in temperature demonstrates that increasing bottom water release will quickly lower temperature in the lower Deschutes River and improves water quality (DRA 2018).

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). Dissolved oxygen concentration is also affected by algae and plant growth. Dense growth 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 in DO. These large diel swings measured at RM 99 can be seen on Figure 11.

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 the end of July (Zimmerman 1996). This means that resident trout incubation continues until the end of August or early September. Under current Oregon standards a minimum DO concentration of 11.0 mg/L (lower minimum of 9.0 mg/L if IDGO data available) is applicable throughout this resident trout spawning and incubation period. In 2018, failure to adhere to this DO standard for salmon/steelhead and trout spawning use occurred from June 7, 2018 through August 14, 2018 (Data interrupted from June 26, 2018 to July 8, 2018)(Figure 11).

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 pH levels to increase. The pH levels measured at the DRA study site in the lower Deschutes River in 2018 showed significant water quality exceedances of the pH standard for the Deschutes basin (6.5-8.5 standard units):

1) Daily pH measurements exceeded the upper limit for the Deschutes basin pH standard (8.5 standard units) from the start of data collection on March 20, 2018 until November 29, 2018 (Data interrupted from June 26, 2018 to July 8, 2018).

2) No management plan for lowering pH has been developed by the Joint Applicants, as required in the WQMMP when pH measurements in Project discharge exceed the weighted average pH of inflows into LBC.

3) Based on ODEQ data, pH showed an immediate and sustained increase when SWW

tower operations began (Figure 14).

The above results describe a river severely impacted by high pH caused by excessive algae and aquatic plant growth stimulated by an increased nutrient load and warmer water released from Lake Billy Chinook via SWW tower operation. Data collected by ODEQ show that this change in pH began immediately after the SWW tower began operation in 2010 (Figure 14). DRA water quality data from 2017 show that pH can be quickly improved by increasing the blend of bottom water at the SWW tower (DRA 2018).

The data record since 2010 indicate that Project operations produce frequent 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 cold-water aquatic life such as juvenile salmonids 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. As a result, 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. For example, as water temperature increases the concentration of dissolved oxygen in water declines, while at the same time salmonid metabolism increases, thus elevating their oxygen demand. Increased water temperatures also lead to increased incidence of parasites and disease in salmonids (Connolly & McLean 2016, Schaaf et al. 2017). Changes in pH affect the toxicity of other potentially toxic constituents in water. For example, the toxicity of unionized toxic ammonia (NH_3) increases as pH increases (Shiwanand & Tripathi 2013). 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 over long periods of time - days and weeks - as we have 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 3-20-18 1119	Riffle Ranch 4-23-18 1110	Riffle Ranch 7-8-18 1300	Riffle Ranch 7-13-18 1324	Riffle Ranch 8-2-2018 1115	Riffle Ranch 9-28-18 1135	Riffle Ranch 11-29-18 1102
Temperature (C)	8.5 C	10.6C	15.2C	15.6C	14.9C	13.2C	9.2C
pH	8.4	9.0	9.0	8.9	8.7	8.72	8.75
Conductivity	0.135	0.129	0.133	0.131	134	125	135
Turbidity (NTU)	5.9	-5.4			*	*	*
Chlorophyll-a	5.6	117	6	5.9	4.1	14	9.5
Dissolved Oxygen (mg/dl)	12.75	13.68	12.5	11.9	12.1	12.31	11.96
Oxygen Saturation (%)	109%	123%	124%	119%	120%	117%	104%
Battery (volts)	12.8	12.3	12.2v	12.3v	12.34	12.3	12.4

Audit Data

Location Date/Time	Riffle Ranch 3-20-18 1119	Riffle Ranch 4-23-18 1110	Riffle Ranch 7-8-18 1300	Riffle Ranch 7-13-18 1324	Riffle Ranch 8-2-2018 1115 hrs.	Riffle Ranch 9-28-18 1135	Riffle Ranch 11-29-18 1102
Temperature (C)		10.5C	15.9C	15.9C	15.1C	13.4C	9.2C
pH	8.82	9.11	9.26	8.90	8.9	9.08	9.09
Turbidity	0.81	1.7	1.4			1.47	1.18
Dissolved Oxygen (mg/L)	12.6	13.42	11.7	12.15	12.3	12.72	11.67
Oxygen Saturation (% sat)	112%	124%	121%	128%	128%	127.7%	107.5%

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:

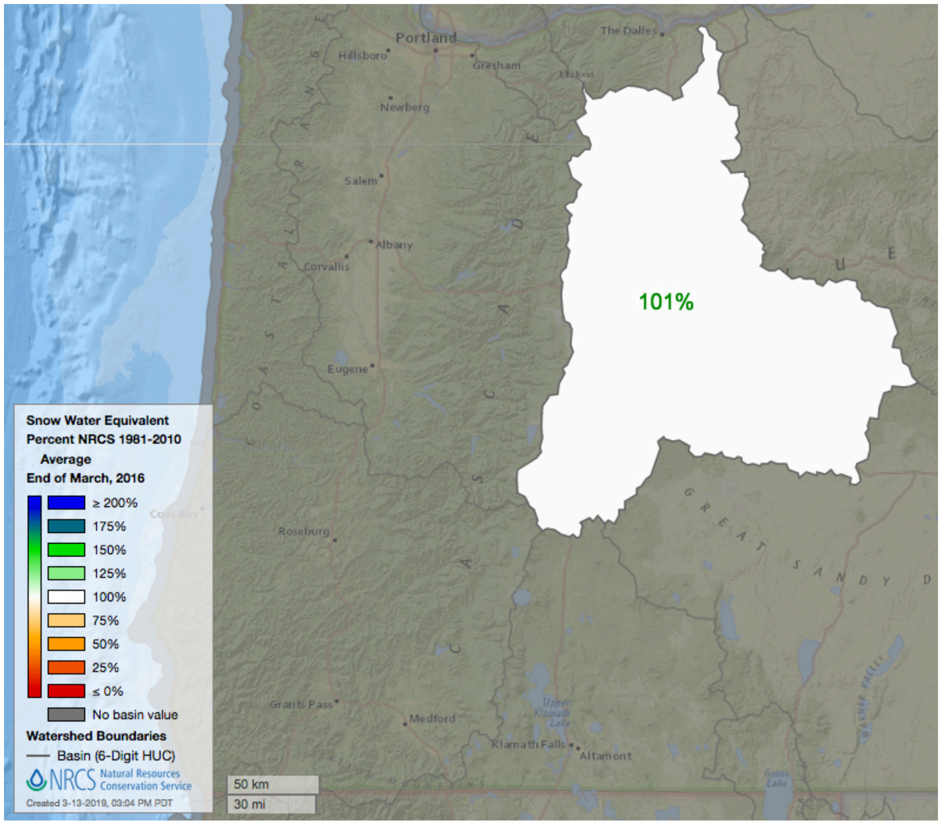
To ensure in-field accuracy, independent meters/instruments were used to measure temperature, pH and DO simultaneously with the YSI datasonde. Re-calibration and/or probe replacement were done when necessary.

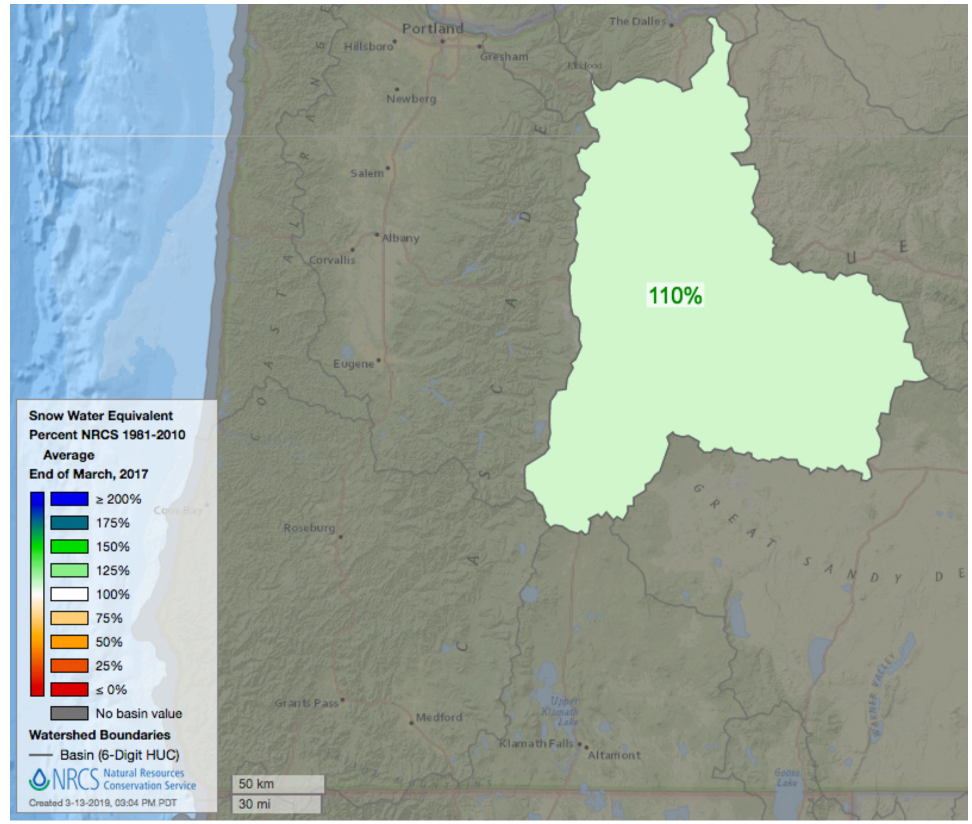
Instrument Storage:

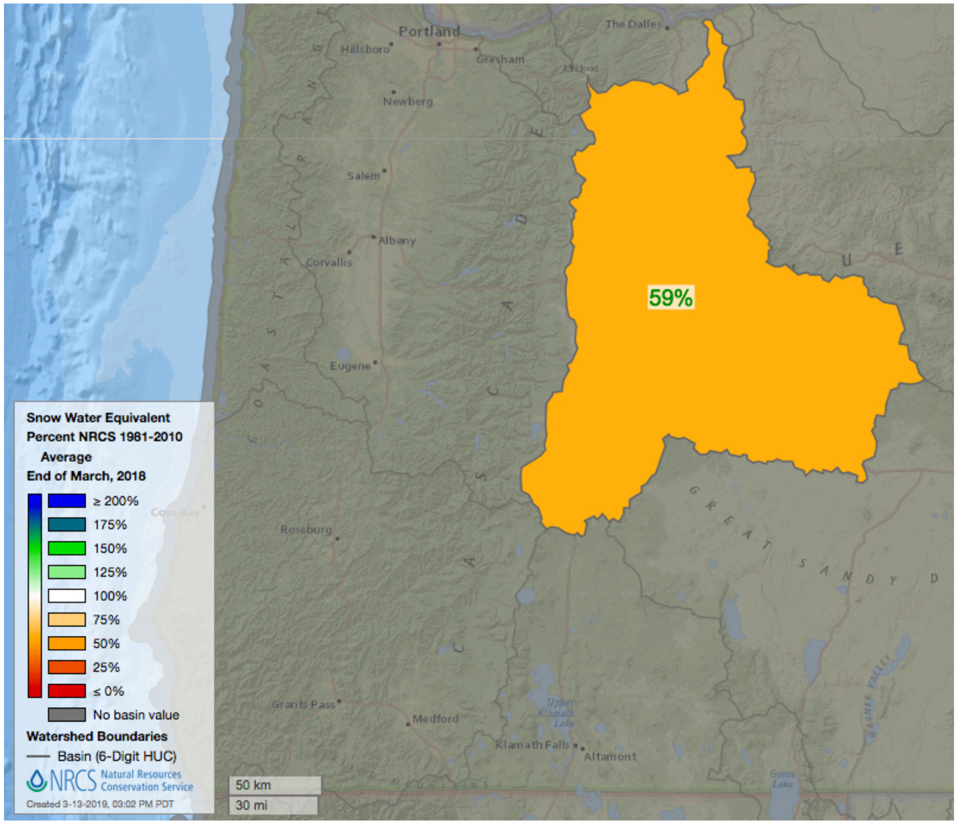
Instruments were stored in a secure and temperature controlled environment when not in use.

APPENDIX C- SUPPLEMENTAL FIGURES

Supplemental figures were queried from the NRCS National Water and Climate Center database for the years 2016-2018 for the end of March. Climate charts were obtained from the NOAA Climate Chart database for Redmond, OR for the years 2016-2018.







59%
Portland
Salem
Eugene
Snow Water Equivalent
Percent NRCS 1981-2010
Average
End of March, 2018
≥ 200%
175%
150%
125%
100%
75%
50%
25%
≤ 0%
No basin value
Watershed Boundaries
Basin (6-Digit HUC)
NRCS Natural Resources Conservation Service
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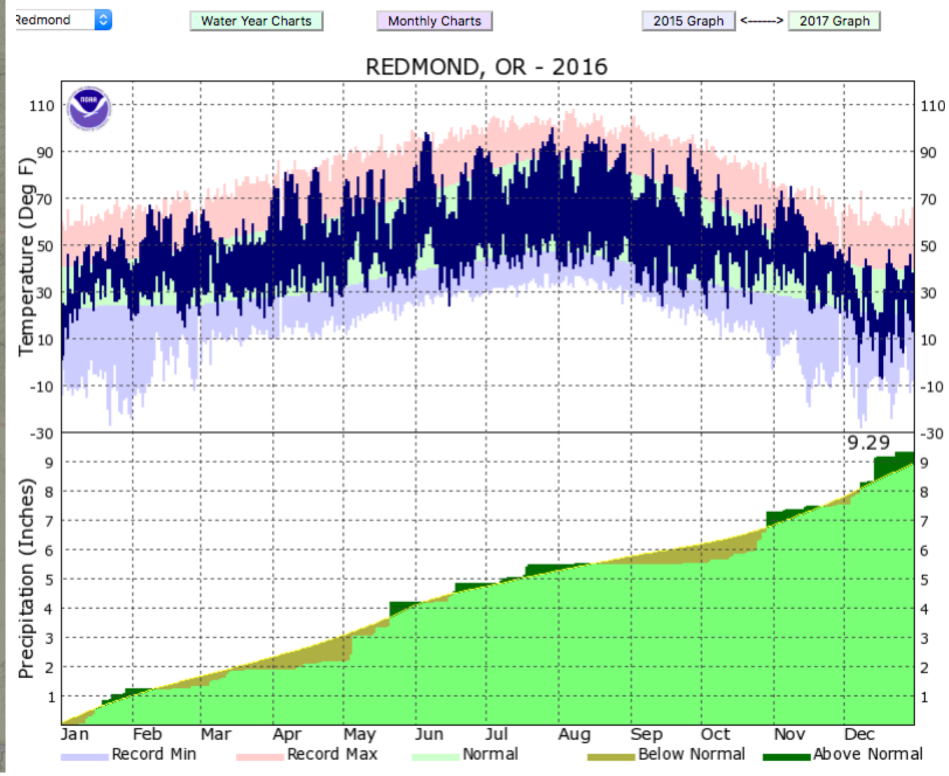
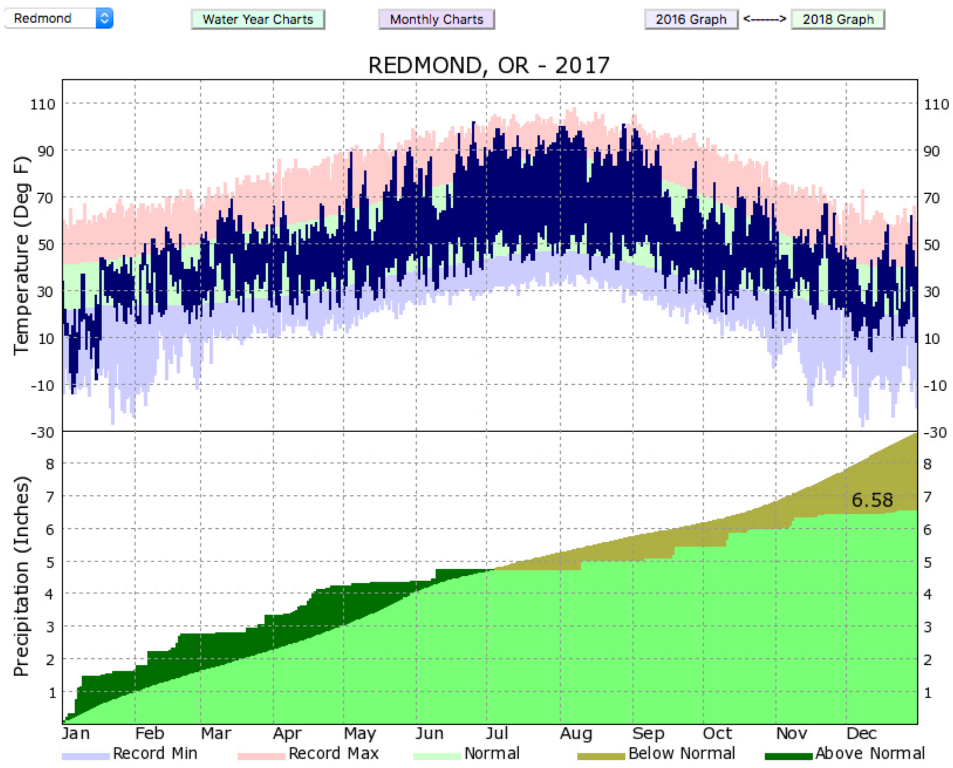
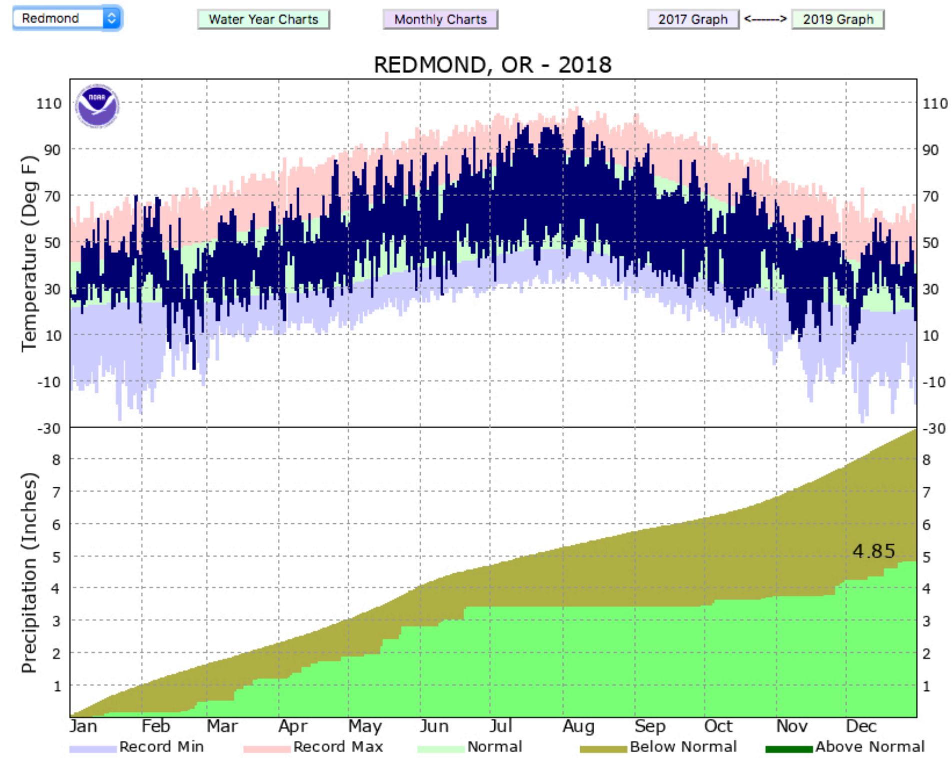
50 km
30 mi



Water Year Charts
Monthly Charts
2015 Graph
2017 Graph
REDMOND, OR - 2016
Temperature (Deg F)
Precipitation (Inches)
9.29
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Record Min
Record Max
Normal
Below Normal
Above Normal



Redmond
Water Year Charts
Monthly Charts
2016 Graph
<------>
2018 Graph
REDMOND, OR - 2017
Temperature (Deg F)
Precipitation (Inches)
6.58
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Record Min
Record Max
Normal
Below Normal
Above Normal



Redmond
Water Year Charts
Monthly Charts
2017 Graph
<------>
2019 Graph
REDMOND, OR - 2018
Temperature (Deg F)
Precipitation (Inches)
4.85
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Record Min
Record Max
Normal
Below Normal
Above Normal