AVISTA CORPORATION

LAKE SPOKANE DISSOLVED OXYGEN WATER QUALITY ATTAINMENT PLAN EIGHT-YEAR REPORT

WASHINGTON 401 CERTIFICATION
FERC LICENSE APPENDIX B, SECTION 5.6

SPOKANE RIVER HYDROELECTRIC PROJECT
FERC PROJECT NO. 2545

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and

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March 30, 2020

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1.0 INTRODUCTION

Avista Corporation (Avista) received a new, 50-year license from the Federal Energy Regulatory Commission (FERC) on June 18, 2009 (FERC 2009) for the Spokane River Hydroelectric Project (Project). The project consists of five dams on the Spokane River, including Long Lake Hydroelectric Development (HED), which creates Lake Spokane. The license incorporates a water quality certification (Certification) issued by The Washington Department of Ecology (Ecology) under Section 401 of the Clean Water Act (Ecology 2009).

Ecology determined that the dissolved oxygen (DO) levels in certain portions of the Spokane River and Lake Spokane do not meet Washington's water quality standards. Consequently, those portions of the river and lake are listed as impaired under Section 303d of the Clean Water Act. To address this, Ecology developed the Spokane River and Lake Spokane Dissolved Oxygen Total Maximum Daily Load Water Quality Improvement Report (issued February 12, 2010).

Avista does not discharge nutrients into either the Spokane River or Lake Spokane, however, the impoundment creating Lake Spokane increases the residence time for water flowing down the Spokane River, and thereby influences nutrients and how they affect DO levels. Reduced DO levels are largely due to the discharge of nutrients into the Spokane River and Lake Spokane. Nutrients are discharged into the Spokane River and Lake Spokane by point sources, such as waste water treatment facilities and industrial facilities, and from non-point sources, such as tributaries, groundwater, and stormwater runoff, relating largely to land-use practices. In an effort to address low DO levels and to comply with Section 5.6.C of the Certification, Avista submitted an Ecology-approved Lake Spokane Dissolved Oxygen Water Quality Attainment Plan (DO WQAP) to FERC on October 8, 2012. Avista began implementing the DO WQAP upon receiving FERC's December 19, 2012 approval.

DO WQAP

The DO WQAP addresses Avista's proportional level of responsibility, as determined in the Spokane River and Lake Spokane Dissolved Oxygen Total Maximum Daily Load (DO TMDL). It identified nine potentially reasonable and feasible measures to improve DO conditions in Lake Spokane by reducing non-point source phosphorus loading into the lake. It also incorporated an implementation schedule to analyze, evaluate, and implement such measures. In addition, it contains benchmarks and reporting sufficient for Ecology to track Avista's progress toward implementing the plan within the ten-year compliance period identified in the DO WQAP (Figure 1).

The DO WQAP included a prioritization of the nine reasonable and feasible mitigation measures based upon several criteria including, but not limited to, quantification of the phosphorus load reduction, DO response time, likelihood of success, practicality of implementation, longevity of load reduction, and assurance of obtaining credit. From highest to lowest priority, the following summarizes the results of the measure prioritization: reducing carp populations; managing aquatic weeds; acquiring, restoring, and enhancing wetlands; reducing phosphorus from Hangman Creek sediment loads; educating the public on improved septic system operations; reducing lawn area; providing native vegetation buffers; and converting grazing land to conservation or recreation use. One measure, which involved modifying the intake of an agricultural irrigation system, was removed from the list, as it was determined infeasible given it would create adverse effects on crop production.

Based on preliminary evaluations, Avista proposed to focus its initial efforts on two measures: reducing carp populations and aquatic weed management, which were expected to have the greatest potential for phosphorus reduction.

Avista concluded in its 2013 Annual Report, that harvesting macrophytes in Lake Spokane at senescence, would not be a reasonable and feasible mitigation measure to reduce total phosphorus in Lake Spokane. However, Avista will continue, as appropriate, to implement winter drawdowns, herbicide applications at public and community lake access sites, and bottom barrier placement to control invasive/noxious aquatic weeds within Lake Spokane. Avista may also, through adaptive management, reassess opportunities to harvest macrophytes to control phosphorus in the future.

Avista included a recommendation in its 2014 Annual Report, to implement a pilot study utilizing a combination of mechanical methods (including spring electrofishing, passive netting, and winter seining), to identify the most effective method to remove carp from Lake Spokane. Ecology approved the 2014 Annual Report and the recommendation to move forward with the carp removal pilot study. Avista has been working with Ecology and Washington Department of Fish and Wildlife (WDFW) to plan and implement the carp removal efforts, a summary of which is provided in Section 3.2 (2019 Implementation Measures) and Section 5.0 (Proposed Activities for 2020).

As required by the DO WQAP, this report provides an Eight-Year Report which broadly assesses the progress made towards improving Lake Spokane's water quality through the implementation of the selected reasonable and feasible measures. The water quality evaluation includes monitoring and modeling results, as available, and addresses year to year variability and trend analyses. In addition, the report includes the 2019 annual climate and flow data, implementation activities, effectiveness of the implementation activities, and proposed actions for 2020. The report, however, does not include modeling results, as Avista did not run the CE-QUAL-W2 hydrodynamic and water quality model (CE-QUAL-W2 model) within the last eight years based on Ecology's determination that water quality improvements, as identified in the DO TMDL, need to occur in the upstream watershed prior to running the model.

Implementation Year[1]

	Activity	2012				Year 1 2013				Year 2 2014				Year 3 2015			
		Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
DO WQAP Submittal	Submit DO WQAP to Ecology		x														
	Receive approval from Ecology*			x													
	Submit DO WQAP to FERC*			x													
	Receive approval from FERC*				x												
Carp	Phase I Analysis: Identify location and population of carp							x	x	x	x	x					
	Summarize Phase I findings [2]*									x				x			
	Phase II Analysis: Evaluate harvest technology									x	x	x	x				
	Select carp removal method(s)												x				
	Summarize Phase II findings[2], consult and discuss with Ecology													x			
	Determine with Ecology whether carp population reduction is reasonable and feasible to implement in Lake Spokane*														x		
	If determined reasonable and feasible, implement measure; if not, revise implementation strategy, monitoring, and schedule*															x	x
	If implemented, monitor for nutrient reductions															x	x
Aquatic Weed Management	Phase I Analysis: Evaluate feasibility of mechanical harvesting						x	x	x								
	Nutrient reduction evaluation							x	x								
	Summarize findings[2], consult and discuss with Ecology*									x							
	Determine with Ecology whether aquatic weed harvesting is reasonable and feasible to implement in Lake Spokane*										x						
	If determined reasonable and feasible, implement measure; if not, revise implementation strategy, monitoring, and schedule*											x	x			x	x
	If implemented, monitor for nutrient reductions											x	x			x	x
	Implement yearly aquatic weed controls through separate program[3]											x	x			x	x
Other Measures	Evaluate & implement additional measures, as appropriate																
Monitoring & Modeling	Baseline Monitoring[4]		x	x	x		x	x	x		x	x	x		x	x	x
	Ongoing Habitat Analysis[5]										x	x			x	x	
	Site Specific Nutrient Reduction Analysis[6]																
	CE-QUAL Modeling[7]																
Compliance Reporting	DO WQAP Annual Summary Report*									x				x			
	Five, Eight, and Ten-Year Reports*																

	Activity	Year 4 2016				Year 5 2017				Year 6 2018				Year 7 2019			
		Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
DO WQAP Submittal	Submit DO WQAP to Ecology																
	Receive approval from Ecology*																
	Submit DO WQAP to FERC*																
	Receive approval from FERC*																
Carp	Phase I Analysis: Identify location and population of carp																
	Summarize Phase I findings [2]*																
	Phase II Analysis: Evaluate harvest technology																
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	Determine with Ecology whether carp population reduction is reasonable and feasible to implement in Lake Spokane*																
	If determined reasonable and feasible, implement measure; if not, revise implementation strategy, monitoring, and schedule*	x	x	x	x												
	If implemented, monitor for nutrient reductions			x	x			x	x			x	x			x	x
Aquatic Weed Management	Phase I Analysis: Evaluate feasibility of mechanical harvesting																
	Nutrient reduction evaluation																
	Summarize findings[2], consult and discuss with Ecology*																
	Determine with Ecology whether aquatic weed harvesting is reasonable and feasible to implement in Lake Spokane*																
	If determined reasonable and feasible, implement measure; if not, revise implementation strategy, monitoring, and schedule*			x	x			x	x			x	x			x	x
	If implemented, monitor for nutrient reductions			x	x			x	x			x	x			x	x
	Implement yearly aquatic weed controls through separate program[3]			x	x			x	x			x	x			x	x
Other Measures	Evaluate & implement additional measures, as appropriate					x	x	x	x	x	x	x	x	x	x	x	x
Monitoring & Modeling	Baseline Monitoring[4]		x	x	x												
	Ongoing Habitat Analysis[5]		x	x			x	x			x	x			x	x	
	Site Specific Nutrient Reduction Analysis[6]																
	CE-QUAL Modeling[7]																
Compliance Reporting	DO WQAP Annual Summary Report*	x								x				x			
	Five, Eight, and Ten-Year Reports*					x											

	Activity	Year 8 2020				Year 9 2021				Year 10 2022			
		Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
DO WQAP Submittal	Submit DO WQAP to Ecology												
	Receive approval from Ecology*												
	Submit DO WQAP to FERC*												
	Receive approval from FERC*												
Carp	Phase I Analysis: Identify location and population of carp												
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	If implemented, monitor for nutrient reductions			x	x			x	x				
Aquatic Weed Management	Phase I Analysis: Evaluate feasibility of mechanical harvesting												
	Nutrient reduction evaluation												
	Summarize findings[2], consult and discuss with Ecology*												
	Determine with Ecology whether aquatic weed harvesting is reasonable and feasible to implement in Lake Spokane*												
	If determined reasonable and feasible, implement measure; if not, revise implementation strategy, monitoring, and schedule*			x	x			x	x				
	If implemented, monitor for nutrient reductions			x	x			x	x				
	Implement yearly aquatic weed controls through separate program[3]			x	x			x	x				
Other Measures	Evaluate & implement additional measures, as appropriate	x	x	x	x	x	x	x	x				
Monitoring & Modeling	Baseline Monitoring[4]												
	Ongoing Habitat Analysis[5]		x	x			x	x					
	Site Specific Nutrient Reduction Analysis[6]												
	CE-QUAL Modeling[7]												
Compliance Reporting	DO WQAP Annual Summary Report*					x							
	Five, Eight, and Ten-Year Reports*	x								x			

Notes:

* Benchmarks

(1) = Implementation Year dependent upon date of FERC approval.

(2) = Findings would be summarized in the DO WQAP Annual Summary/Report, which will be submitted to Ecology for review and approval.

(3) = Annual aquatic weed control activities implemented under the Lake Spokane and Nine Mile Reservoir Aquatic Weed Management Program.

(4) = Avista and Ecology will re-evaluate baseline nutrient monitoring program following the completeing of the 2016 season.

(5) = Ongoing in nature with periodic reporting to Ecology.

(6) = Dependent upon outcome of carp population reduction and aquatic weed management phased analyses.

(7) = Avista will continue to work with Ecology to determine the timing for future CE-QUAL model runs.

Revised Figure 1. DO WQAP Implementation Schedule (Source: Figure 3-3, DO WQAP)

Revised: March 2016

2.0 BASELINE MONITORING

Beginning in 2010, Avista contracted with Tetra Tech to complete baseline monitoring in Lake Spokane at six established stations during May through October. Longitudinally, the lake can be classified as having three distinct zones, which consist of a riverine, transition and lacustrine zone. Six water quality monitoring stations, LL5 through LL0, exist within these three zones (Figure 2). Station LL5 is the most upstream station and is located within a riverine zone, Stations LL3 and LL4 are located in the transition zone, and Stations LL0 through LL2 are located in the lacustrine zone. The vertical structure of Lake Spokane is set up by thermal stratification, largely determined by its inflow rates, atmospheric and water temperature, and location of the powerhouse intake. Within Lake Spokane's lacustrine zone, thermal stratification creates three layers (the epilimnion, metalimnion, and hypolimnion) that are generally present between late spring and early fall. The epilimnion is the uppermost layer, and the warmest due to solar radiation. The metalimnion is the transition layer between the epilimnion and the hypolimnion that contains the thermocline and is influenced by both surface and interflow inflows. The hypolimnion is the deepest layer and is present throughout the lacustrine zone.

Sampling events, both nutrient sampling and in-situ monitoring were completed at all six established stations from 2010 - 2017. In 2018, four supplemental monitoring locations, identified in the Quality Assurance Project Plan (QAPP) Addendum, Lake Spokane Baseline Nutrient Monitoring (approved 2018) were also sampled, May through October (Figure 2). Nutrient sampling (nitrogen and phosphorus) and phytoplankton sampling were not conducted in 2018 but in-situ dissolved oxygen (DO), temperature, conductivity and pH were measured and zooplankton samples were collected at all ten monitoring locations.

Avista has collected baseline nutrient monitoring over the full spectrum of flows that were likely to exist in the Spokane River under current license conditions (see Section 2.2.1). In the 2018 Annual Summary Report, approved by Ecology, Avista postponed baseline monitoring in order to focus on more detailed analyses of the 2010 - 2018 water quality monitoring data in an effort to explore the relationship between rainbow trout habitat utilization in Lake Spokane and the multitude of water quality attribute information available.

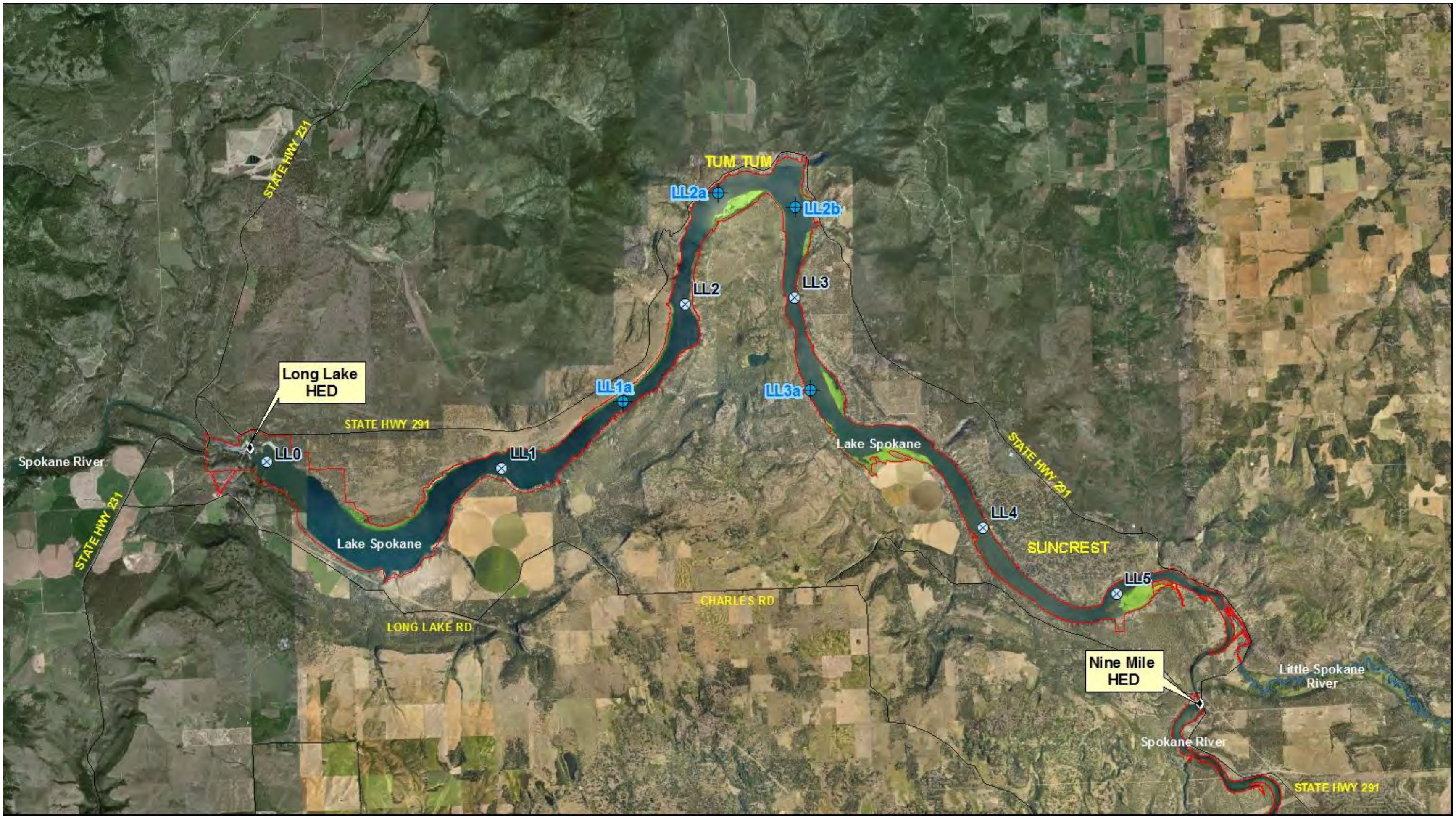

Figure 2. Location of Lake Spokane baseline monitoring stations and the four supplemental monitoring stations

2.1 2019 Results

Although baseline monitoring was not conducted in 2019 in Lake Spokane, a description of the general hydrologic and climatic conditions, residence time and algae bloom occurrences are summarized below.

2.1.1 Climatic Conditions

Weather during 2019 differed from the 30-year norm reported at Spokane International Airport (Figure 3). The year started out warmer than normal with the coldest air temperature in January at 15°F (-9.4°C) for the entire month. This is similar to warm temperatures experienced in January 2018 when the coldest temperature during the month was 14°F (-10°C). February brought dramatic changes compared to the mild January. Spokane recorded its 4th coldest February on record with an average temperature of 21.3°C (-5.9°C), which was 11.7°F (6.5°C) colder than the normal mean temperature of 33.0°F (0.6°C). March began with unseasonable cold temperatures with a minimum temperature of -1°F (-18.3°C) on March 1. Warmer to more normal temperatures were observed mid-March through April. May was warmer than normal with an average temperature of 59.4°F (15.2°C). June temperatures fluctuated between colder than normal and much warmer than normal but ended up on average just above normal with an average temperature of 64.4°F (18.0°C). On the 13th of June, temperatures reached 91°F (32.8°C) which was a record high for the month. Most of July and August had normal air temperatures with separate maximums of 94°F (94.4°C) and 98°F (36.7°C). Normal air temperature continued into September, however much colder temperatures arrived near the end of September. The high temperature of 38°F (3.3°C) on September 29 was the coldest high temperature ever recorded for the month. Well below normal temperatures continued through October and was the coldest October on record for Spokane. December started with normal temperatures but for most of the month was warmer than normal. Temperatures ranged from a high of 98°F (36.7°C) on August 7 to a low of -1°F (-18.3°C) on March 1 (Figure 3). The annual cumulative rainfall total was 15.45 inches (39.2 cm), which was below normal (Figure 3).

Precipitation was above normal during the end of January, February, September, and October and was well below normal in March, May through August, and in November. The year began with slightly less than normal precipitation in early January which was followed by wetter than normal conditions in late January and February. Precipitation was 1.07 inches (2.7 cm) above normal in February and was the second snowiest February on record. Precipitation in March was below normal with a total of just 0.71 inches (1.8 cm). April precipitation was just slightly above normal with a total of 1.47 inches (3.7 cm). Drier than normal conditions started in May with only 1.35 inches (3.4 cm), similar to May 2018 with only 1.45 inches (3.7 cm) but significantly greater than May 2016 with only 0.78 inches (2.0 cm), which was slightly less than half the normal of 1.62 inches (4.1cm) for that month.

Similar to 2018, drought conditions started in June with only 0.44 inches (1.1 cm) of precipitation; 0.81 inches (2.1 cm) below normal. That was slightly less precipitation than in 2018 (0.55 inches (1.4 cm)) and contrasts with June 2014 with above normal precipitation including a maximum one-day total of 1.01 inches (2.6 cm) on June 17. June 2019 precipitation also compares with the extremely dry June in 2015 with only 0.07 inches (0.2 cm). That was also the warmest June on record with an average temperature of 71.4°F (21.9°C). The Spokane International Airport recorded a high temperature of 105°F (40.6°C) on June 28, 2015. Average air temperature in June 2019 was 64.4°F (18.0°C).

Drier than normal conditions continued through July and August 2019 with only 0.52 inches (0.1.3 cm) for July. This is wetter than July 2018 when only 0.06 inches (0.15 cm) of precipitation was recorded. July is typically a dry month, averaging only 0.64 inches (1.6 cm). There were several large thunderstorms around the area in July, one on July 16 which resulted in 0.29 inches (0.7 cm) of precipitation at the Spokane Airport. August had a total of 0.48 inches (1.2 cm) of precipitation; 0.11 inches (0.3 cm) below normal. Even with drier than normal monthly totals recorded at the Spokane International Airport, August experienced severe thunderstorms that produced heavy rain on August 10 and 11. Rain amounts recorded within the watershed ranged from 3.91 inches (9.9 cm) in Colbert, on August 10 to 0.36 inches (0.9 cm) of rain on August 11 in Spokane, setting a daily record.

September and October 2019 were much wetter than normal with September being the snowiest September on record in Spokane. Winter like weather occurred near the end of the month with high temperatures in the upper 30s and the airport receiving 3 inches (7.6 cm) of snow. On September 9 a daily precipitation record was set with 0.64 inches (1.6 cm) and on September 28 both the daily precipitation and snowfall set records with 0.72 inches (1.8 cm) and 1.9 inches (4.8 cm), respectively. On September 29 the snowfall of 1.4 inches (3.6 cm) set another daily record. October, besides being the coldest October on record, set several daily records including 3.3 inches (8.4 cm) of snow on the October 8 along with 0.64 inches (1.6 cm) of precipitation. Total precipitation in October was 1.53 inches (3.9 cm) which was 0.35 inches (0.9 cm) above normal.

Precipitation in November was well below normal with only 0.68 inches (1.7 cm) of precipitation which was 1.62 inches (4.1 cm) below normal. November 2019 was the 12th driest November on record for Spokane. There was a small snow squall on November 26 that brought 0.6 inches (1.5 cm) of snow to the Spokane Airport within 30 minutes. December was slightly drier than normal with a total of 2.14 inches (5.4 cm) of precipitation; 0.16 inches (0.4 cm) below normal. Snowfall for the month of December was well below normal with only 10.5 inches (26.7 cm) which was just over 4 inches (10.2 cm) below normal for the month.

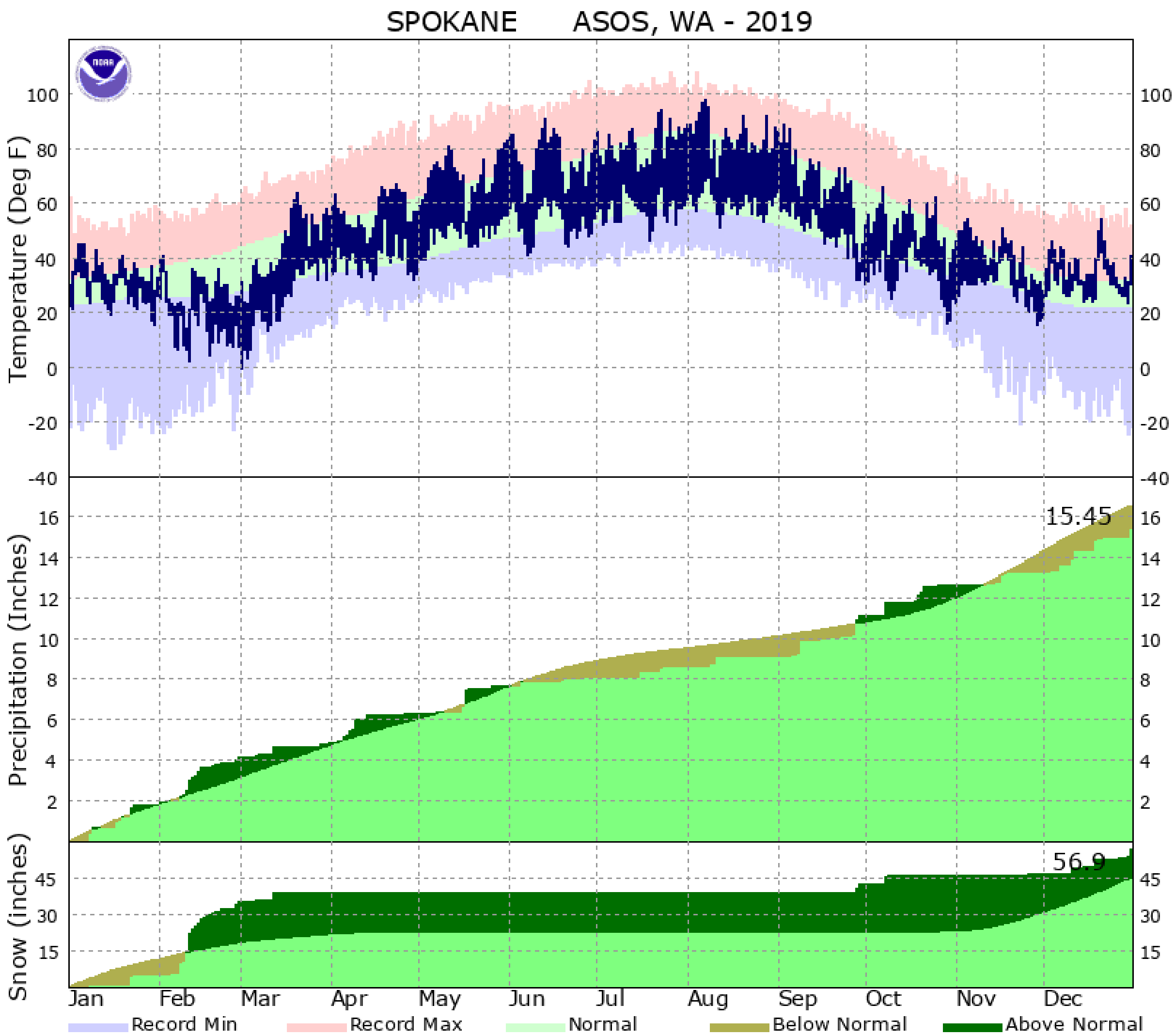

Figure 3. Air temperature and precipitation at the Spokane International Airport for 2019.

2.1.2 Hydrologic Conditions

Figures 4 and 5 show inflows and outflows, respectively, during 2019. Inflows include all incoming water as calculated by Avista using midnight to midnight reservoir elevation and daily average outflow as recorded at midnight at Long Lake Dam. Inflows and outflows to/from Lake Spokane are usually very similar, with only slight differences between inflow and outflow during annual drawdown in the early part of the year. Annual drawdown started at the end of December 2018 and lasted until about March 23, 2019. Figures 4 and 5 show the difference between inflows and outflows in the early part of 2019. Maximum inflows typically occur during March, April, and May due to spring runoff. However, the magnitude of and timing of peak inflows have varied greatly over the past ten years, compared to those in 2001, which was the 7Q10 for the DO TMDL (Figure 6). Peak flows in 2019 were less than 2018 and most similar to those in

2014 and 2015 (Figure 6). Peak flow in 2019 occurred in April, with another peak occurring in May, similar to the pattern in 2014 (Figure 6).

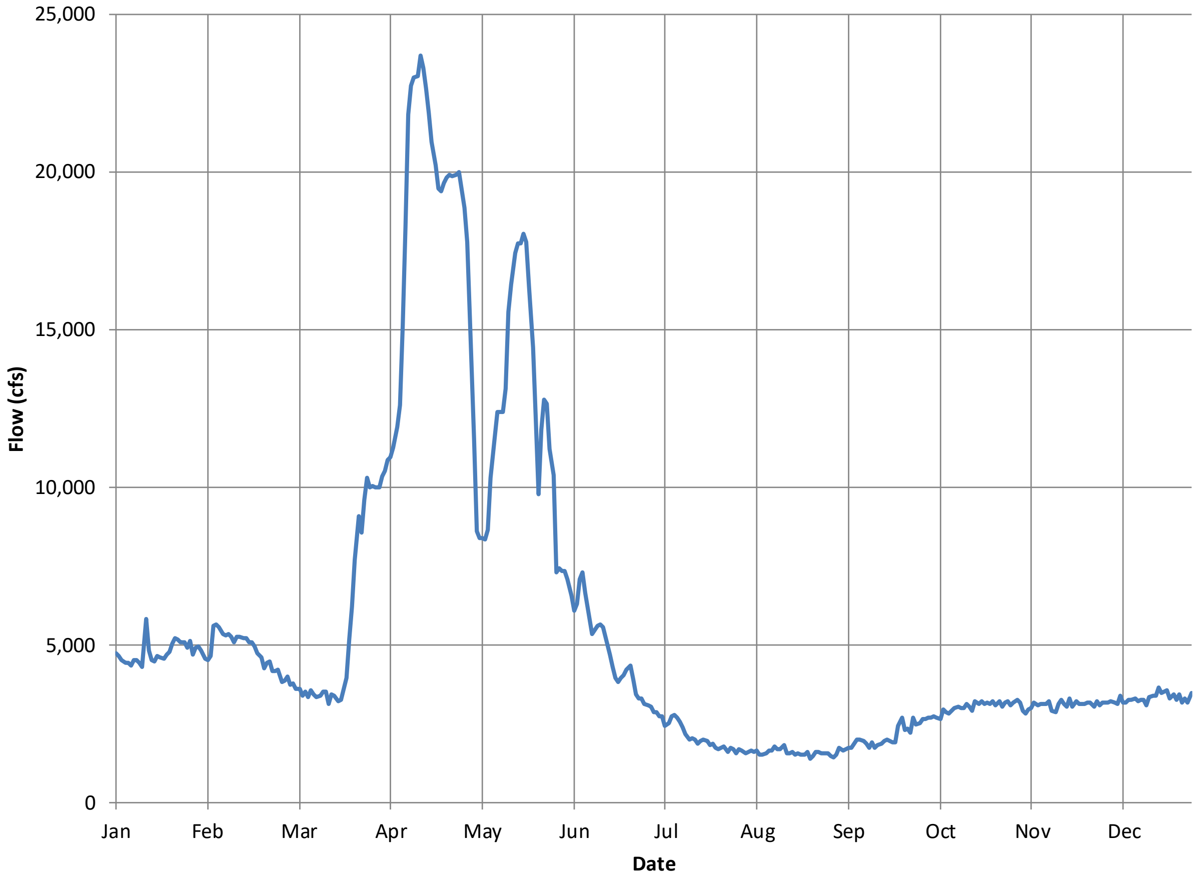

Figure 4. Total inflow into Lake Spokane, 2019. (Inflows calculated based on midnight to midnight reservoir elevation and day average outflow at midnight as recorded at Long Lake Dam).

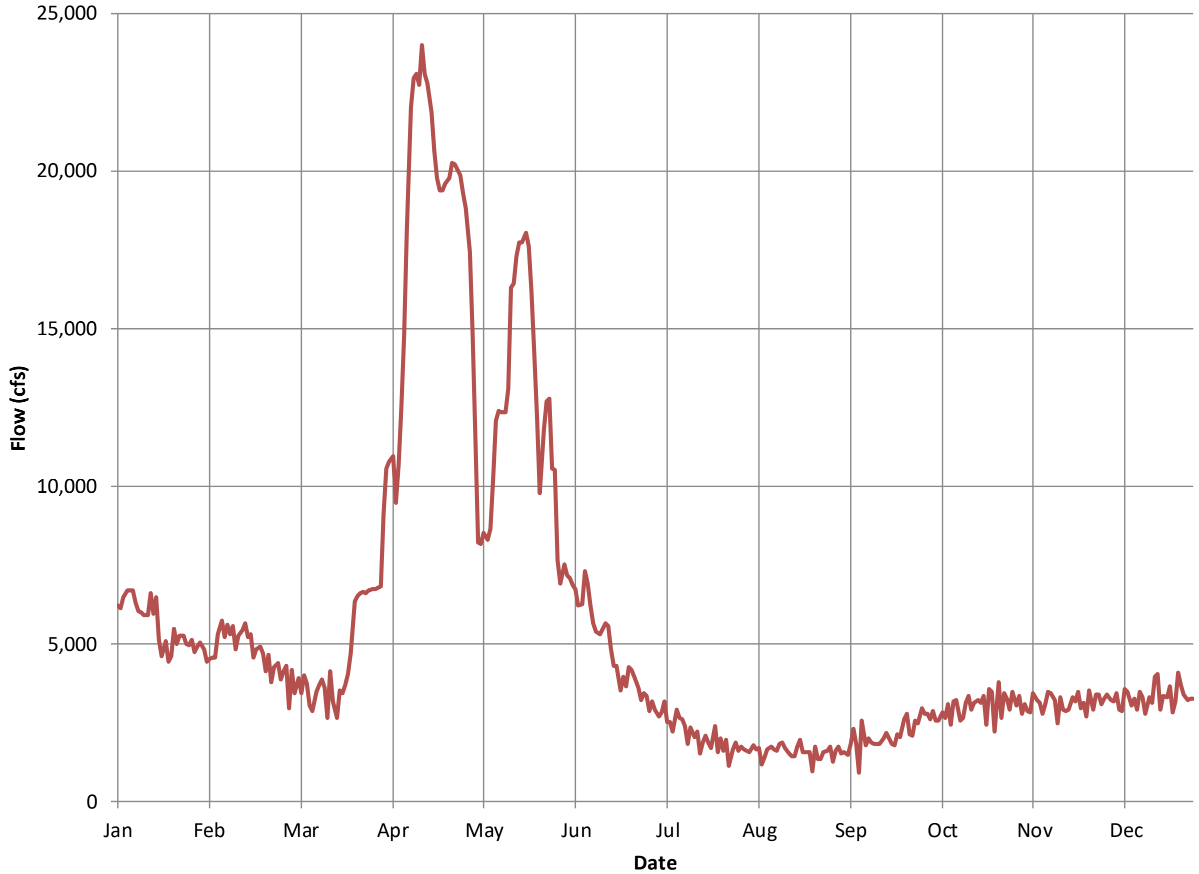

Figure 5. Total outflow from Lake Spokane, 2019. (Outflows as reported at Long Lake Dam at midnight daily).

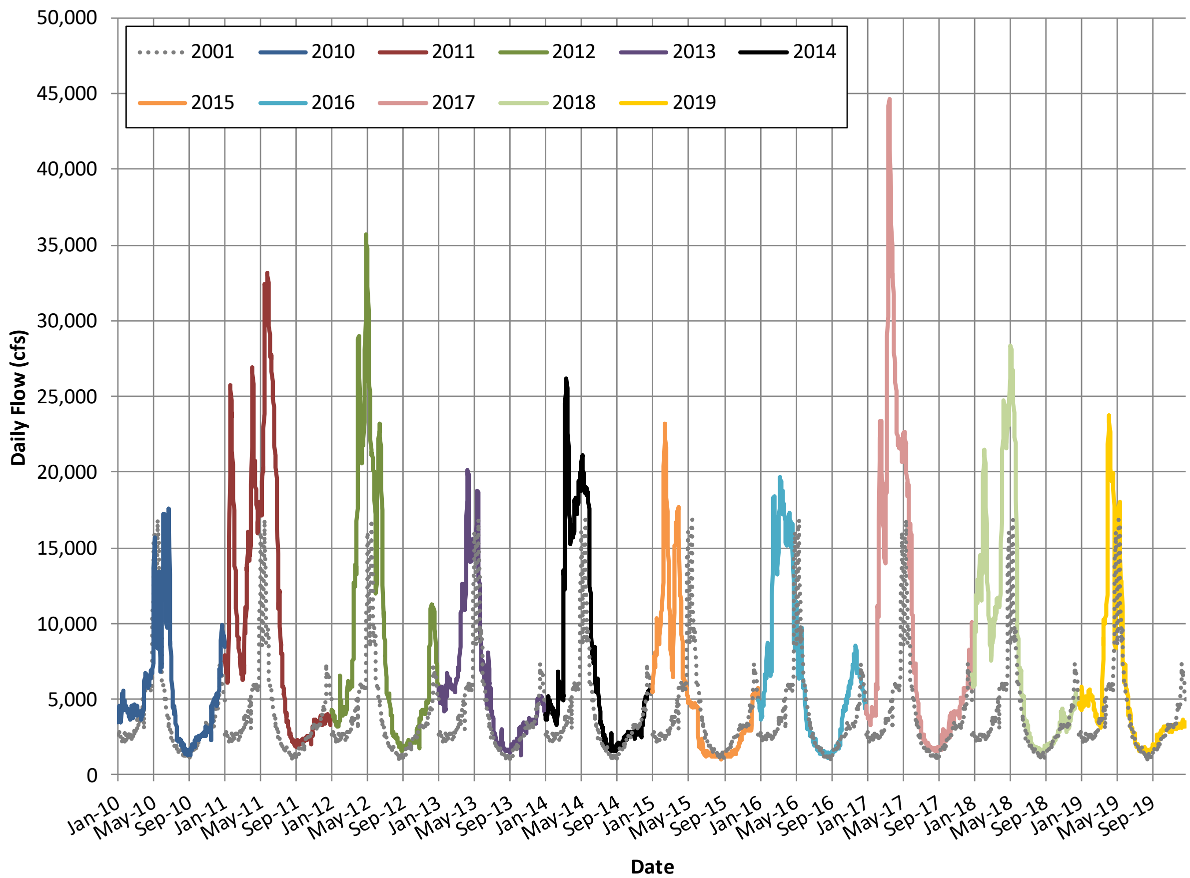

Figure 6. Total inflows into Lake Spokane 2010-2019. (Inflows calculated based on midnight to midnight reservoir elevation and day average outflow at midnight as recorded at Long Lake Dam).

Flows in the Spokane River and the Little Spokane River were average to above average during January and early February and decreased sharply in both rivers in mid-February to early March (Figures 7 and 8). Peak flow in the Spokane River was earlier (mid-April vs late May) than historically recorded (Figure 7). Peak flows in the Spokane River were slightly higher than the historical median and less than the 90th percentile peak. Peak flow in the Spokane River reached 21,100 cfs in 2019, which was slightly less than the peak observed in 2018 of 27,800 cfs. The peak of 42,900 cfs in 2017, which was the 4th largest since record keeping began in 1891, is the largest peak observed during the baseline water quality monitoring period. Flows from May through September 2019 were below the historical median (Figure 7). The peak flow in the Little Spokane River of 1,130 cfs was similar to the historical median in both magnitude and timing (Figure 8). Flows in the Little Spokane River dropped below the historical median following the peaks in April and May through July. Flows were above the historical median and approached the 90th percentile starting in August through early October (Figure 8).

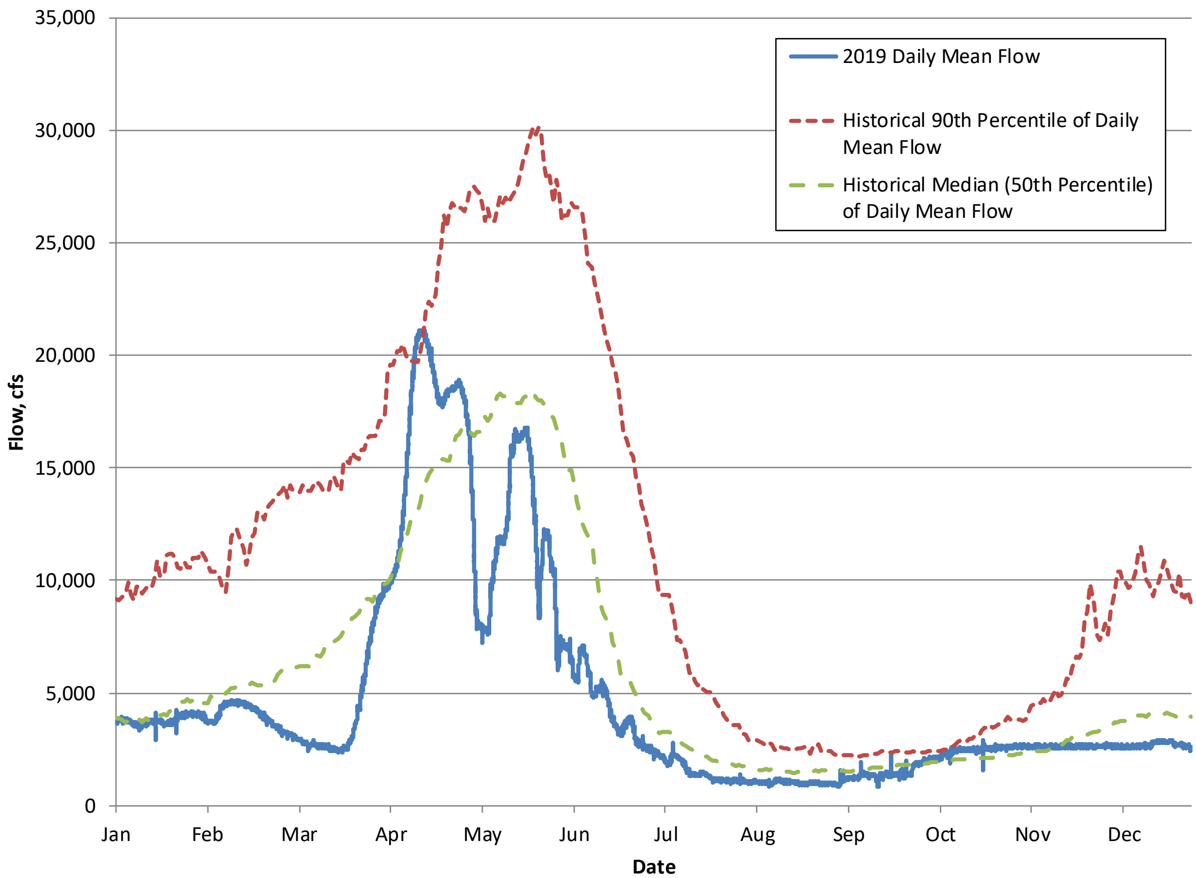

Figure 7. Spokane River at Spokane (USGS Gage #12422500) daily mean flow, 2019, compared to historical daily mean flow.

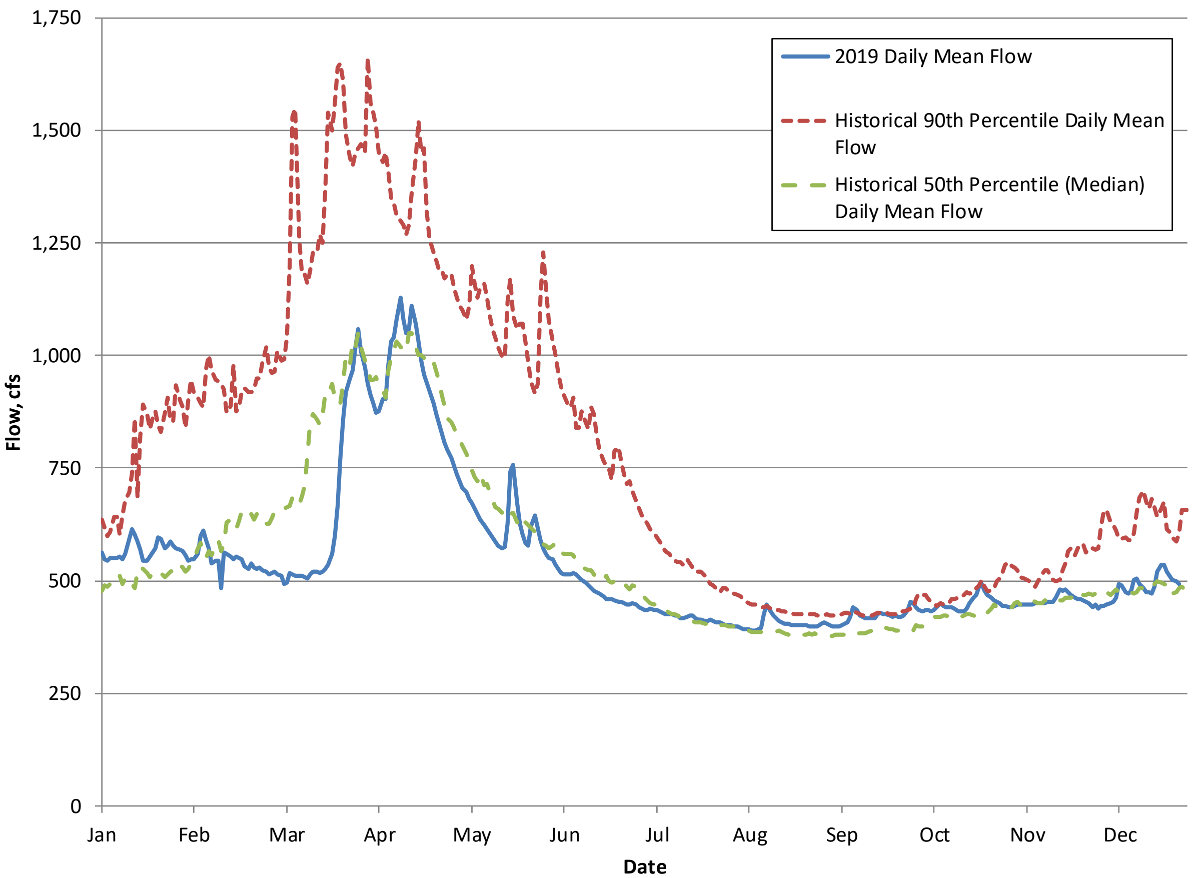

Figure 8. Little Spokane River near Dartford (USGS Gage #12431500) daily mean flow, 2019, compared to historical daily mean flow.

Water residence time can markedly affect reservoir quality. Long residence times tend to allow for more settling of particulate matter, including phosphorus in algae, and usually greater transparency. If residence times are relatively short, on the order of 10 days or less, algal biomass accumulation may be limited. Both effects can occur in reservoirs, which usually have shorter residence times than natural lakes.

Whole reservoir water residence time during 2019 (June through October) was about 40.4 days, similar to residence time observed in 2016, but much lower than the above-normal residence times in 2015 (Table 1).   Including 2015 and 2016, whole reservoir residence time averaged 34.6 days for the past ten years (2010 through 2019). Whole reservoir residence time was calculated based on reservoir volume and mean June through October discharge from Long Lake Dam. Outflow, rather than inflow, is normally used to calculate residence time of a waterbody (Welch and Jacoby, 2004). Residence times in the transition and riverine zones were calculated based on total volume of these two zones and the mean June through October discharge from Long Lake Dam, under the assumption that water is not retained in these zones due to their shallower depth. Residence times in the transition and riverine zones averaged 4.7 days in 2010 –

2014 but were much higher in 2015 at 13.2 days and in 2016 at 8.1 days (Table 1). Residence time in the transition and riverine zones in 2019 was 7.6 days, lower than that observed in 2015 and 2016 and only slightly higher than the ten-year average (6.5 days). Thus, algal bloom development would be limited, on average, in these zones during normal years, especially in the spring, but would not be limited during low flow periods in August through September in most years. Bloom development may have been limited by residence time in the riverine/transition zones during the spring and early summer in 2019, but most likely not limited in late August and September when inflows decreased.

Inflows and water residence times during 2010 - 2019, were separated into the seasonal timeframes consistent with the DO TMDL (Table 2). Mean outflow for each seasonal timeframe was used to calculate respective residence times. The whole reservoir residence time was 58.3 days in 2019 during the DO TMDL seasonal timeframe of July through September. That was much less than in 2015 (84.8 days) but higher than 2010 – 2014 average (41.2 days).

Table 1. Inflows and water residence times in Lake Spokane during 2001 and 2010-2019. Residence times are for June through October.

Year	Total Annual Flow Volume (cf x10^6)	Annual Mean Daily Flow (cfs)	Mean Daily Summer (June-October) Flow (cfs)	Residence Time[1] Whole Reservoir (days)	Residence Time[1] Transition/Riverine Zones (days)
2001	125,782	3,989	2,413	46.3	8.7
2010	167,113	5,299	4,671	23.9	4.5
2011	337,576	10,704	7,828	14.4	2.7
2012	293,971	9,296	5,768	19.4	3.6
2013	189,846	6,020	3,035	36.8	6.9
2014	234,999	7,452	3,581	31.3	5.9
2015	171,137	5,427	1,595	70.1	13.2
2016	216,855	6,858	2,523	43.3	8.1
2017	317,811	10,078	3,697	30.2	5.7
2018	270,253	8,570	3,089	36.3	6.8
2019	173,136	5,490	2,762	40.4	7.6

[1]residence time = reservoir volume/outflow

Table 2. Daily flows and water residence times in Lake Spokane during 2001 and 2010-2019, using DO TDML seasonal timeframes.

Year	Mean Daily Summer Flow (cfs)				Residence Time[1] Whole Reservoir (days)				Residence Time[1] Transition/Riverine Zones (days)			
	May	June	July – Sept.	Oct.	May	June	July – Sept.	Oct.	May	June	July– Sept.	Oct.
2001	11,872	4,560	1,637	2,635	10.1	24.5	68.6	42.1	1.9	4.6	12.9	7.9

2010	10,036	13,297	2,550	2,620	11.2	8.4	43.8	42.7	2.1	1.6	8.2	8.0
2011	25,596	24,323	4,232	2,538	4.3	4.6	26.5	44.1	0.8	0.9	5.0	8.3
2012	23,667	17,333	3,092	2,520	4.8	6.5	36.1	44.4	0.9	1.2	6.8	8.3
2013	9,037	5,956	2,133	2,884	8.5	18.7	52.5	38.8	1.6	3.5	9.8	7.3
2014	19,127	8,243	2,373	2,657	5.9	13.6	47.2	41.9	1.1	2.6	8.9	7.9
2015	4,724	2,360	1,317	1,678	23.8	47.5	84.8	66.6	4.5	8.9	15.9	12.5
2016	8,101	3,865	1,677	3,735	13.8	28.8	66.8	27.7	2.6	5.4	12.5	5.2
2017	20,395	8,737	2,212	3,229	5.5	12.8	50.7	34.5	1.0	2.4	9.5	6.5
2018	24,568	6,711	2,056	2,647	4.6	16.8	54.3	42.2	0.9	3.1	10.2	7.9
2019	12,485	5,155	1,919	2,976	9.0	21.7	58.3	37.6	1.7	4.1	10.9	7.1

[1]residence time = reservoir volume/outflow

2.1.3 Algal Bloom Occurrence

Cyanobacteria (blue-green algae) blooms were reported in Lake Spokane during the summer of 2019. According to an article published by KXLY, a local broadcast station, cyanobacteria blooms were claimed to be present near Suncrest Park during the month of August. Galen Buterbaugh, who serves as a technical advisor to the Lake Spokane Association, indicated cyanobacteria blooms were observed on and off all August and were very spotty, never covering the whole lake (https://www.kxly.com/what-you-need-to-know-about-toxic-blue-green-algae-in-local-lakes/). According to the Washington State Toxic Algae website no samples were collected in Lake Spokane during the summer of 2019 for cyanotoxin analysis. Caution signs were posted at the Washington State Parks and Recreation Commission Parks (State Parks) Riverside boat launch, the Nine Mile Recreation Area, as well as the Suncrest boat launch, warning lake users that a cyanobacteria bloom could be present in the lake and to avoid contact with the water if a bloom is visible.

2.2 Assessment of Lake Spokane Water Quality (2010 – 2019)

2.2.1 Temperature

Water and air temperature data were analyzed to determine if there were long-term trends in temperature. The data indicates that air temperature in the Pacific NW has increased over the past several decades. Air temperature during 1952 – 1965 was similar to 1972 – 1985, but increased slightly by 1°C, on average, for June – October during 2010 – 2019 (Table 3). Correspondingly, the data indicate that surface temperature in Lake Spokane has increased slightly more than 1°C since the 1970s – 1980s. Average temperature with depth throughout the reservoir during June – October is shown for 2010 – 2018, compared with those during 1972 – 1985 (Patmont 1987; Figures 9 and 10). Note that there is only a small area that averaged greater than 19°C during 1972 – 1985, but the 19°C isopleth and portions of the 20°C isopleth encompassed nearly the whole reservoir surface during 2010 – 2018. Also, mean temperature in the top 5 m of the lacustrine zone, determined from numerical data, averaged 19.8°C during 2010

– 2018, and 20.2°C at the surface (Table 4). That was about 1°C warmer than in 1972 – 1985. Lacustrine surface and epilimnion average water temperatures were slightly lower in 2018 than those observed in 2017 and in most cases were the lowest average temperatures observed since 2011 (Table 4).

The Spokane River at Riverside June – October mean temperature for 2010 – 2019 was 15.5°C, which was only 0.5°C higher than the overall mean for 1982 – 2019 (15.0°C ± 1.1°C). Average November – May temperature varied slightly more over the time period of record with a mean of 6.2°C ± 0.8°C (Figure 11).

Table 3. Average annual and June – October air temperature at Spokane International Airport.

Time Period	Annual Average (°C)	June – October Average (°C)
1952 - 1965	8.6 (±0.9)	16.4 (±1.0)
1972 - 1985	8.3 (±0.6)	16.1 (±0.6)
2010 - 2019	9.0 (±0.9)	17.1 (±0.9)

Table 4. Average water temperatures in lacustrine zone of Lake Spokane, June – October 2010 – 2018. Water temperature was not measured in Lake Spokane during 2019.

Year	LL0			LL1			LL2		
	Surface	Epi (0-5 m)	Hypo (15 m+)	Surface	Epi (0-5 m)	Hypo (15 m+)	Surface	Epi (0-5 m)	Hypo (15 m+)
2010	19.1	18.7	14.9	19.3	18.9	15.3	19.4	19.0	15.5
2011	18.7	18.2	14.8	19.6	19.1	15.8	19.8	19.1	15.7
2012	19.9	19.4	14.7	20.0	19.7	15.3	20.0	19.5	15.8
2013	20.3	20.0	14.6	21.0	20.6	15.5	21.3	20.8	15.6
2014	20.8	20.3	15.3	21.2	20.8	15.9	21.4	20.8	16.2
2015	20.8	20.5	12.5	21.2	20.9	14.5	21.3	21.1	15.5
2016	19.7	19.4	14.8	20.3	19.8	15.6	20.4	20.0	15.8
2017	20.3	19.9	15.3	20.7	20.3	15.8	20.7	20.3	16.0
2018	19.3	19.1	15.6	19.7	19.4	15.8	20.0	19.7	15.7
Mean	19.9	19.5	14.7	20.3	19.9	15.5	20.5	20.0	15.8
STDEV	0.7	0.8	0.9	0.7	0.7	0.4	0.7	0.8	0.2

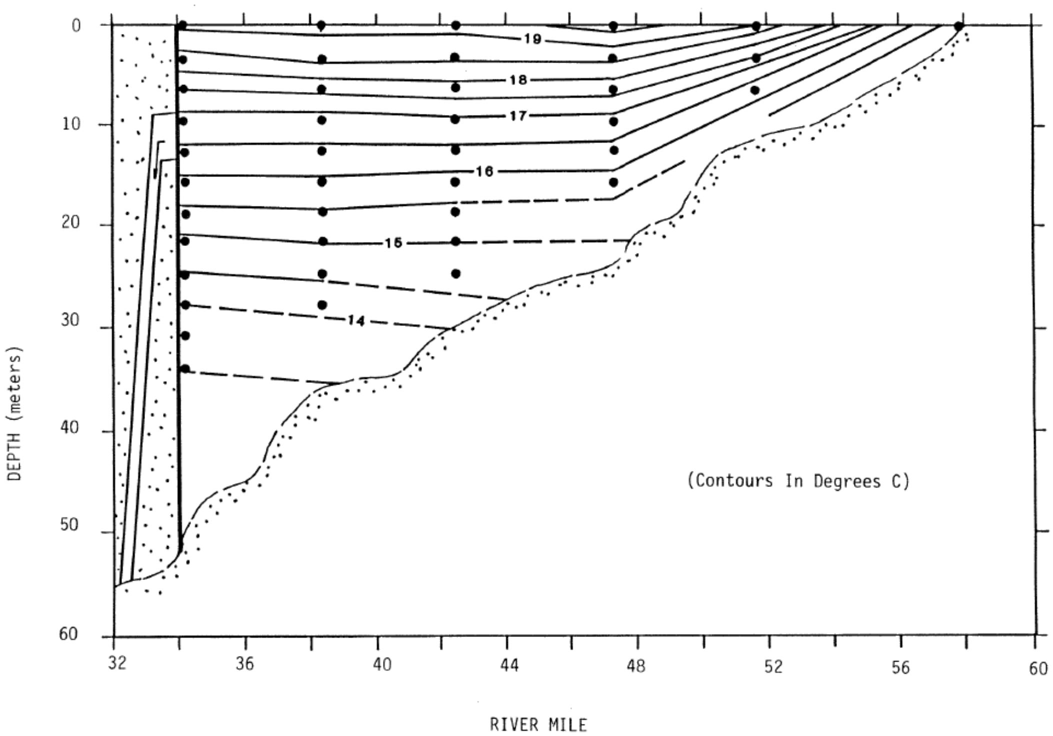

Figure 9. Average June – October water temperature contours in Lake Spokane, 1972 – 1985 (Patmont 1987).

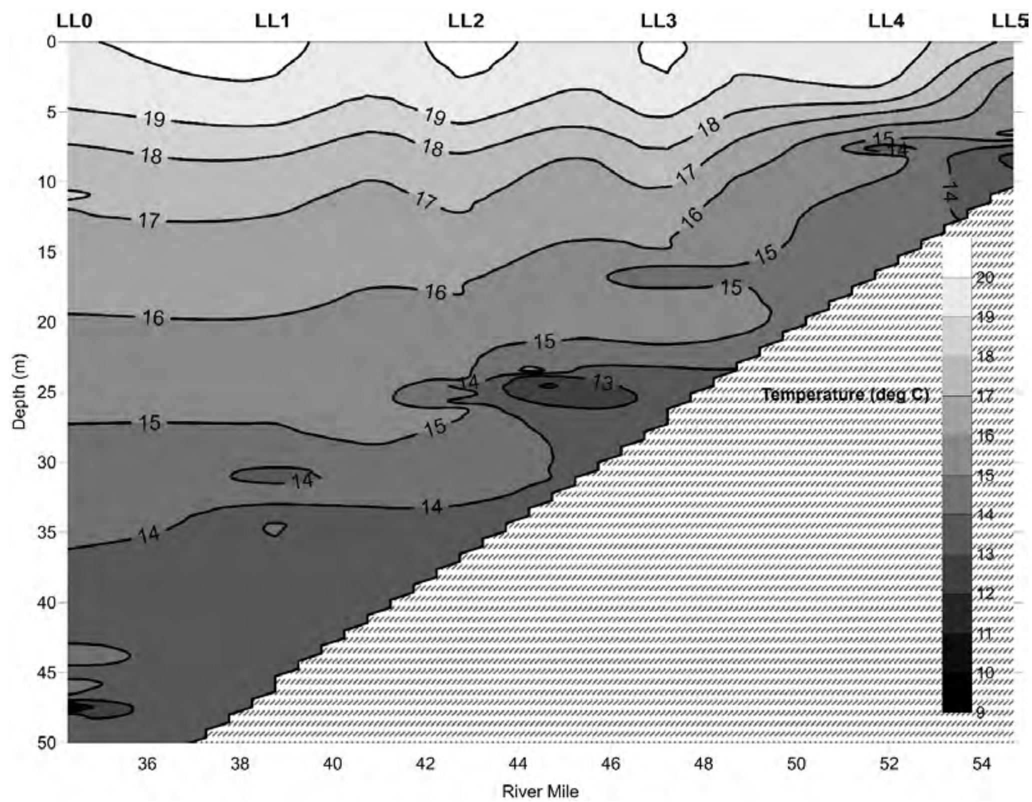

Figure 10. Average June – October water temperature contours in Lake Spokane, 2010 – 2018.

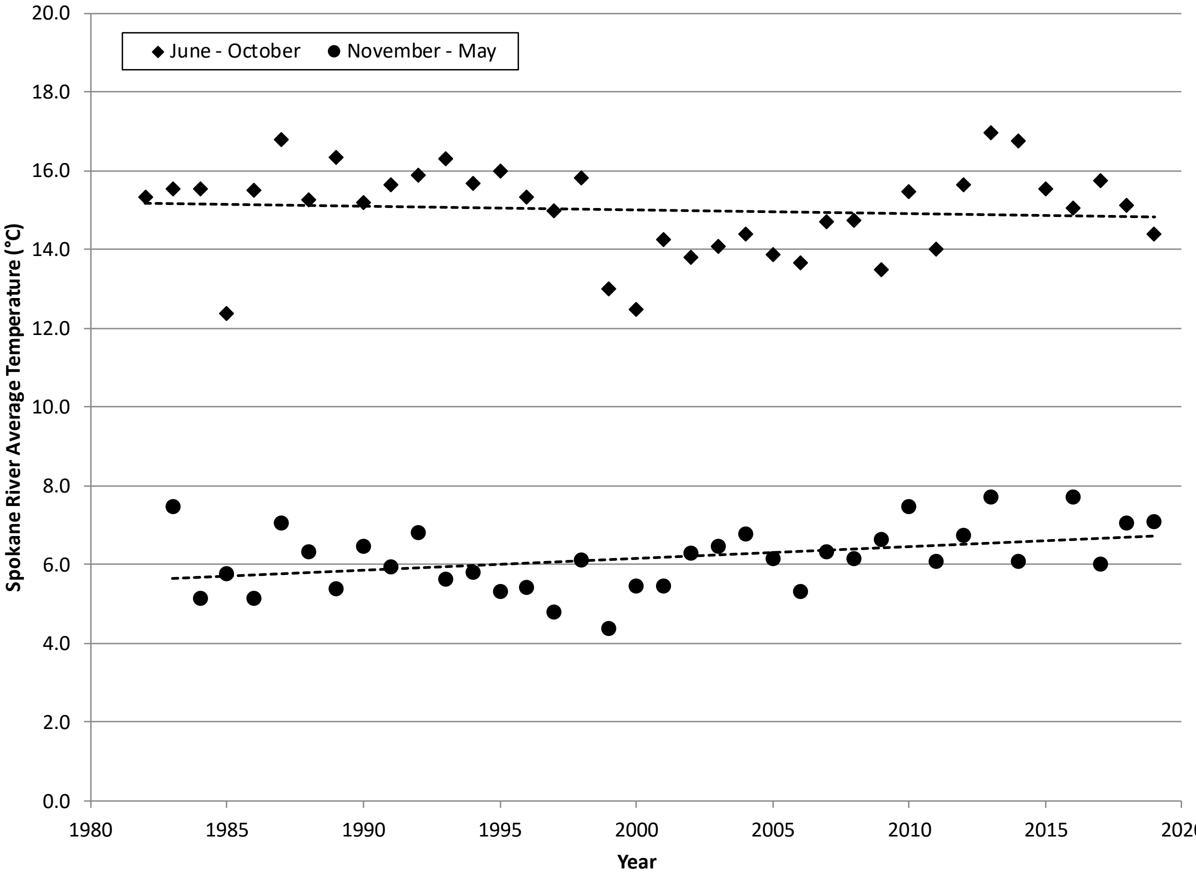

Figure 11. Seasonal average water temperatures in the Spokane River at Riverside State Park, 1982-2019.

2.2.2 Dissolved Oxygen

The reservoir's DO resource has remained consistently improved during the past nine years of monitoring (2010-2018) as inflow TP remained relatively low. That improved condition occurred as the reservoir's trophic state also improved from hypereutrophic to meso-oligotrophic after 85% of point source effluent TP was removed in 1977 (Welch et al. 2015). The dependence of minimum hypolimnetic DO on TP is shown in Figure 12 (modified from Patmont 1987). During 1972 to 1977, minimum volume weighted hypolimnetic DO (below 15 m) ranged from 0.2 to 3.4 mg/L, with a mean of 1.4 mg/L. After phosphorus reduction, minimum volume weighted hypolimnetic DO gradually increased to a mean of 2.5 mg/L during 1978 to 1981, and then to 4.5 mg/L during 1982 to 1985, as inflow TP declined from 85 to 25 µg/L (Patmont 1987). Almost three generations later, minimum volume weighted hypolimnetic DO, calculated using volumes from Patmont (1987) and DO data from the lacustrine zone, averaged 6.2 mg/L during 2010 to 2018 at inflow TPs averaging 14.5 µg/L. Inflow TP was determined as the riverine zone volume weighted TP concentration at LL5 for 2010-2017 and flow-weighted average inflow TP concentrations from the Spokane River at Nine Mile Bridge and Little Spokane for 2018. Total phosphorus data from the Spokane River at Nine Mile Bridge and the Little Spokane River were obtained from the Ecology Environmental Information Management (EIM) system and are collected as part of the ambient monitoring program. While minimum hypolimnetic DO has remained consistently around 6 mg/L, there has been some variation (± 12%) between the years during the past nine years of monitoring (Figure 12).

The data indicate that DO at depth in Lake Spokane has increased since the 1970s – 1980s. Average DO with depth throughout the reservoir during June – October is shown for 2010 – 2018, compared with those during 1972 – 1985 (Patmont 1987; Figures 14 and 15). Note that most of the hypolimnion, depths greater than 25 m, had average June – October DO of 5.0 mg/L or less, with bottom concentrations (30 m and below) of 4.5 mg/L or less during 1972 – 1985 (Figure 13). During 2010 – 2018, average June – October DO in most of the hypolimnion averaged between 7.5 and 5.0 mg/L with only a very small area at the very bottom (45 to 50 m) with DO less than 5.0 mg/L (Figure 14).

The year-to-year variability in minimum DO in Figure 12 was likely due to water inflow and residence time, with higher inflows, and shorter residence times, producing higher DO minimums in the 1970s through 1980s (Patmont 1987). Specifically, the high minimum volume weighted hypolimnetic DOs in 1974 – 1975 had the highest June – October inflows during the time period of 1960 to 1985. Nevertheless, the principal control on minimum volume weighted hypolimnetic DO over the large range in inflow TP, from immediately before to after phosphorus reduction, was inflow TP (Figure 12), with a lesser effect from residence time (Figure 13). Conversely, during 2010-2018, with consistently low inflow TP, minimum volume weighted hypolimnetic DO seems to be more dependent on residence time. Minimum volume weighted hypolimnetic DO during 2010-2018 ranged from 5.1 mg/L to nearly 8 mg/L, while summer volume weighted riverine TP (surrogate for flow-weighted inflow TP) ranged from only 11.4 to 20 µg/L, indicating less of a correlation between DO and TP in recent years (r^2 = 0.26).

Instead, minimum hypolimnetic DO was strongly related to June-October water residence time (r^2 = 0.84; Figure 13). Residence times ranged from about 24 to 70 days during 2010, 2013, 2014, 2015, 2016, 2017, and 2018, corresponding with the lowest minimum volume weighted hypolimnetic DOs, while residence times of about 14 to 19 days in 2011 and 2012 were associated with the highest minimum hypolimnetic DOs (Figures 13). However, the lowest minimum volume weighted hypolimnetic DO during recent years was 5.1 mg/L which occurred in 2015, which also had the highest June through October mean inflow TP (20 µg/L), and the longest June – October water residence time of about 70 days. Nevertheless, there was a full 1 mg/L difference in minimum DO in 2013 and 2015 at essentially the same TP, further suggesting greater dependence of DO on residence time.

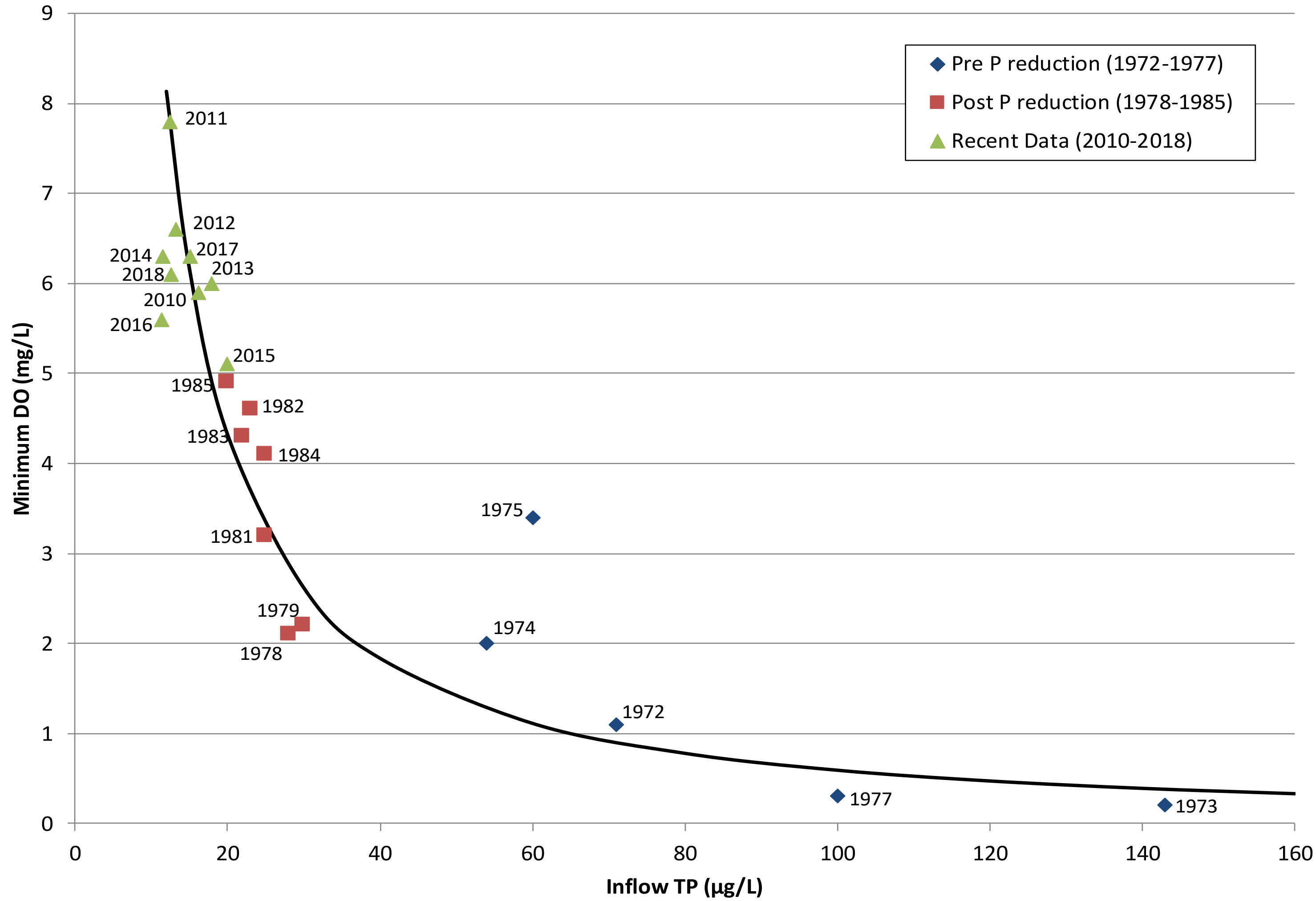

Figure 12. Volume-weighted mean inflow TP concentration related to minimum v-w hypolimnetic DO concentration during June-October before and after advanced wastewater treatment TP reduction in 1977. Concentrations from 1972 through 1985 were from observed loading at Nine Mile Dam (Patmont 1987). Mean inflow TP concentrations from 2010-2017 were taken as v-w mean TP concentrations at Station LL5, in lieu of loading data from Nine Mile Dam. Inflow TP in 2018 was calculated as the flow-weighted average from observations at Nine Mile and Little Spokane River. Equation for the line: $y = 175.4587x^{-1.2360}$, $r^2 = 0.84$.

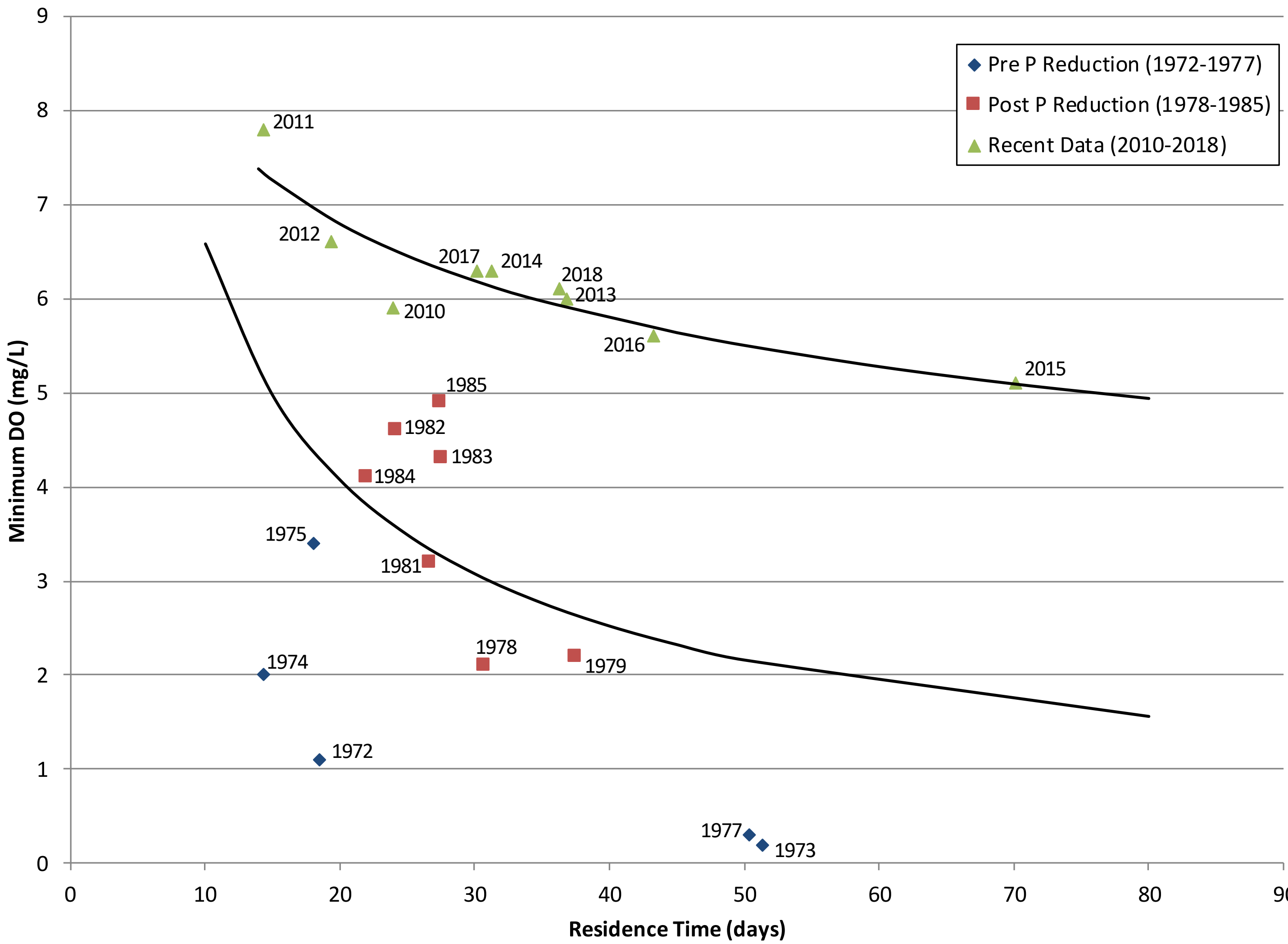

Figure 13. Mean hydraulic residence time (June-October) related to minimum v-w hypolimnetic (below 15 m) DO before and after wastewater TP reduction in 1977. Residence time was calculated using reservoir outflows gaged by USGS (1972-1985) and Avista (2010-2018) at Long Lake Dam. Equation for line for all years: $y = 32.525x^{-0.694}$, $r^2 = 0.09$. Equation for line for 2010-2018: $y = 13.583x^{-0.231}$, $r^2 = 0.84$.

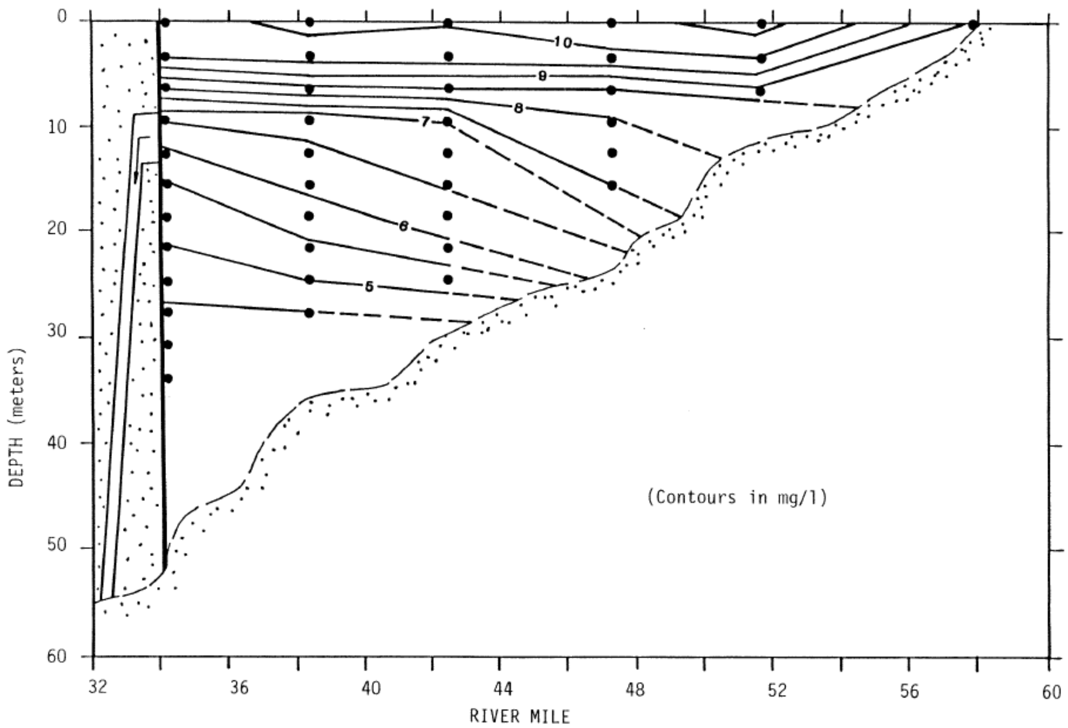

Figure 14. Average June – October DO contours in Lake Spokane, 1972 – 1985 (Patmont 1987).

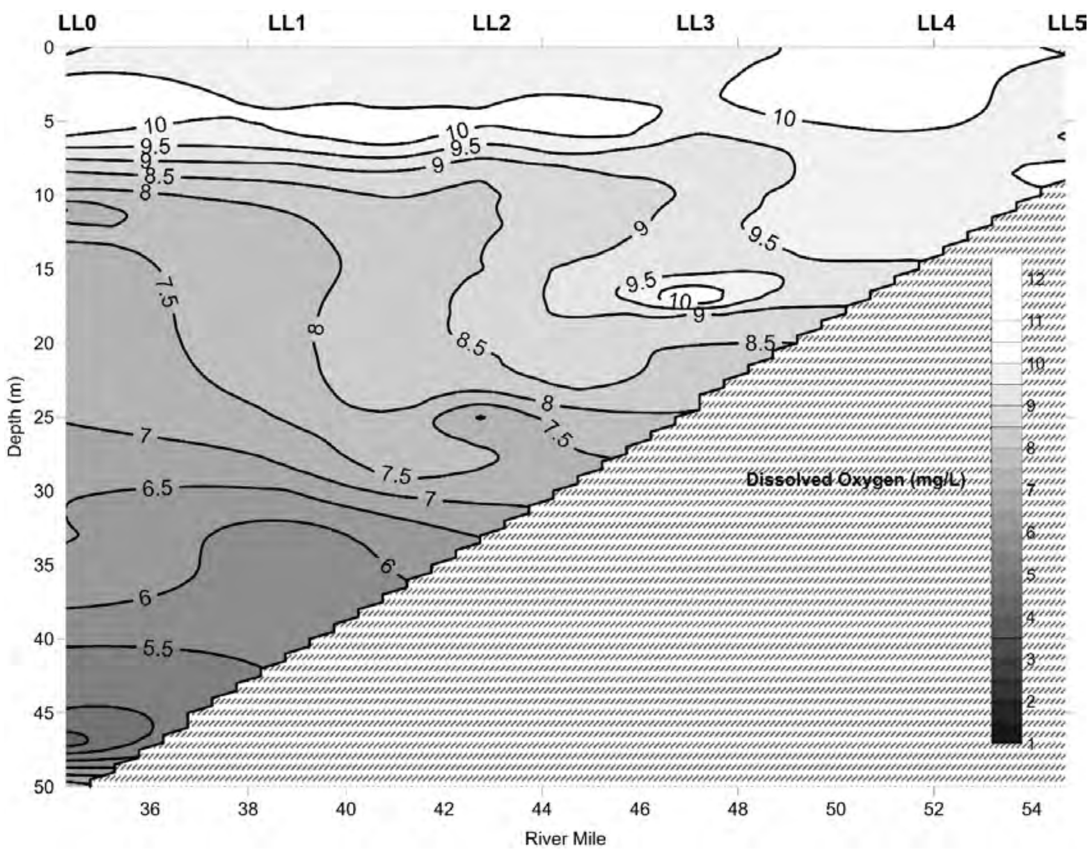

Figure 15. Average June – October DO contours in Lake Spokane, 2010 – 2018.

The amount of oxygen present in a waterbody can also be measured as a percent saturation, with 100% saturation indicating that the water is holding as much oxygen as it can in equilibrium with the atmosphere. Oxygen solubility, as well as concentration, is influenced by the temperature of the water. The solubility of oxygen decreases as temperature increases meaning that warmer water requires less DO to reach 100% saturation then does colder water. Waters with 100% DO saturation, but different temperatures, will have different DO concentrations. Variations in DO of lakes, reservoir, and rivers, can provide a measure of their trophic state; oligotrophic (less productive) waterbodies have small variations in saturation, while eutrophic (over-productive) waterbodies can have large variations in saturation. Photosynthetic activities of aquatic plants and algae are a major source of oxygen within aquatic environments and are usually responsible for DO above 100% saturation. Dissolved oxygen saturation measurements recorded in Lake Spokane provide information regarding the magnitude of production (photosynthetic activity) at locations throughout the reservoir, which is dependent on nutrient availability. Understanding long-term trends associated with DO percent saturation, as well as concentration, may provide a better understanding of the reservoir trophic state and seasonal productivity.

Photosynthesis causes diel fluctuations in DO, as well as pH, due to the availability of light. During peak photosynthesis, usually mid-afternoon, eutrophic waterbodies can have incredibly high DO percent saturation values (200-300%). These waterbodies then have very high levels of respiration at night and DO percent saturation can fall to 0% even in the surface water. Less productive waterbodies, mesotrophic and oligotrophic waterbodies, will have the same diel fluctuations in DO however the magnitude of the variation will be much smaller. Conducting diel monitoring of DO percent saturation would provide information regarding the magnitude of supersaturation (>100%) during the day as well as the magnitude of respiration overnight. Avista will work with Ecology to develop a monitoring plan and conduct diel monitoring in Lake Spokane in 2020.

Figures 16 through 21 show mean DO percent saturation recorded at each monitoring station during 2012 through 2018. Epilimnetic, metalimnetic, and hypolimnetic means were calculated for stations LL0, LL1, LL2 and LL3. Bottom water means were also calculated for station LL0. Since stations LL4 and LL5 are much shallower, surface and bottom means were calculated for LL4 and a whole water column mean was calculated for LL5.

A general description of trends observed throughout the season include the following. DO percentages in the epilimnion is typically above 100 % saturation, with the lowest values observed in October at approximately 90% saturation (LL0, LL1, and LL2), and the highest values observed in late July and August at approximately 130 to 140% saturation (all stations). Metalimnion DO percentages range from approximately 115% saturation in May, increase approximately 5% in mid-summer and then drop to 60 to 80% saturation in September. Hypolimnion DO percentagess range from approximately 100% saturation in May, to 30 to 60% saturation in August and often increase to approximately 100% saturation by October.

There are similar patterns in DO saturation between years and between stations. DO saturation in May, at the start of the monitoring season, is influenced by water column stratification and to some degree, flow. There is a greater difference in DO saturation between the layers when the water column is stratified. In 2015 and 2016, the water column at all stations except LL4 and LL5 was strongly stratified in May, which led to large differences in DO saturation between the epilimnion, metalimnion and hypolimnion. The strong stratification already present in May during 2015 and 2016 was likely due to low spring flows and warmer than normal temperatures.

Peak DO saturation values measured in the epilimnion at all stations corresponded with peak chlorophyll *a* concentrations. Typical of lakes and reservoirs, there is usually a spring peak of chlorophyll *a* that corresponds with diatom production followed by a mid to late summer chlorophyll *a* peak that corresponds with blooms of green algae and cyanobacteria. During the process of photosynthesis, oxygen is produced as a waste product and adds to the DO concentration of the water, usually bringing it above 100% saturation. Wind and wave action can also increase the DO concentration above 100% saturation but the correlation between DO saturation and chlorophyll *a* indicates that in Lake Spokane, DO above 100% saturation in the epilimnion, and in some cases the metalimnion, is most likely due to photosynthesis.

During the latter part of the summer, the respiration of algae and settling of organic matter from the epilimnion, contribute to a decreased DO saturation in the metalimnion. Additionally, DO depletion is often greater in the metalimnion in reservoirs due to the plunging inflows that form density-determined layers and transport organic matter, from the nutrient enriched riverine and transition zones, as well as the inflowing river, into the metalimnion of the lacustrine zone, which may cause DO saturation to decline below 100% saturation (Cooke et al. 2011; Welch et al. 2011). During some years, metalimnetic mean DO saturation is less than that measured in the hypolimnion likely due to this DO depletion in the interflow zone. This occurs more often at LL2 and LL3 than at LL0 and LL1, which have larger hypolimnions.

Over the course of the summer the hypolimnion and bottom waters are isolated due to stratification by temperature and conductivity and not exposed to the atmosphere, causing them to slowly lose oxygen during the time of stratification. The decline in hypolimnetic and bottom water DO saturation over the course of each year can be seen in Figures 16 through 19. The decline in DO saturation is greater at the deeper stations but in most years, by the last monitoring event in October, the hypolimnion and bottom waters have mixed and DO saturation increases. The late summer increase in hypolimnetic DO saturation corresponds to higher conductivity values and a deepening of the interflow zone; in other words, mixing of the interflow zone and the top portions of the hypolimnion. However, in some years (2013 and 2015) the hypolimnion and bottom waters at LL0 did not mix and remained isolated in October, resulting in low to zero DO saturation near the bottom (Figure 16).

DO saturation patterns at stations LL4 and LL5 are somewhat similar to those at stations LL0 – LL3 in that epilimnetic peaks correspond to peaks in chlorophyll *a*. However, because stations

LL4 and LL5 are much shallower than other stations, DO saturation does not typically fall below 100%. The entire water column at both LL4 and LL5 are within the photic zone and photosynthesis can occur even near the bottom. Even when the water column at stations LL4 and LL5 stratifies, the bottom water is still actively mixed due to the interflow zone and inflow from the Spokane River.

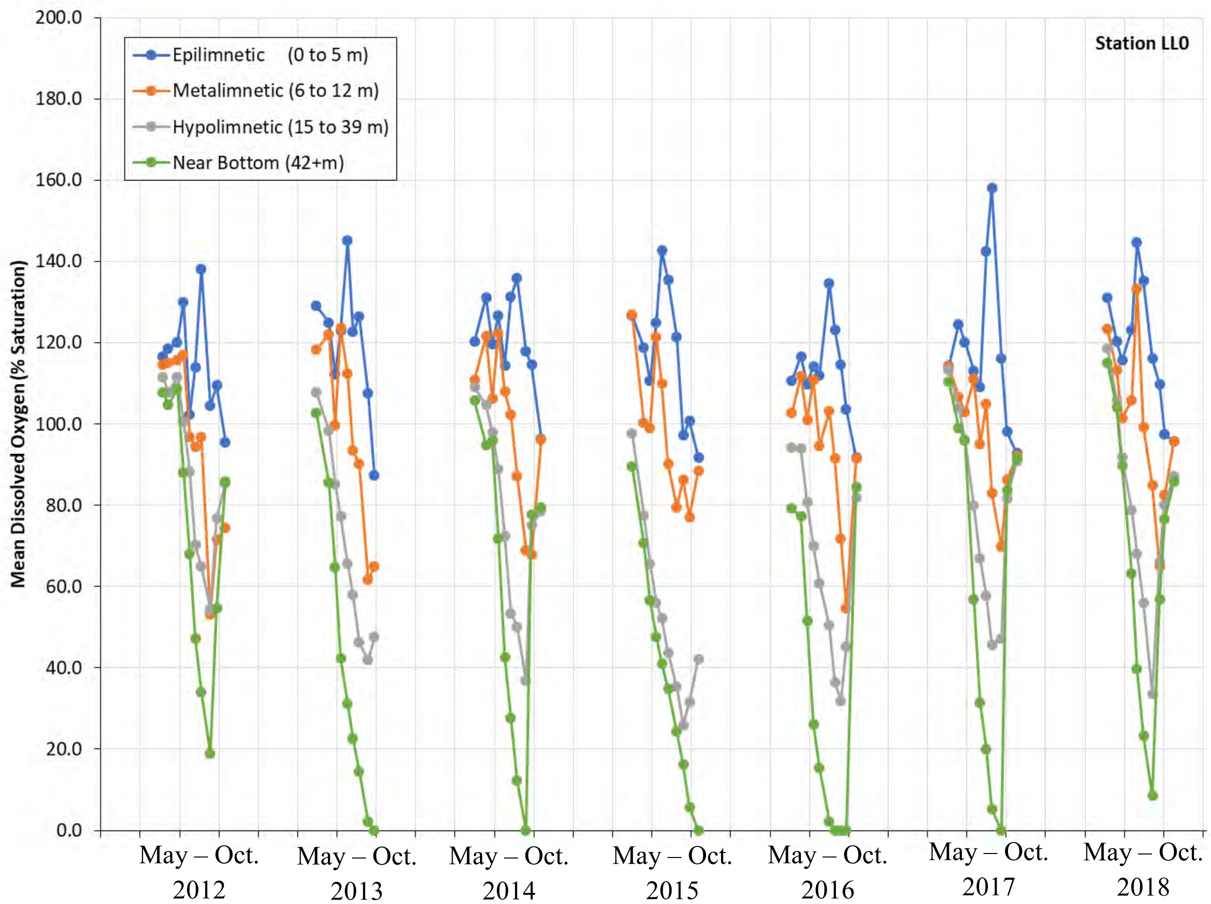

Figure 16. Mean epilimnetic, metalimnetic, hypolimnetic and near bottom DO percent saturation at LLO during 2012 through 2018.

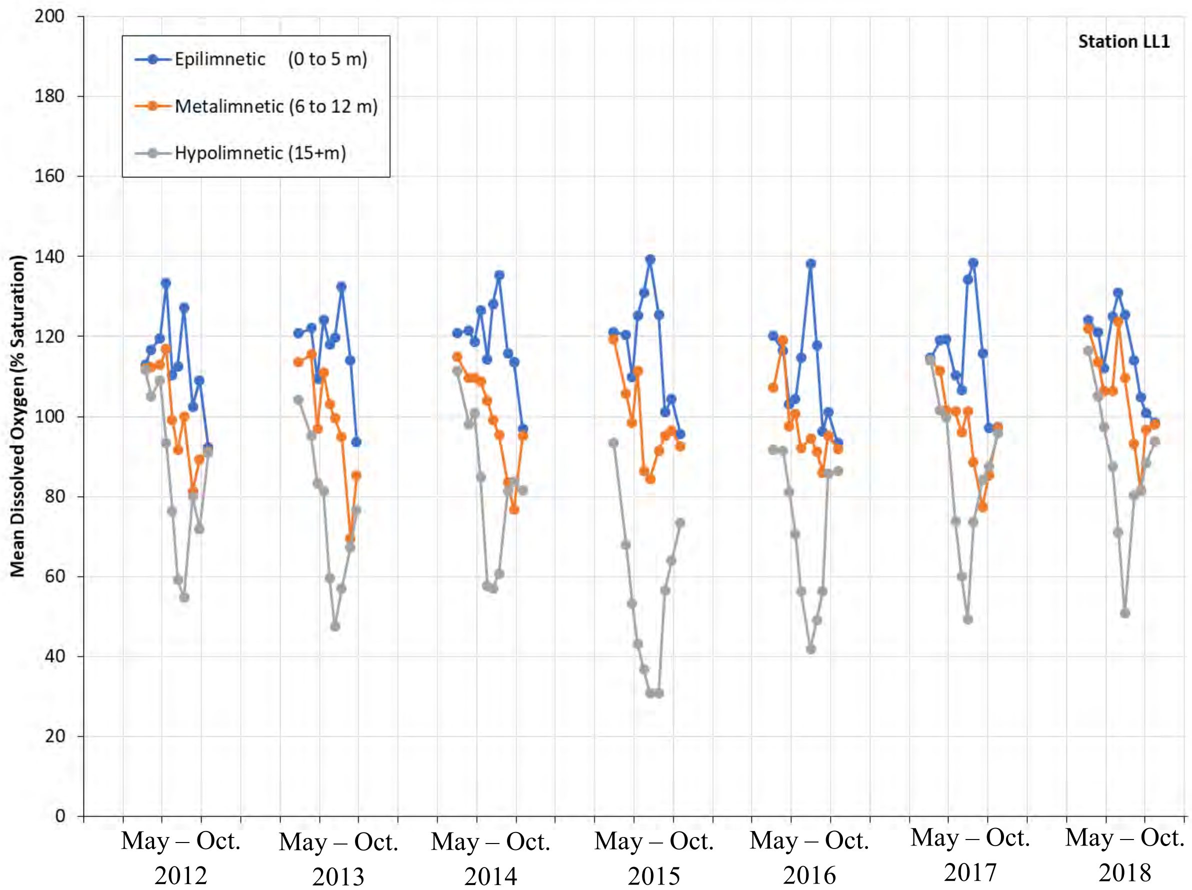

Figure 17. Mean epilimnetic, metalimnetic, and hypolimnetic DO percent saturation at LL1 during 2012 through 2018.

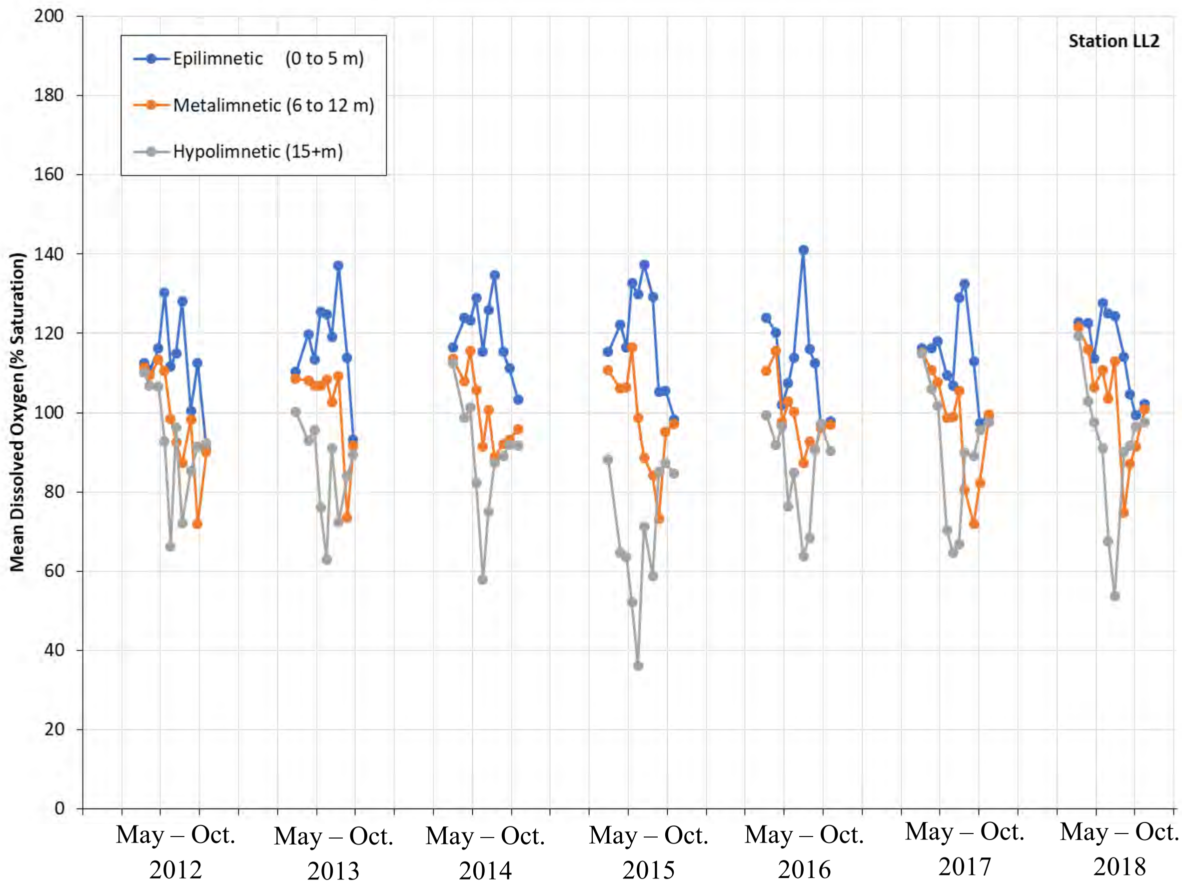

Figure 18. Mean epilimnetic, metalimnetic, and hypolimnetic DO percent saturation at LL2 during 2012 through 2018.

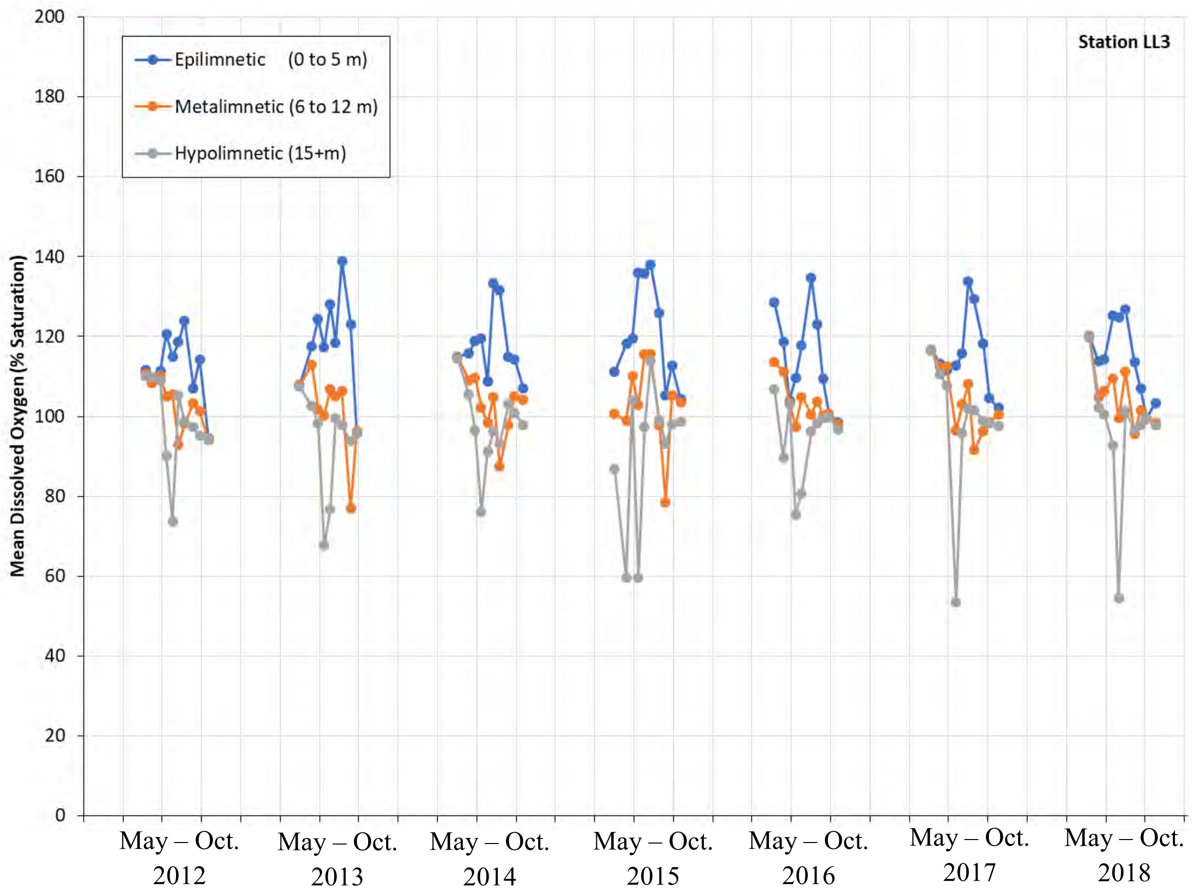

Figure 19. Mean epilimnetic, metalimnetic, and hypolimnetic DO percent saturation at LL3 during 2012 through 2018.

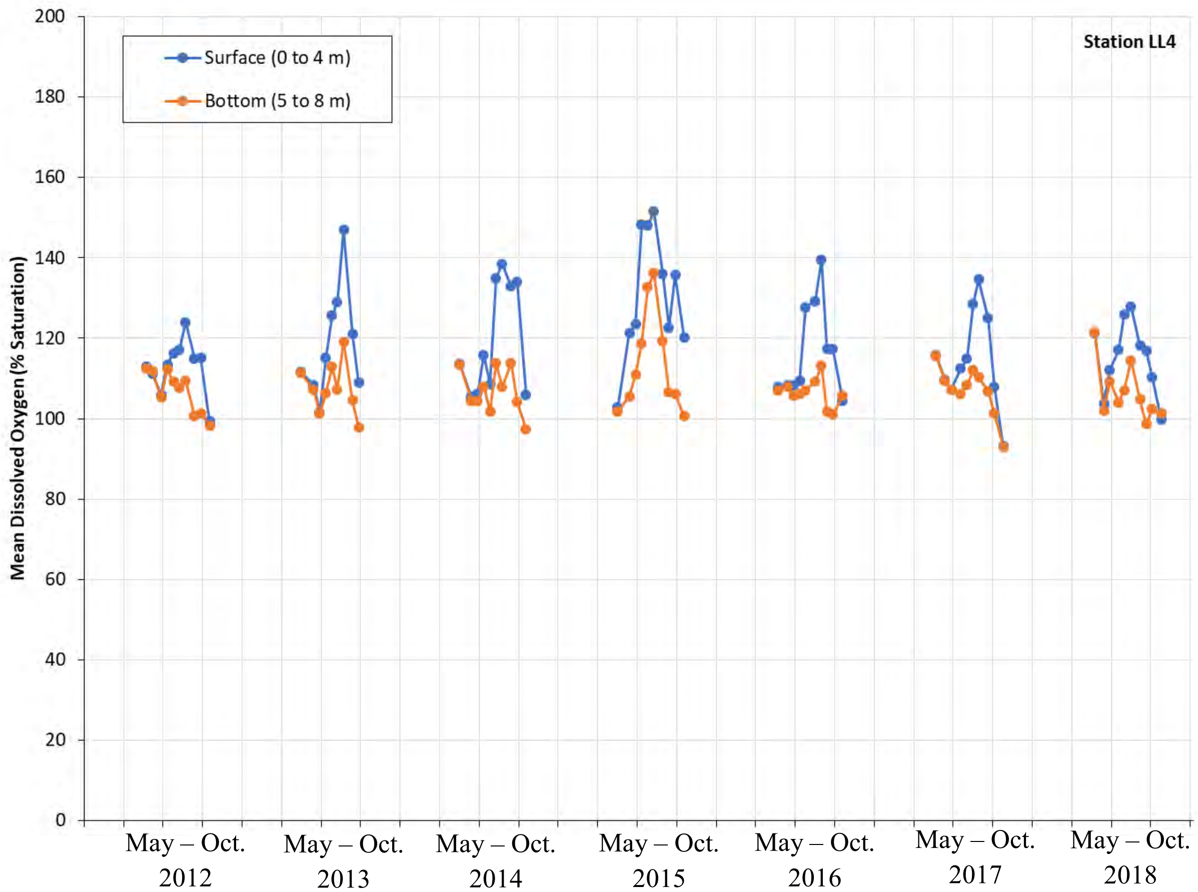

Figure 20. Mean surface and bottom DO percent saturation at LL4 during 2012 through 2018.

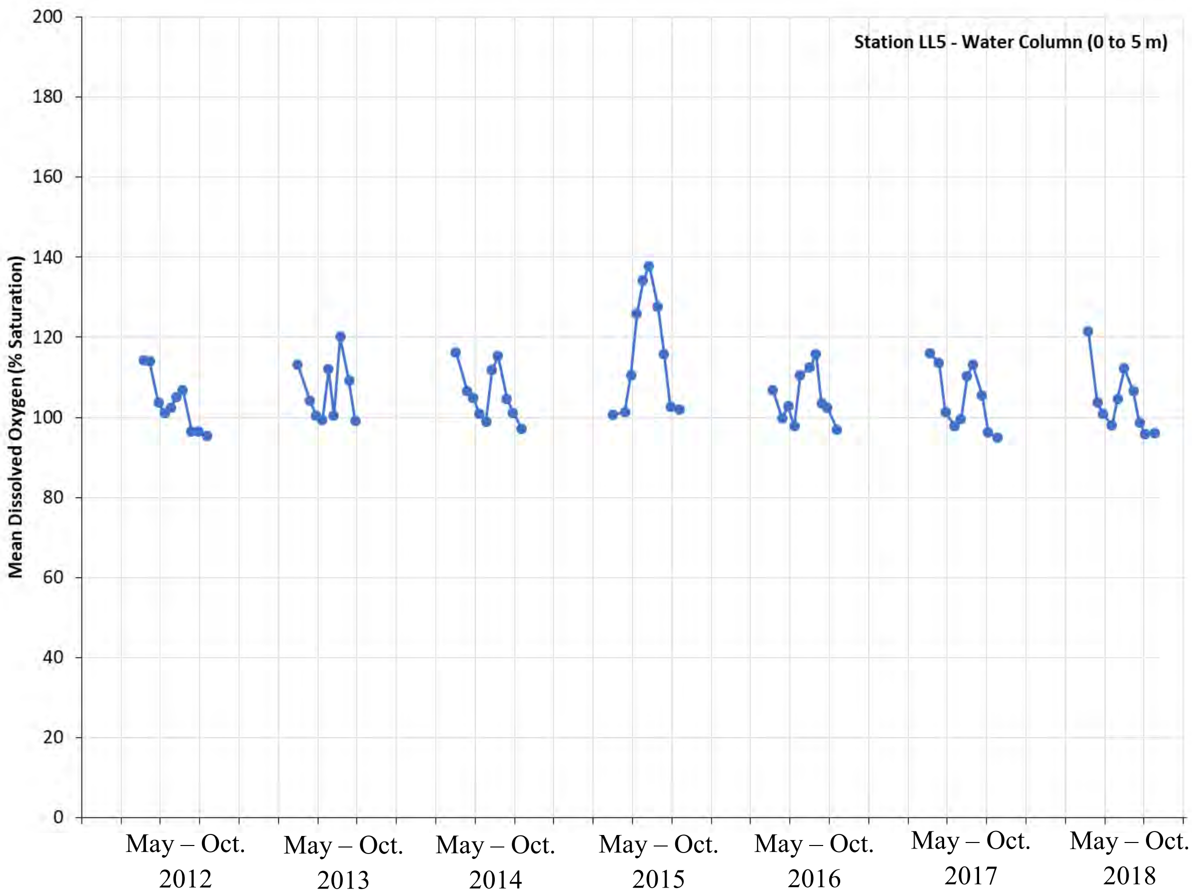

Figure 21. Mean water column DO percent saturation at LL5 during 2012 through 2018.

In Ecology's *Lake Spokane Measuring Improvement in Dissolved Oxygen and Ecosystem Health, A Literature Review* (Ecology 2018), Hypolimnetic Oxygen Deficit (HOD) was given a high prioritization as a method to assess the health of Lake Spokane. Areal HOD (AHOD) is the product of DO depletion rate in g/m^3 per day and hypolimnetic mean depth. In Lake Spokane AHOD is an indicator that shows that DO resources in the reservoir have increased markedly. AHOD gradually declined following phosphorus reductions in the 1970s following phosphorus removal. Whole hypolimnetic DO demand, including sediment, in Lake Spokane ranged from 2.2 to 6.3 g/m^2 per day before to 1.8 to 2.6 g/m^2 per day after phosphorus removal (Patmont 1987). The rate in 2000 was 0.75 g/m^2 per day and 0.54, 0.67, 0.85, 0.58, 0.71, 0.56, 0.48, 0.66, 0.74 g/m^2 per day in 2010 – 2018, respectively. These recent rates average 0.64 ± 0.11 g/m^2 per day (± 18%). The rate in 2000 was within that variation, thus showing that DO depletion rate has not changed in the past 19 years, which is suggested by minimum DO as well (Figure 12).

For comparison, Lake Washington AHOD decreased from a mean of 0.71 ± 0.1 g/m^2 per day during its eutrophic period in 1957 to 1969, before wastewater diversion, to 0.58 ± 0.05 g/m^2 per day in 1970 to 1983, to 0.47 ± 0.09 g/m^2 per day for this now oligotrophic lake (Lake Washington AHOD was 0.42 g/m^2 per day in 1933 before eutrophication (Lehman 1988; Welch et al. 2015)). The total decrease in Lake Spokane AHOD (68-89%) was much greater than that in Lake Washington (34%) in relative and absolute terms; 1.57-5.7 versus 0.24 g/m^2 per day, respectively.

The AHOD rate in Lake Spokane in 2018 (0.74 g/m^2 per day) was slightly higher than the latest Lake Washington rate. The rate in 2016 of 0.48 g/m^2 per day was very similar to the latest Lake Washington rate. Reservoirs tend to have higher AHODs than lakes due to usually higher phosphorus inflows and temperature. Walker (1985) determined AHODs for 34 lakes and 37 U.S. Army Corps of Engineers reservoirs and concluded that rates for reservoirs averaged 1.4 times higher than for lakes, when correlated with chl.

The average Lake Spokane AHOD rate over 2010-2017 was about equal to that predicted from average chl concentrations – 0.63 vs 0.58 g/m^2 per day – according to Walker's model (Table 5; No chl samples were collected in the reservoir in 2018 or 2019). However, observed AHOD before and immediately following phosphorus reduction of the 1970s and 1980s was much greater than predicted from chl – on the order of 2 to 3 fold (Table 5). While the average observed AHOD in Lake Spokane during 2010-2017 was nearly equal to the predicted AHOD, the latter was still 40% greater than the predicted rate for lakes, as shown in Walker's comparison. Chlorophyll samples were not collected in 2018, therefore, 2018 AHOD numbers were not included in this comparison.

Table 5. Observed and predicted AHOD as range and mean in g/m2 per day in Lake Spokane before; immediately after and 25 – 30 years after advanced wastewater treatment. Predicted AHOD from mean seasonal (June – October) chl in ug/L based on equations from Walker (1985)

Year		Chl (June – October)	AHOD Observed	AHOD Predicted, Reservoirs	AHOD Predicted, Lakes
Pre-Advanced WWT	1972 – 1977	17 – 27.8 (20.5)	2.2 – 6.3	1.11 – 1.38 (1.2)	0.78 – 0.98 (0.85)
Post Advanced WWT	1978 – 1985	7.9 – 15.2 (11.1)	1.8 – 2.6	0.78 – 1.05 (0.91)	0.55 – 0.74 (0.64)
Recent	2010 – 2017	2.7 – 5.2 (4.1)	0.54 – 0.85 (0.63)	0.48 – 0.65 (0.58)	0.34 – 0.46 (0.41)

2.2.3 Phosphorus

Summer (June to September) epilimnetic mean TP concentrations in 2017, the most recent year with phosphorus monitoring data in Lake Spokane, were about average for the eight-year period of monitoring for most stations (Figure 22). Phosphorus samples were not collected in Lake Spokane during 2018 or 2019. Summer mean epilimnetic TPs in 2012 through 2017 were calculated using concentrations at 0.5 and 5 m for stations LL0 to LL2, and concentrations at 0.5 m for stations LL3 to LL5. Summer means for 2010 and 2011 are based on averages from euphotic zone composite samples.

Summer mean epilimnetic TP decreased slightly longitudinally through the reservoir in all eight years with the lowest TP usually at station LL0. Area-weighted, whole-reservoir, epilimnetic TPs averaged 11.3 ± 1.5 µg/L for the eight years, with a variation of only 13%, and with no evident trend. Whole-reservoir epilimnetic TP ranged from 8.9 µg/L in 2016 to 13.4 µg/L in 2013. The eight-year mean puts the reservoir at the meso-oligotrophic state boundary and is lower than epilimnetic TP observed in Lake Washington (14 µg/L, King County 2003) and Lake Sammamish (12 µg/L, Welch and Bouchard 2014), both classified as mesotrophic waterbodies.

Summer (June to September) hypolimnetic TPs also were rather consistent over the eight-year monitoring period with a mean of 26.4 ± 22%. Hypolimnetic TP was determined in the lacustrine zone for stations LL0, LL1, and LL2 for all eight years (Figure 23). The means were calculated using samples collected at 20 m and deeper in 2012 through 2017. This excludes the top 5 m of the hypolimnion, which is necessary in order to compare 2012-2017 data with those from 2010 and 2011 that were based on composite samples at various depths from 21 m and deeper. Hypolimnetic TPs were volume-weighted for stations LL0 and LL1, while those at station LL2 used 1 m meter off the bottom only.

Maximum hypolimnetic TPs were relatively low during the eight years of monitoring, usually less than 45 µg/L, and the average was only 24.6 µg/L (May-October). The lowest concentrations were in 2011 while the highest were in 2017, with a peak in early August at just over 62 µg/L. The second highest peak was in 2016, also in early August, at just over 55 µg/L

(Figure 23). The lowest volume-weighted epilimnetic TP concentrations also occurred in 2016. Release of phosphorus from anoxic bottom sediments – the principal process of internal loading - likely occurred in the hypolimnion in 2017, similar to 2016. Total phosphorus concentrations had not exceeded 70 µg/L during the previous four years until 2016 when bottom TP reached 122 µg/L in early August at LL0. Peak bottom TP concentrations in 2017 ranged from 67 to 109 µg/L in the lacustrine zone.

Table 6 summarizes TP data from 2010 through 2019 in both the Spokane River (two Ecology monitoring stations upstream of Lake Spokane) and Little Spokane River as well as LL4 and LL5 (2010 – 2017 only). There was no apparent trend in mean summer TP at any site during the eight to ten years of monitoring. It should be noted that TP at LL5 is higher than river inflow at Nine Mile, which is expected given the TP inflow from the Little Spokane River (Table 6). Separating out the July – September low flow period shows that epilimnetic/euphotic TPs in the riverine and transition area (LL5 and LL4) contained higher TP than the down-reservoir concentrations (Table 7).

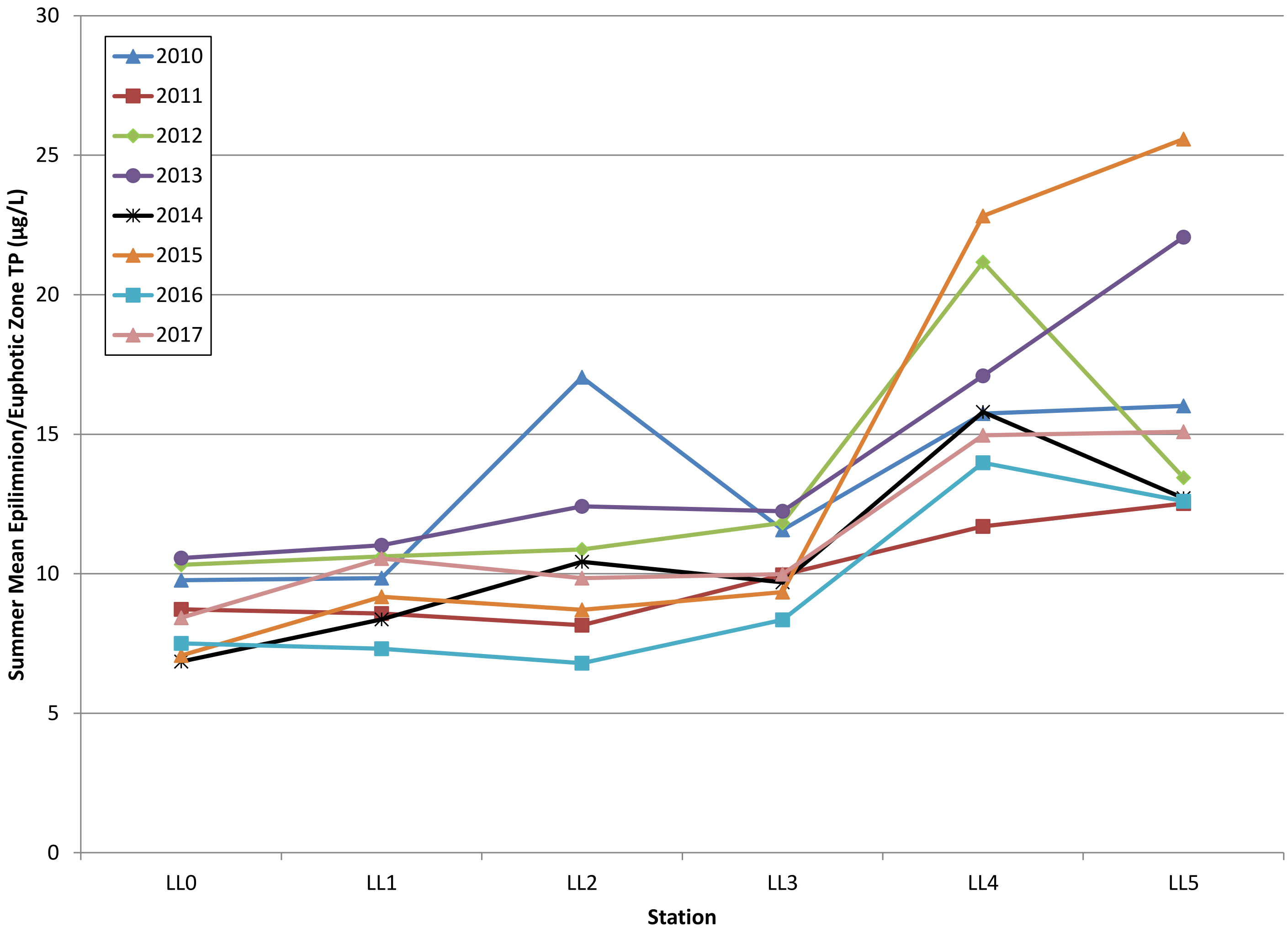

Figure 22. Summer (June-September) mean epilimnion/euphotic zone TP concentrations, 2010-2017 (Data is presented from down-reservoir to up-reservoir, left to right.)

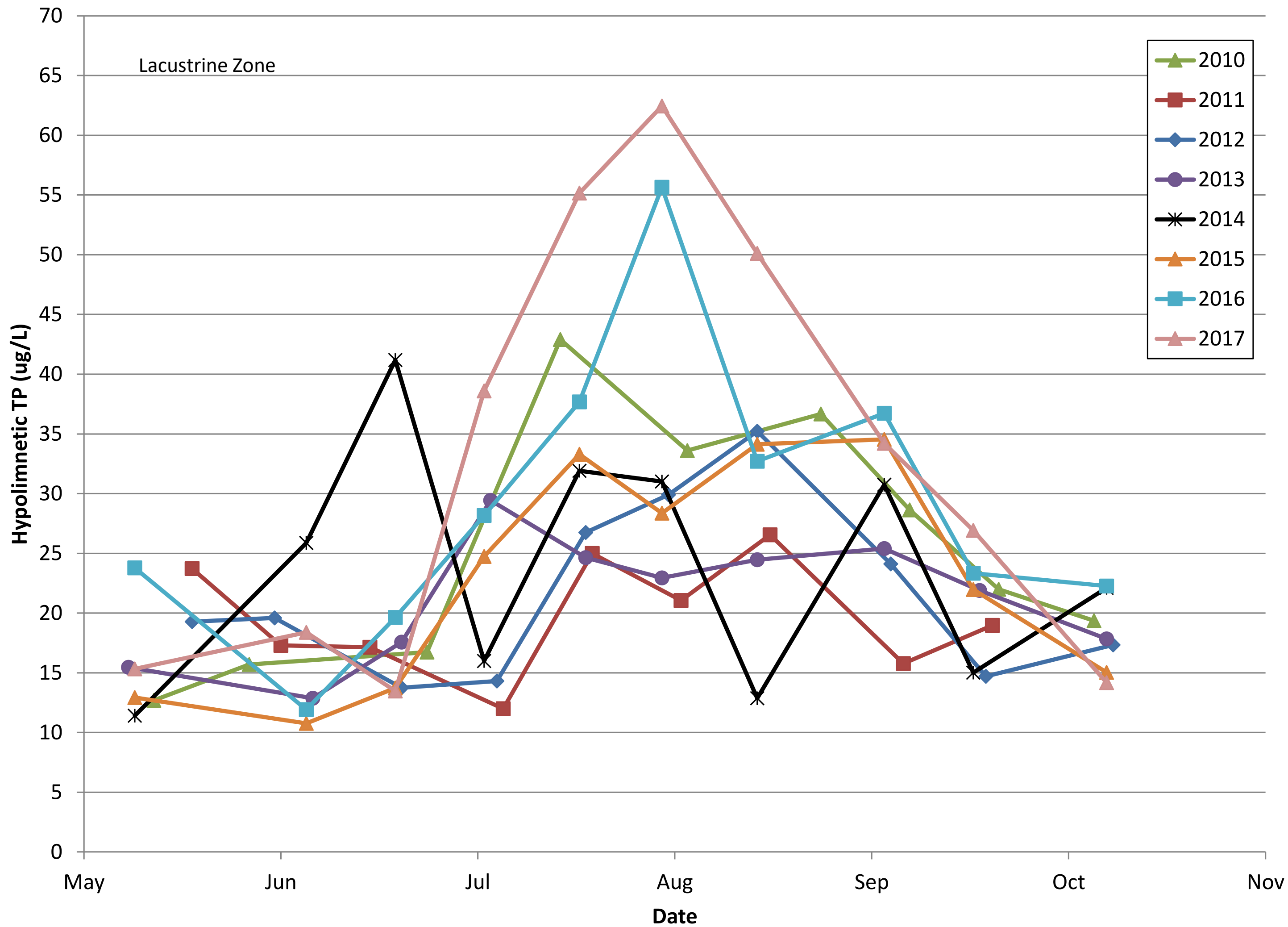

Figure 23. Lacustrine zone mean hypolimnetic TP concentrations, 2010-2017.

Table 6. Summer (June – September) mean TP concentrations (µg/L) in the Spokane River compared to summer mean volume-weighted TP concentrations in Lake Spokane at LL4 and LL5. Volume weighted TPs for 2010 and 2011 at LL4 and LL5 are based on composite samples.

Year	Spokane River @ Riverside State Park	Spokane River @ Nine Mile	Little Spokane River near Mouth	Lake Spokane @ LL5	Lake Spokane @ LL4
2010	24	18.1	19.3	15.9	15.9
2011	15.4	--	21.6	12.5	11.9
2012	10.6	--	19.6	13.4	18.0
2013	14.3	12.9	17.5	19.0	19.9
2014	11.9	12.6	14.6	11.9	16.1
2015	21.3	15.4	107[1]	21.1	22.1
2016	15.5	11.1	11.9	11.4	14.5
2017	20.0	13.1	19.3	15.7	14.9
2018	15.6	12.6	12.1[2]	No data	No data
2019	15.4[3]	13.1	15.0	No data	No data
Mean	16.4	13.6	25.8	15.1	16.7
STDEV	4.2	2.2	28.7	3.5	3.2

[1]June – September average for 2015 includes a very high value, 397 µg/L, which was measured on June 2nd, 2015. This value corresponds with an extreme precipitation and runoff event in the Little Spokane River watershed. The summer average for the Little Spokane River without this value is 17.7 µg/L.
[2]Summer average does not include data from June. No TP data reported for Little Spokane Station for June 2018.
[3]The June TP concentration was reported by Ecology as a non-detect with a detection limit of 10 µg/L. The concentration was set to the detection limit (10 µg/L) for analysis and mean calculation purposes.

Table 7. Mean epilimnetic/euphotic zone TP concentrations for Lake Spokane for 2010 – 2017.

Lake Station	Mean Epilimnion/Euphotic Zone TP (µg/L)			
	May	**June**	**July – Sept.**	**Oct.**
LL5	15.8	11.8	18.0	11.5
LL4	15.4	11.5	18.4	13.4
LL3	17.1	10.5	10.3	13.3
LL2	15.9	10.0	9.7	9.0
LL1	15.0	9.5	9.5	9.1
LL0	14.2	9.5	8.2	7.4

2.2.4 Nitrogen

Epilimnetic mean TN concentrations in summer (June to September) 2017, the most recent year with nitrogen monitoring data, were similar or slightly higher than in 2015 and 2016 (Figure 24). Mean summer TN concentrations in 2015 – 2017 were higher at the deeper lacustrine stations than the previous five years (Figure 24). Summer TN at LL4 was lowest in 2012 through 2015 and highest in 2017, while the near opposite occurred at LL5, with the lowest concentrations in

2010 and highest in 2014, 2016, and 2017 (Figure 24). Epilimnetic TN was generally higher in 2017 than in other years in the transition and riverine zones and higher in 2016 in the lacustrine zone. Summer mean epilimnetic TNs in 2012 through 2017 were calculated using concentrations at 0.5 and 5 m for stations LL0 to LL2, and concentrations at 0.5 m for stations LL3 to LL5. Summer means for 2010 and 2011 are based on averages from euphotic zone composite samples. Samples were not collected for nitrogen analysis in 2018 or 2019.

Total N concentrations have been increasing in the Spokane River for several decades (Figure 24). Mean (June – October) TN in the Spokane River at Riverside State Park, just downstream of the City of Spokane WWTP effluent discharge, has increased from 697 in 1997 to a peak of 2,293 µg/L in 2015 while dissolved inorganic nitrogen (DIN) increased from 420 µg/L in 1978 to a peak of 2,130 µg/L in 2015. The higher TN and DIN concentrations in 2015 and 2016 may be partly due to low river flows and greater influence of groundwater. This may have also been the case during low river flows in summer 2018. However, the near doubling of TN from around 800 µg/L in the 1990s to near 1,500 µg/L since then was not due to a concentration effect of low flow. Average June – October flow in the Spokane River differed by only 7% from the 1990s to 2000 – 2019, while TN increased by 37% between the same time periods. Increased nitrogen has occurred while TP concentrations at Riverside steadily decreased following wastewater phosphorus reduction, reaching a rather stable level since the 1990s, ranging between about 15 – 20 µg/L, except for 1997 and 1998 (Figure 25). Water quality data for the Spokane River at Riverside State Park was available through Ecology's EIM system and is collected as part of the ambient monitoring program.

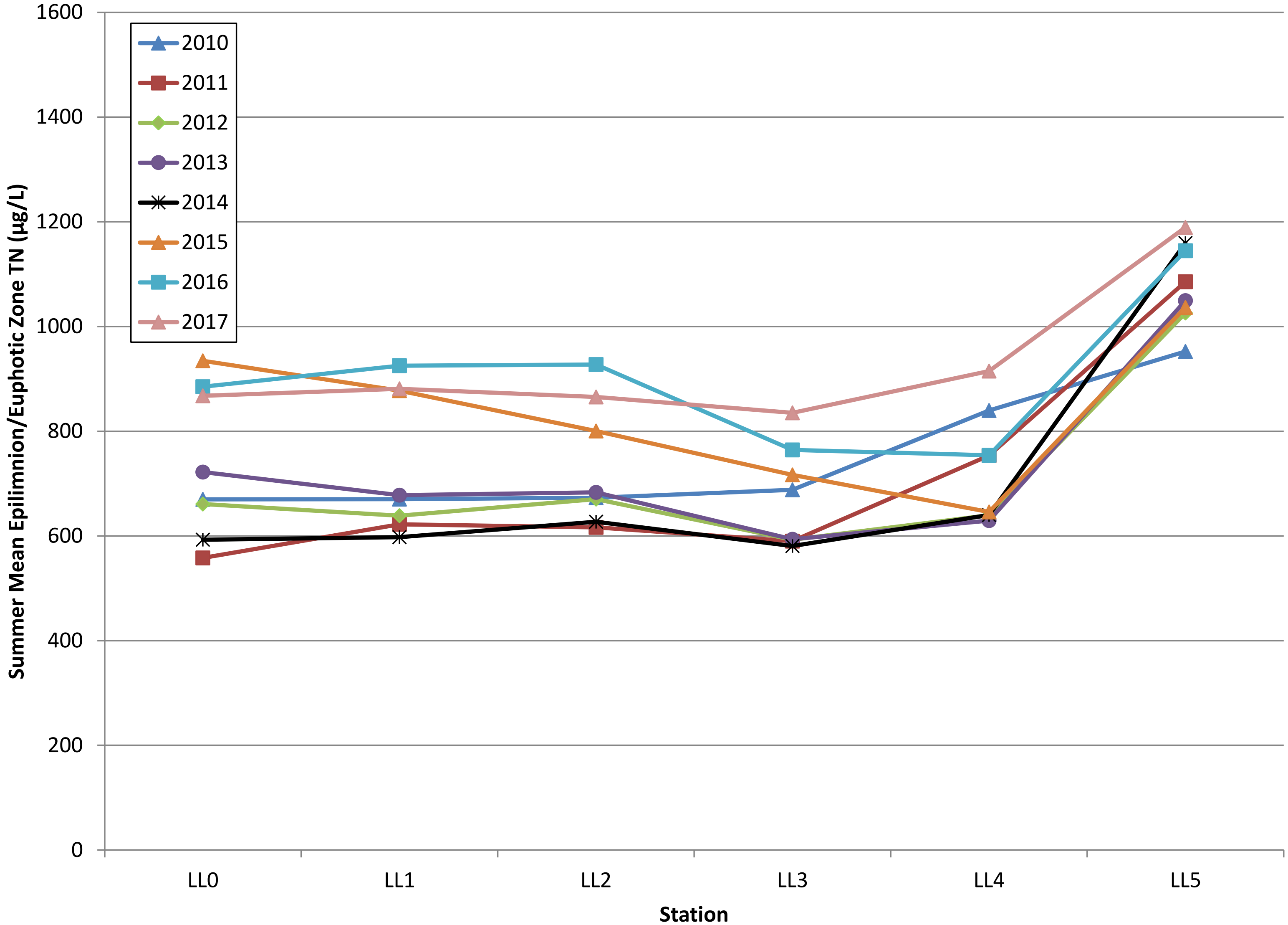

Figure 24. Summer (June-September) mean epilimnion/euphotic zone TN concentrations, 2010-2017 (Data is presented from down-reservoir to up-reservoir, left to right.)

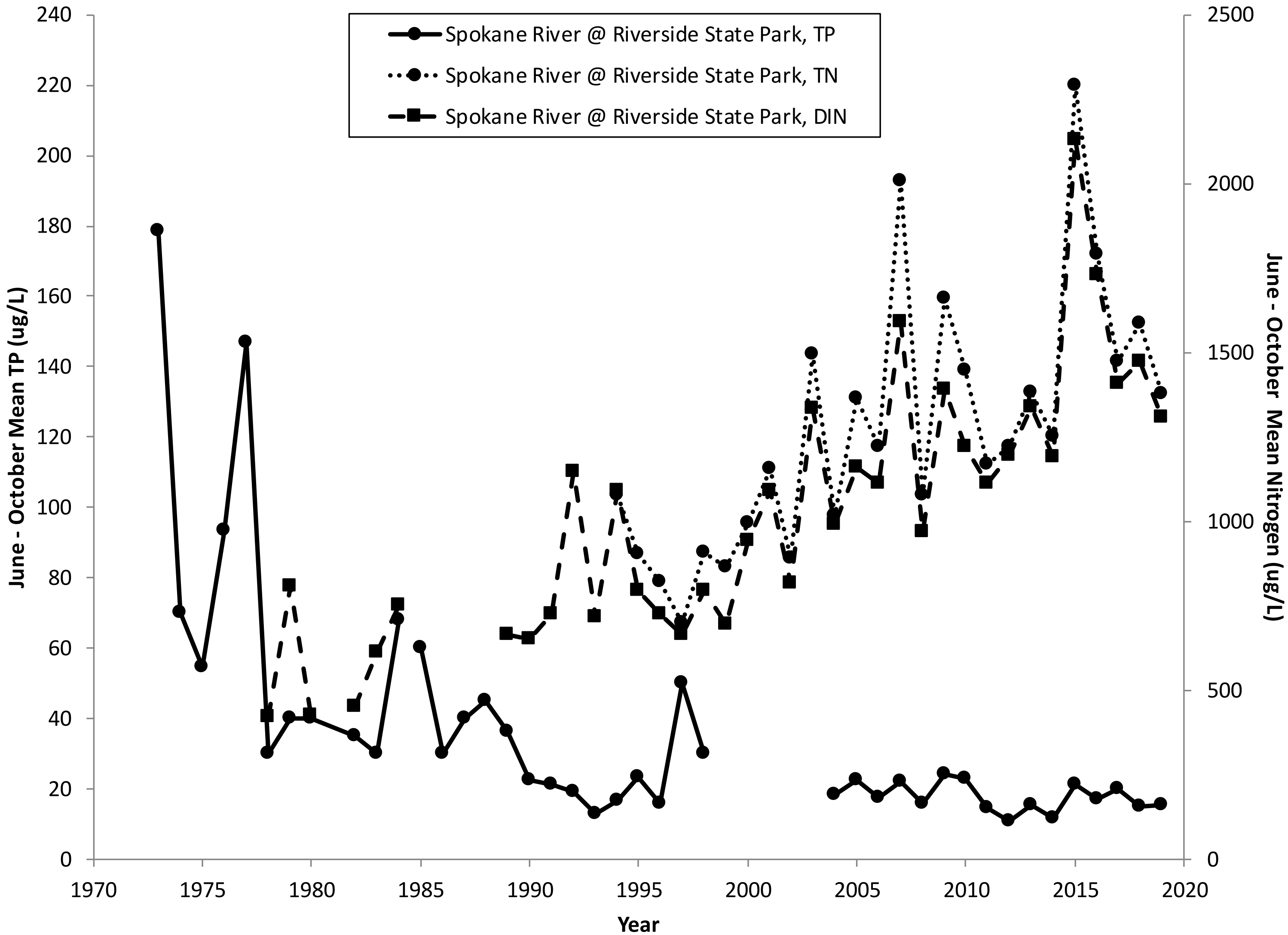

Figure 25. Mean (June-October) TN, DIN, and TP in the Spokane River at Riverside State Park**.**

2.2.5 Trophic State/Production

During the last eight years of nutrient monitoring (2010 – 2017), Lake Spokane was at or near borderline oligotrophy-mesotrophy on average in all zones, except for the transition and riverine zones with slightly greater TP than 10 µg/L, which is the oligotrophic-mesotrophic boundary (Tables 8 and 9). Slightly higher whole-lake, eight-year average chl and TP was due to higher concentrations in the transition and riverine zones in 2015.

Table 8. Summer (June to September) epilimnetic means during 2012-2017 compared to 2010 and 2011 summer euphotic zone means in lacustrine, Transition, and Riverine Zones in Lake Spokane. Whole reservoir means are area weighted; Lacustrine 61%, Transition 29%, and Riverine 11% of the total reservoir area.

Year	Lacustrine (0.5, 5 m)			Transition (0.5 m)			Riverine Zone (0.5 m)			Whole Reservoir		
	TP (µg/L)	Chl (µg/L)	Secchi (m)	TP (µg/L)	Chl (µg/L)	Secchi (m)	TP (µg/L)	Chl (µg/L)	Secchi (m)	TP (µg/L)	Chl (µg/L)	Secchi (m)
2010	9.8	5.1	5.1	13.7	4.7	3.7	16.0	3.2	3.6	11.6	4.7	4.5
2011	9.1	3.3	5.8	10.8	1.9	4.7	12.5	1.4	4.8	10.0	2.7	5.4
2012	10.6	4.8	4.4	16.5	4.0	3.9	13.4	2.7	4.7	12.6	4.3	4.3
2013	11.3	3.0	5.7	14.7	5.5	3.9	22.1	3.2	4.1	13.4	3.7	5.0
2014	8.5	3.8	5.0	12.7	5.9	3.6	12.7	4.2	4.0	10.2	4.4	4.5
2015	8.3	3.8	5.3	16.1	7.2	3.3	25.6	7.4	2.9	12.4	5.1	4.5
2016	7.2	3.4	5.6	11.2	4.7	4.0	12.6	3.8	5.0	8.9	3.8	5.1
2017	9.6	3.8	5.6	12.5	4.1	4.4	16.8	5.7	4.3	11.2	4.1	5.1
Average	9.3	3.9	5.3	13.5	4.7	3.9	16.5	3.9	4.2	11.3	4.1	4.8

Table 9. Trophic state boundaries (Nurnberg 1996).

Parameter	Oligo-Mesotrophic	Meso-Eutrophic
TP (µg/L)	10	30
Chl (µg/L)	3	9
Secchi (m)	4	2

Source: Nurnberg 1996

Average trophic state indices (TSI) in the upper reservoir zones in 2017, the year with the most recent monitoring data, were at or slightly above the oligo-mesotrophic boundary – TSI of 40 (Table 10). TSIs for TP and chl indicated mesotrophy throughout the reservoir. Average TSIs, did not indicate a eutrophic state at any site in 2017.

Average TSIs for chl, TP and secchi depth for each zone over the eight-year period are shown in Figures 26 through 28. Indices in the lacustrine zone were fairly consistent over the eight-year period. TSIs for TP and secchi disk depth were below the oligotrophic-mesotrophic boundary while those for chl varied from just above the boundary to halfway to eutrophy (Figure 26).

Average TSIs were slightly higher in the transition and riverine zones, with near borderline meso-eutrophy reached a couple years but were usually around the meso-oligotrophic boundary.

The higher chl TSIs in 2013 – 2015 in the transition zone and 2015 in the riverine zone were not that much above the respective average chl TSIs for all years, which varied by only 9% and 12%, respectively, among the years. Such variation is well within the variability of climatic conditions.

Table 10. Trophic state indices for lacustrine, transition, and riverine zones in Lake Spokane, 2017. Shaded indices (≥40) indicate mesotrophy and unshaded oligotrophy.

2017	Lacustrine	Transition	Riverine
TSI-TP	37	41	45
TSI-Chl	44	44	48
TSI-Secchi	35	40	37
TSI-Average	38	42	43

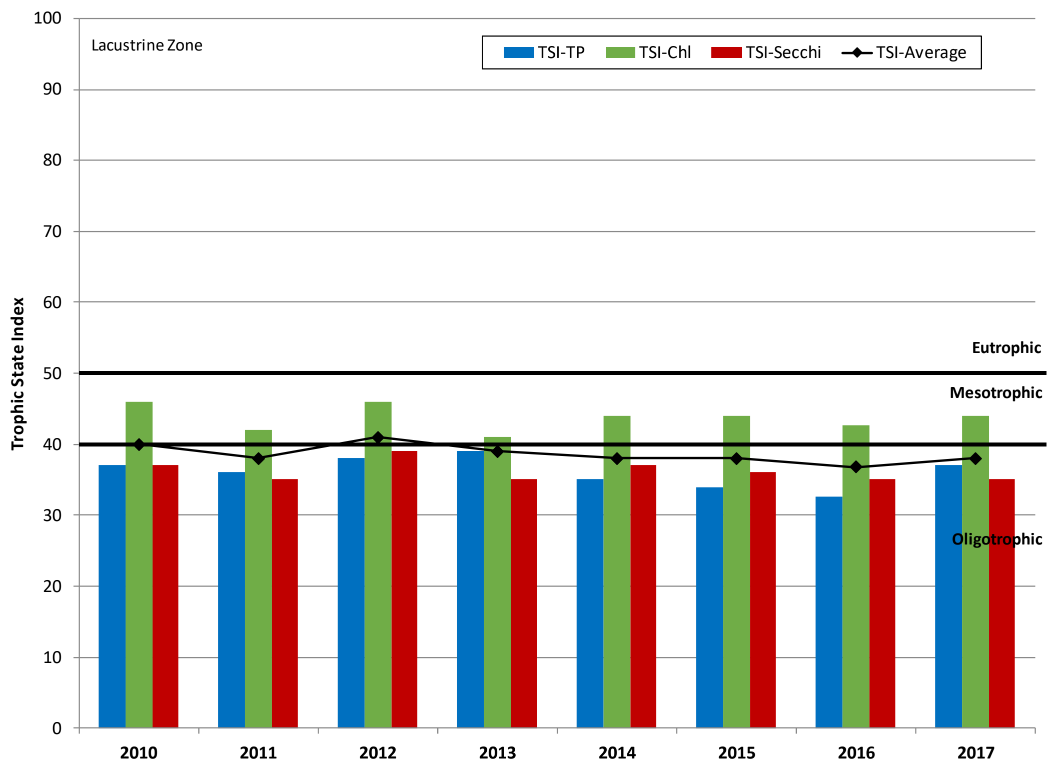

Figure 26. Average TSI indices for the lacustrine zone in Lake Spokane, 2010 – 2017.

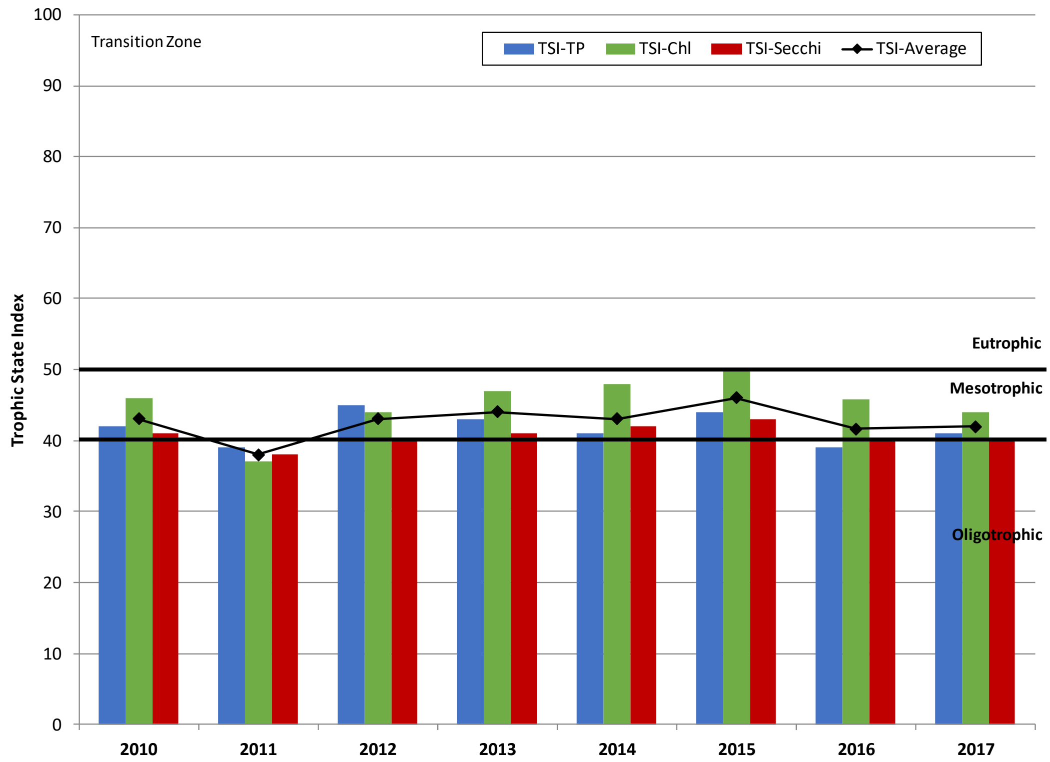

Figure 27. Average TSI indices for the transition zone in Lake Spokane, 2010 – 2017.

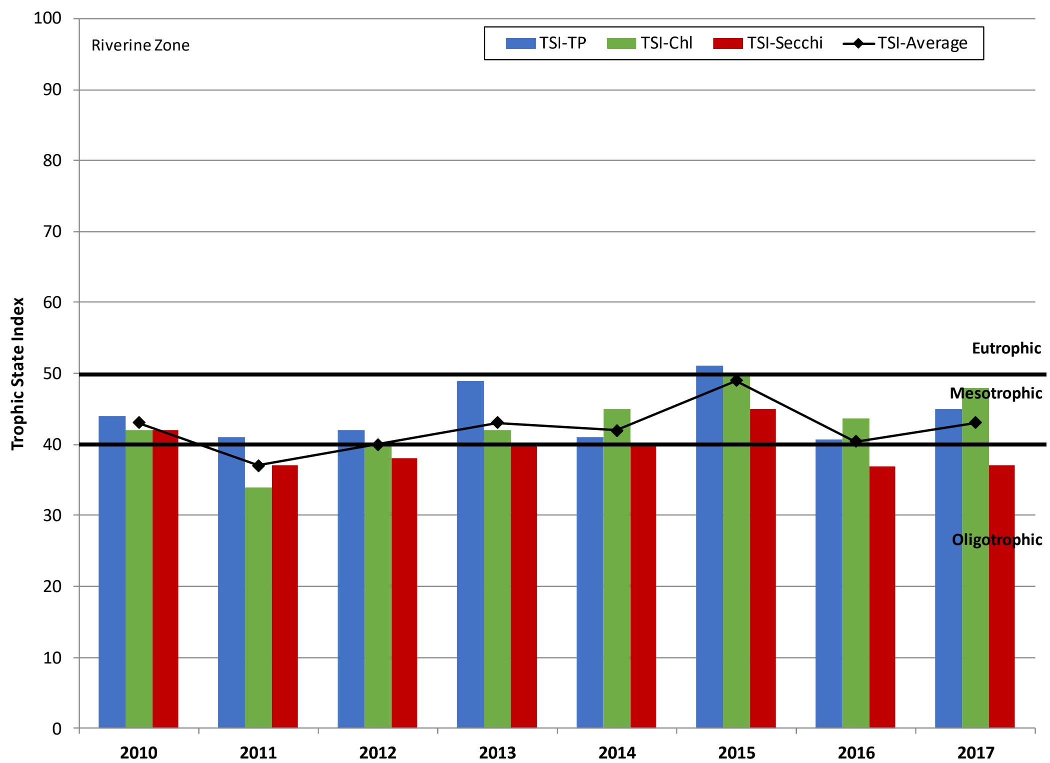

Figure 28. Average TSI indices for the riverine zone in Lake Spokane, 2010 – 2017.

Total N:TP ratios tended to be higher the last three years of nutrient monitoring, with slightly lower values in 2017 (Table 11). Ratios throughout the reservoir during 2010 – 2017 were all very high. The lowest ratio observed at the six stations during 2010 through 2017, was at LL4 in 2015 and mostly due to higher epilimnetic TP. Ratios were all well above the Redfield ratio of 7.2, which represents the demand by algae.

The reservoir inflow TN:TP during 1974 to 1978, before wastewater phosphorus reduction, averaged 15 and algal growth potential bioassays indicated that N alone, or N+P, limited algal growth 60% of the time on average (Patmont 1987). Reducing phosphorus alone has greatly improved water quality of the reservoir, as well as increasing the inflow TN:TP ratio (LL5) three to almost six-fold in recent years, compared to pre-phosphorus reduction inflow ratios. The increased ratio was also due partly to increased river N. The data suggest that removing phosphorus alone seems to have dramatically improved the trophic state of Lake Spokane.

The progression of trophic state improvement is illustrated in Figure 29. The reservoir was near hypereutrophy, determined by chl and TP, before wastewater phosphorus reduction. That was due more to excess phosphorus, than chl, because TN:TP was low and nitrogen was usually limiting. After phosphorus reduction, phosphorus became the most limiting nutrient. Since then chl has been directly related to TP, as inflow TP continued to decline, moving the reservoir from border-line meso-eutrophic in 1982 – 1985 to borderline meso-oligotrophic during 2010 – 2017.

Table 11. Summer mean epilimnetic TN:TP ratios.

Station	2010	2011	2012	2013	2014	2015	2016	2017
LL0	68.5	64.0	64.0	68.3	86.5	132	118	103
LL1	68.1	72.5	60.2	61.5	71.4	95.7	127	83.6
LL2	39.5	75.5	61.6	55.0	60.1	91.9	136	87.9
LL3	59.4	59.3	50.1	48.5	59.9	76.7	91.5	83.7
LL4	53.3	64.4	30.2	36.8	40.5	28.3	53.9	61.1
LL5	59.5	86.7	76.3	47.5	91.2	40.5	90.8	78.8

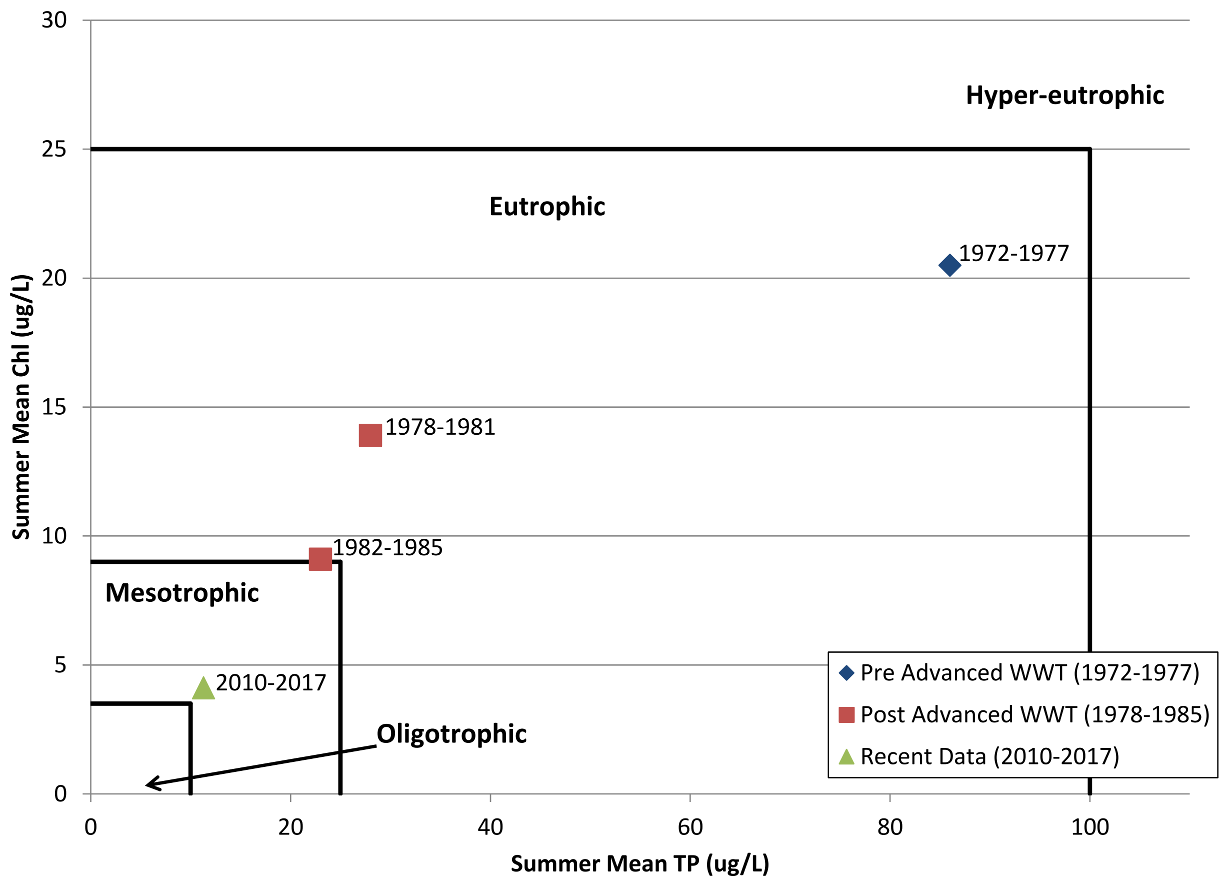

Figure 29. Transition of Lake Spokane from borderline hypereutrophy to meso-oligotrophy over a period of 45 years.

2.2.6 DO, Temperature and Fish Habitat

In order to gain a cursory understanding of the percent of reservoir volume acceptable for growth of rainbow trout, temperature and DO were analyzed for each station from 2010 through 2018 and displayed in habitat volume diagrams, Figures 30 through 35. Temperature (≤ 18°C) and DO (≥ 6.0 mg/L) criterion, based upon the USFWS Habitat Suitability Information (USFWS, 1984), for rainbow trout growth were used to construct the habitat volume diagrams.

The data suggest that temperature restricted habitat for rainbow trout far more than DO during spring and early summer at all sites and that temperature continued to be more restrictive than DO for the rest of much of the year at the shallower sites. While DO was restrictive at LL0 later in the summer, there was little restrictive effect from DO at other sites. Temperature and DO habitat became very restrictive for trout at LL0 during late July, August and early September when either no or a small percent of favorable habitat volume existed with temperatures less than 18°C and DO greater than 6 mg/L. The greater restriction by DO at LL0 than at other sites was due to longer residence times of largely isolated bottom water, given the much longer water residence times in 2016 as well as in 2015. There was more acceptable habitat available farther upstream at LL1, LL2, and LL3.

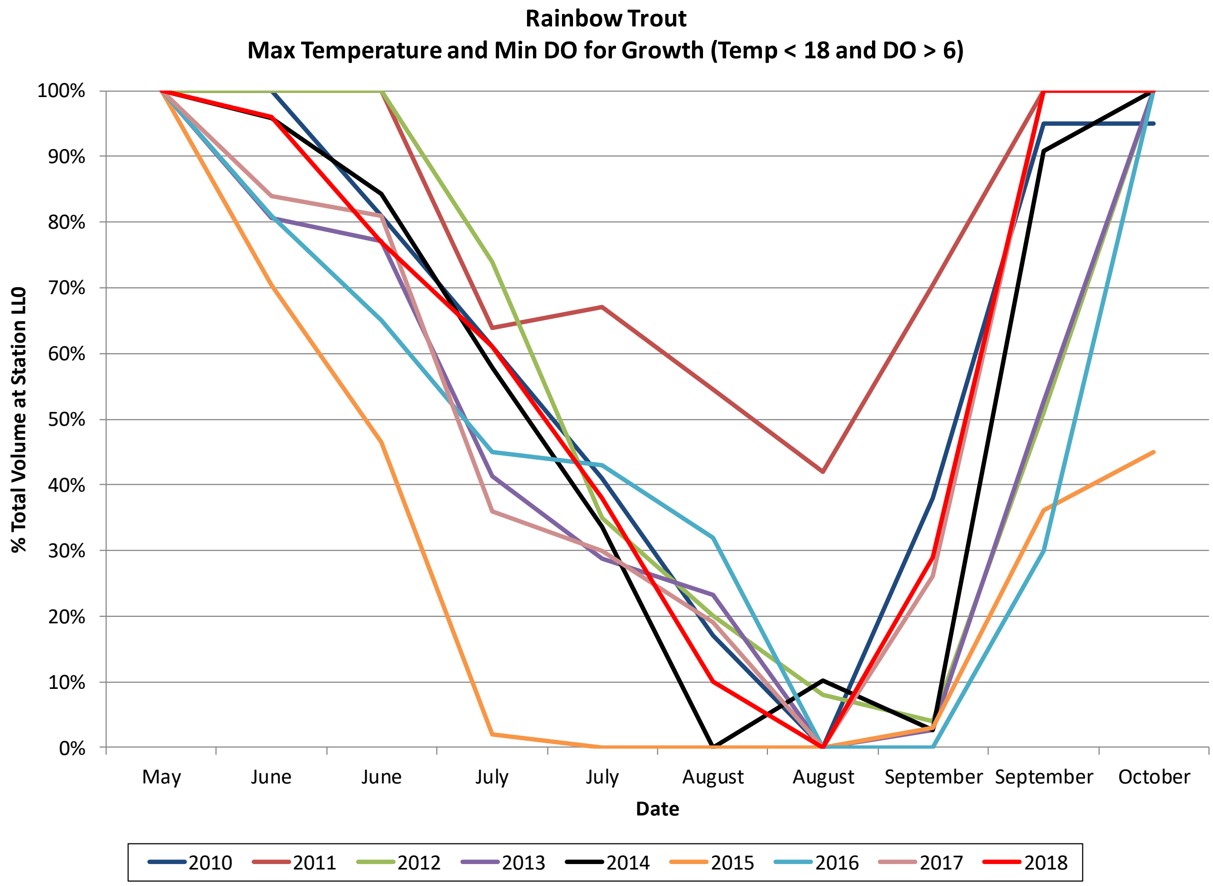

Figure 30. Habitat conditions at station LL0 for rainbow trout in 2010 – 2018, based on maximum temperature (18°C) and minimum DO (6.0 mg/L) for growth.

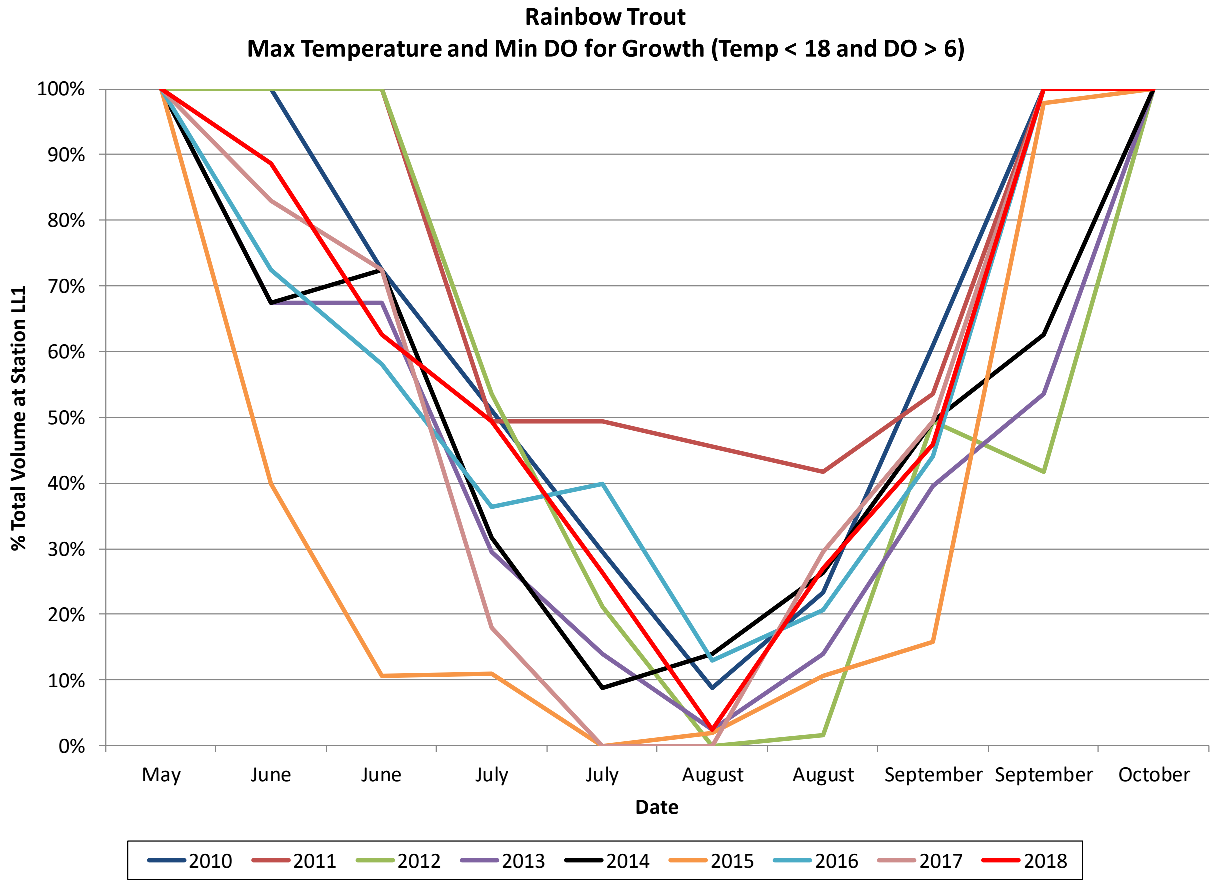

Figure 31. Habitat conditions at station LL1 for rainbow trout in 2010 – 2018, based on maximum temperature (18°C) and minimum DO (6.0 mg/L) for growth.

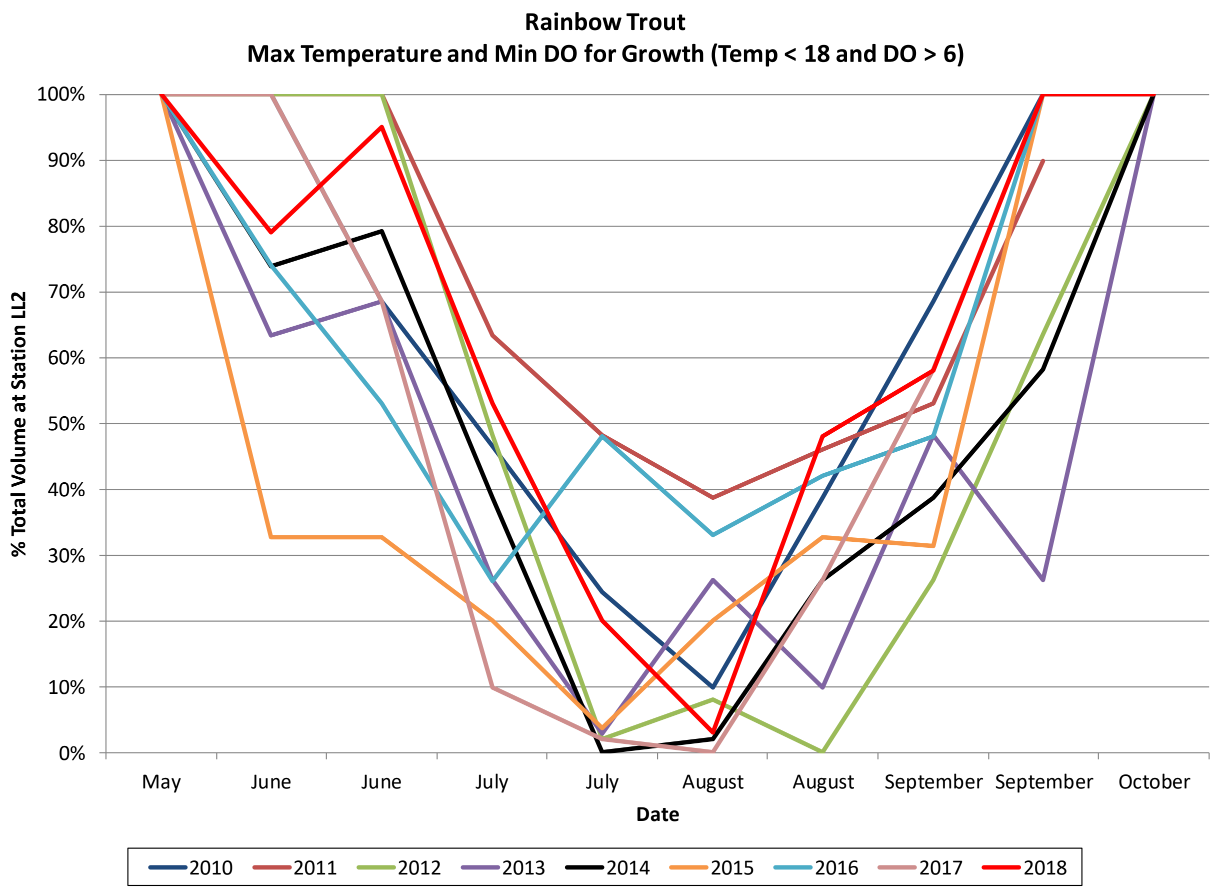

Figure 32. Habitat conditions at station LL2 for rainbow trout in 2010 – 2018, based on maximum temperature (18°C) and minimum DO (6.0 mg/L) for growth.

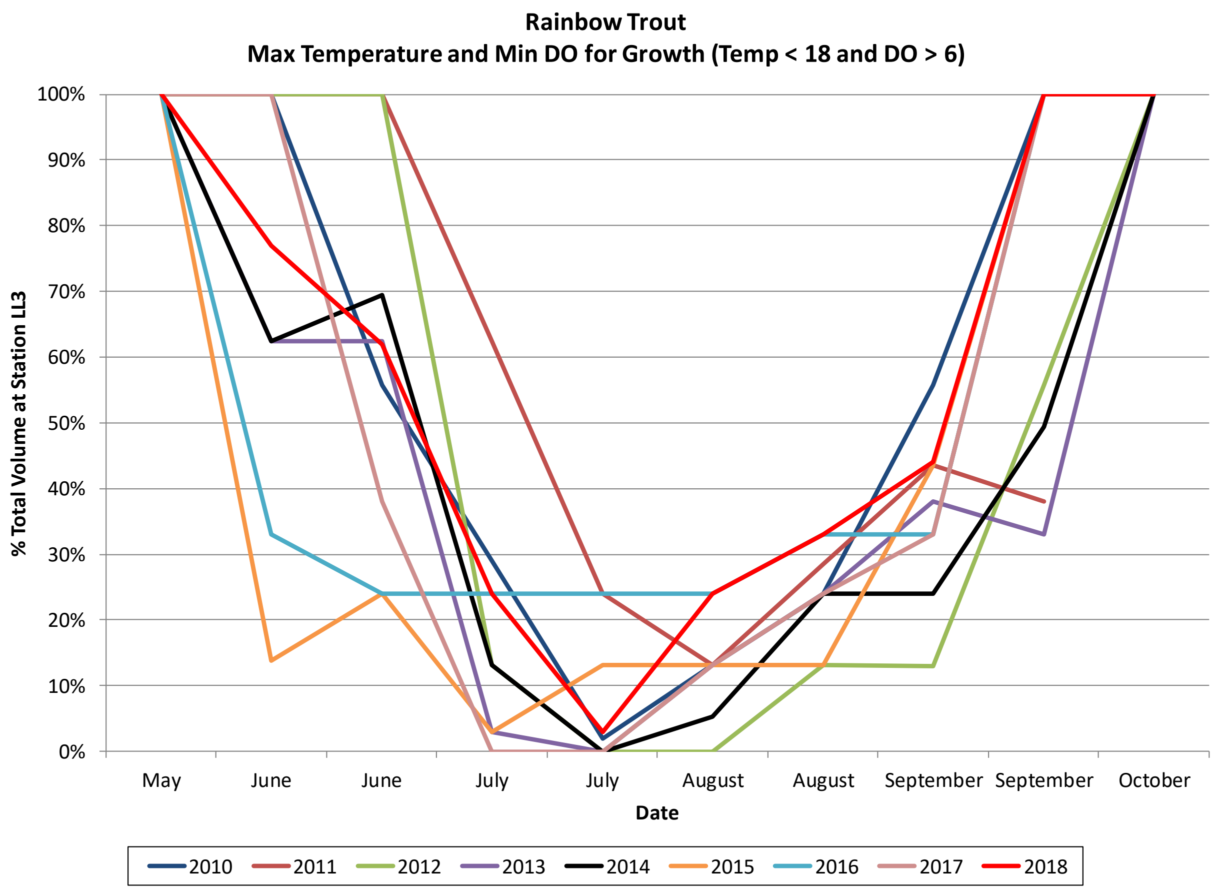

Figure 33. Habitat conditions at station LL3 for rainbow trout in 2010 – 2018, based on maximum temperature (18°C) and minimum DO (6.0 mg/L) for growth.

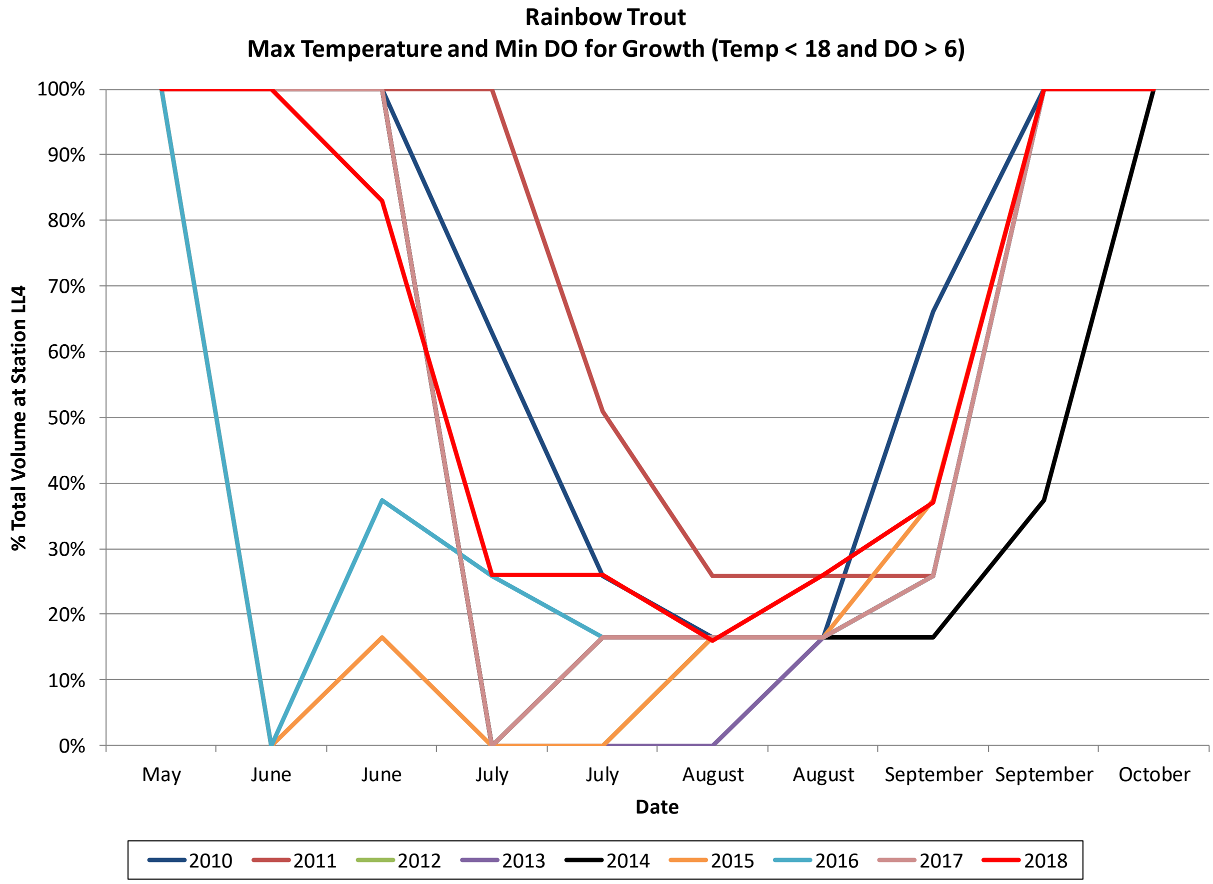

Figure 34. Habitat conditions at station LL4 for rainbow trout in 2010 – 2018, based on maximum temperature (18°C) and minimum DO (6.0 mg/L) for growth.

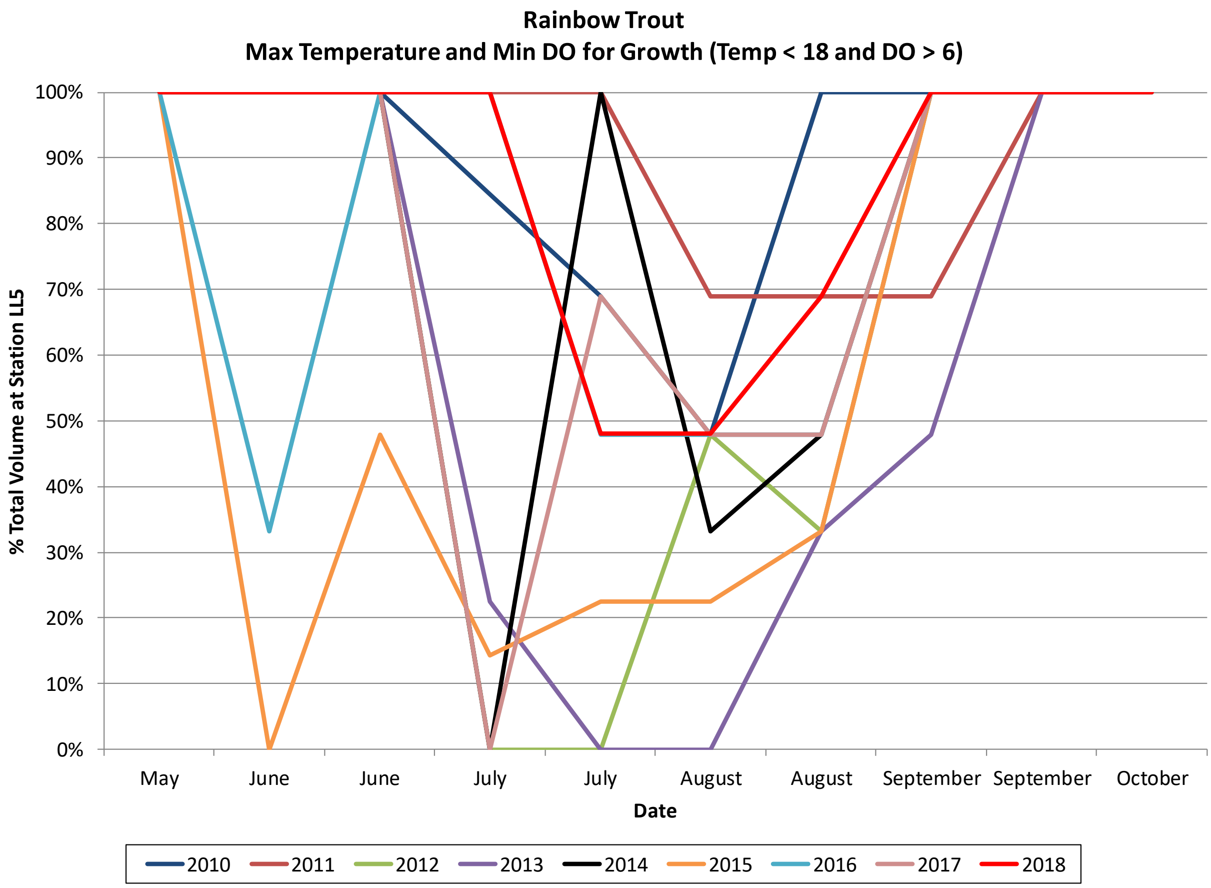

Figure 35. Habitat conditions at station LL5 for rainbow trout in 2010 – 2018, based on maximum temperature (18°C) and minimum DO (6.0 mg/L) for growth.

2.3 Monitoring Recommendations

In an effort to coordinate monitoring efforts on Lake Spokane, Avista met with Ecology in September 2019 to discuss the timelines of the Avista DO WQAP Compliance Schedule and the DO TMDL 10-Year Assessment Study. It was discussed that baseline monitoring would remain postponed until the City of Spokane's Riverside Park Water Reclamation Facility has come online. Avista will continue discussions with Ecology concerning the timeline for monitoring, specifically during May through October of 2021. Additionally, Avista will continue to work with Ecology to develop a plan for monthly 24-hour DO monitoring from June to September in Lake Spokane. Any monitoring will be conducted in accordance with the Ecology approved QAPP for Lake Spokane Nutrient Monitoring (Tetra Tech 2014).

Until such time that baseline monitoring is reinitiated, Avista will work with their partners including Ecology, Washington Department of Fish and Wildlife (WDFS), Spokane Community College, Stevens County Conservation District and the Spokane Tribe, to explore the data that has been collected from 2010 - 2018. Detailed analysis may be helpful in understanding the complex connections between fish habitat utilization, water quality, and zooplankton/phytoplankton data available for Lake Spokane. Results of analysis could be used to more accurately assess the core summer salmonid habitat available in Lake Spokane or identify data gaps in the existing water quality data. We anticipate the results of past and future sampling may be incorporated in the CE-QUAL-W2 model as a means to extrapolate the point data to help characterize habitat in the entire reservoir.

3.0 IMPLEMENTATION ACTIVITIES

3.1 Studies

In accordance with the DO WQAP and its Revised Implementation Schedule (Figure 1), Avista focused its initial efforts on analyzing two measures: reducing carp populations and aquatic weed management, which were identified as having high potential for phosphorus reduction. Additionally, in 2016, Avista initiated a Rainbow Trout Habitat Assessment in Lake Spokane in an effort to better understand growth, mortality and habitat usability.

3.1.1 Carp Population Reduction Program

In order to investigate whether removing carp would improve water quality in Lake Spokane, a Lake Spokane Carp Population Abundance and Distribution Study consisting of a Phase I and Phase II component, was initiated during 2013 and 2014. The purpose of this study was to better understand carp population abundance, distribution, and seasonal habitat use, as well as to help define a carp population reduction program, that may benefit Lake Spokane water quality.

Three contractors were utilized to complete different components of the Phase I and II Analyses, including Golder Associates (Golder), Ned Horner LLC (Avista contract Fishery Biologist), and Tetra Tech. The results of the Phase I and II Analyses were summarized in the Lake Spokane DO WQAP 2014 Annual Summary Report (Avista 2015).

Results of the Phase I and Phase II Analyses indicate that carp removal from Lake Spokane may provide meaningful reductions in TP directly through removal of TP in carp biomass (5g of TP/kg of carp) and indirectly through the reduction of re-suspended TP from sediments that carp disturb (bioturbation). The telemetry study, conducted in 2014, defined two time periods when carp were concentrated and vulnerable to harvest; during the winter and during the spring spawning period (May/June). The Phase II Analysis indicated that several different mechanical methods, including but not limited to, spring electrofishing, passive netting, and winter seining would be the most biologically effective and cost efficient means to reduce carp in Lake Spokane. In 2017, Avista implemented a pilot study utilizing a combination of passive netting and electrofishing to identify which is the most effective way to remove carp from Lake Spokane. Netting was found to be the more successful of the two methods and was the method used exclusively in the 2018 and 2019 carp reduction program.

3.1.2 Aquatic Weed Management

There are approximately 940 acres of aquatic plants present in Lake Spokane, of which 315 acres consist of the non-native yellow floating heart and fragrant water lily (AquaTechnex 2012). In order to evaluate harvesting aquatic plants as a viable method of reducing phosphorus in the lake, Avista contracted Tetra Tech to complete a Phase I Analysis, which: 1) assessed whether harvesting would be a reasonable and feasible activity to perform in Lake Spokane; 2) refined TP concentrations of relevant weed species in Lake Spokane; and 3) quantified TP load reductions associated with selected control methods.

The results of the Phase I Analysis and Nutrient Reduction Evaluation were summarized in the Lake Spokane Dissolved Oxygen Water Quality Attainment Plan 2013 Annual Summary Report. Based upon the results, Avista concluded that harvesting aquatic plants in Lake Spokane at senescence, would not be effective in reducing TP in Lake Spokane. However, Avista will continue to implement winter drawdowns, herbicide applications at public and community lake access sites, and bottom barrier placement to control invasive/noxious aquatic weeds within the lake. Avista may also, through adaptive management, reassess opportunities to harvest aquatic plants to control phosphorus in the future.

3.1.3 Rainbow Trout Habitat Assessment

As outlined in the Lake Spokane DO WQAP Five Year Report (Avista 2017), Avista initiated a multi-year fish population and habitat assessment in Lake Spokane, to gain an understanding of the status of the rainbow trout population in the lake and determine habitat utilization. The study, developed in coordination with WDFW and Ecology, included the following three components: (1) determine whether stocked rainbow trout survive the summer and maintain healthy body conditions; (2) identify the water quality conditions that were present during the study; and (3) identify the precise coordinates and depth rainbow trout occupy.

The first component was addressed as described below under Floy Tags. The second component included continuing water quality monitoring during 2017 and 2018 with additional *in-situ* monitoring sites added in 2018, in accordance with the Ecology approved Quality Assurance Project Plan Addendum for Lake Spokane Baseline Nutrient Monitoring. These additional sites allow a closer comparison of water quality conditions to fish location. The third component was addressed with acoustic tagging and tracking during the summers of 2017 and 2018, as described below under Acoustic Tracking Study.

Floy Tags – Growth and Mortality Study

During 2017, in an effort to gain a better understanding of how rainbow trout are performing once they are released, Avista, in cooperation with WDFW, initiated a multi-year growth and mortality study on the hatchery rainbow trout released in Lake Spokane. In 2017, Avista tagged 636 hatchery fish before they were released into the lake with colored, individually numbered ID tags and recorded each of the fish's length and weight to establish a baseline body condition for each fish before it was stocked. In 2018, Avista tagged 882 hatchery rainbow trout with the same ID tags. Growth is calculated when those same fish are collected a second time and the length is recorded.

In total, the length of fifteen tagged fish have been reported by anglers. Of these fish, growth rate averaged around 0.52 mm/d and fish tend to be around 15 inches after one year in the lake. Not enough tags were reported to estimate mortality. Fish will not be tagged in 2020 but angler returns will continue to be recorded as they are received.

Acoustic Tracking Study

The acoustic tracking study began in 2017 and consisted of surgically implanting acoustic tags into the body cavity of twenty hatchery fish caught in Lake Spokane. Fish lengths and weights were recorded at the time of tagging (Table 12). These fish were tracked from early July to early November identifying the latitude and longitude they were found, along with the depth in the water column and the temperature they were inhabiting when tracking occurred.

In 2018 acoustic tags were again surgically implanted into the body cavities of twenty-five additional rainbow trout caught from the lake. Fish lengths and weights were recorded at the time of tagging (Table 12). Tracking was conducted on a weekly basis from April to November. During each tracking event, the latitude and longitude of the fish was documented, along with their depth in the water column and the temperature they were inhabiting at that time.

Table 12. Quantity, length and weight of acoustic tagged fish in 2017 and 2018.

Year	Quantity Tagged	Length Range (in)	Weight Range (lb)
2017	20	14.5 - 17.5	1.12 - 1.76
2018	25	13.5 - 18.1	0.9 - 2.2

Tracking was conducted using a directional hydrophone with a 180° baffle (Lotek Wireless, Seattle, WA) that detects the signal emitted by the acoustic tag. The acoustic tags transmitted a tag ID, temperature and depth data, with accuracies of (±) 0.8° C and (±) 1.4 m respectively.

Fish Quantity and Temperature Results

Of the twenty fish tagged during 2017, thirteen were found on a consistent basis. Tagged fish were found in depths ranging between 0 – 16 meters from the surface of the water (Figure 36). Fish were found lower in the water column in July averaging slightly over 6 meters in depth, compared to average depths ranging from 1.8 to 3.2 meters in August through October. These fish occupied water temperatures ranging from 8.4 °C in November to 23.6 °C in mid-August (Figure 37). Fish were frequently found above 16 °C in late summer. In fact, during one tracking event on September 8, 2017, seven fish were found inhabiting water that was above 20°C.

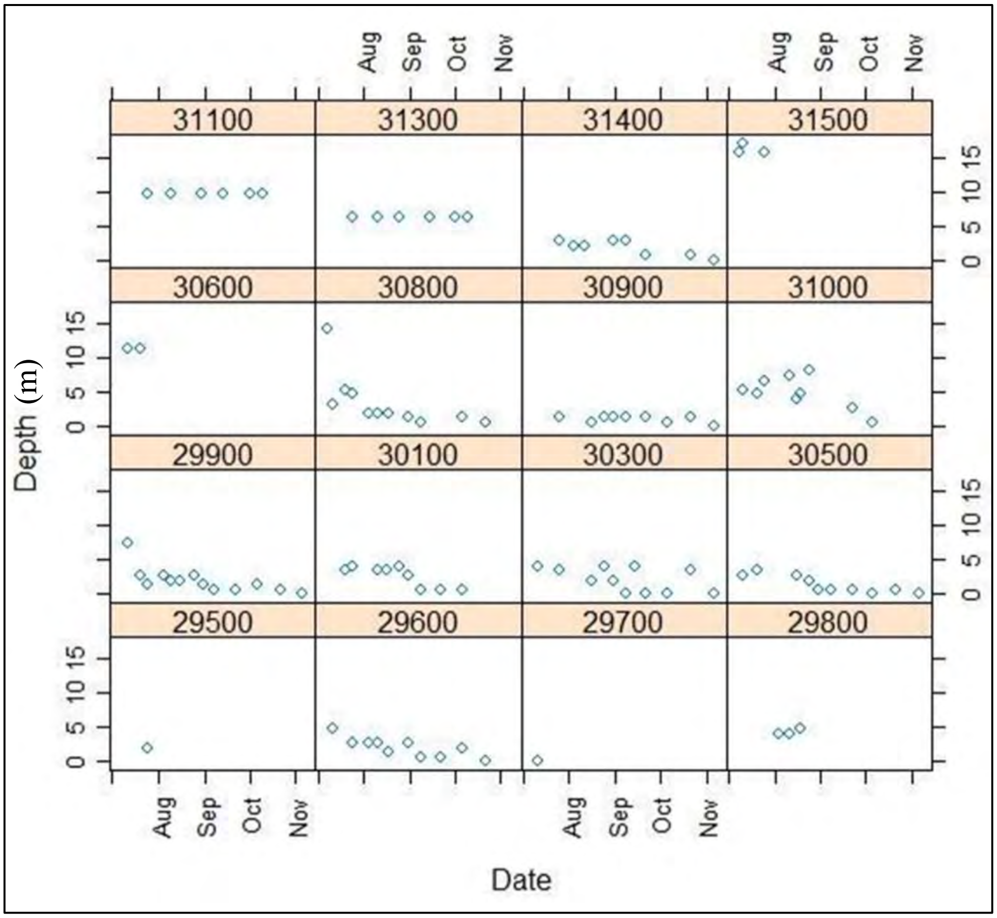

Figure 36. Depth lattice graph showing depth location of fish during the 2017 tracking event. This graph displays each individual fish, marked by its unique acoustic number (31100 through 29800). The cell below each unique number represents the fish's depth each time it was tracked throughout the 2017 season. Depth along the y-axis increases from surface water (0) to deeper segments (15 m). Date is grouped in months along the x-axis.

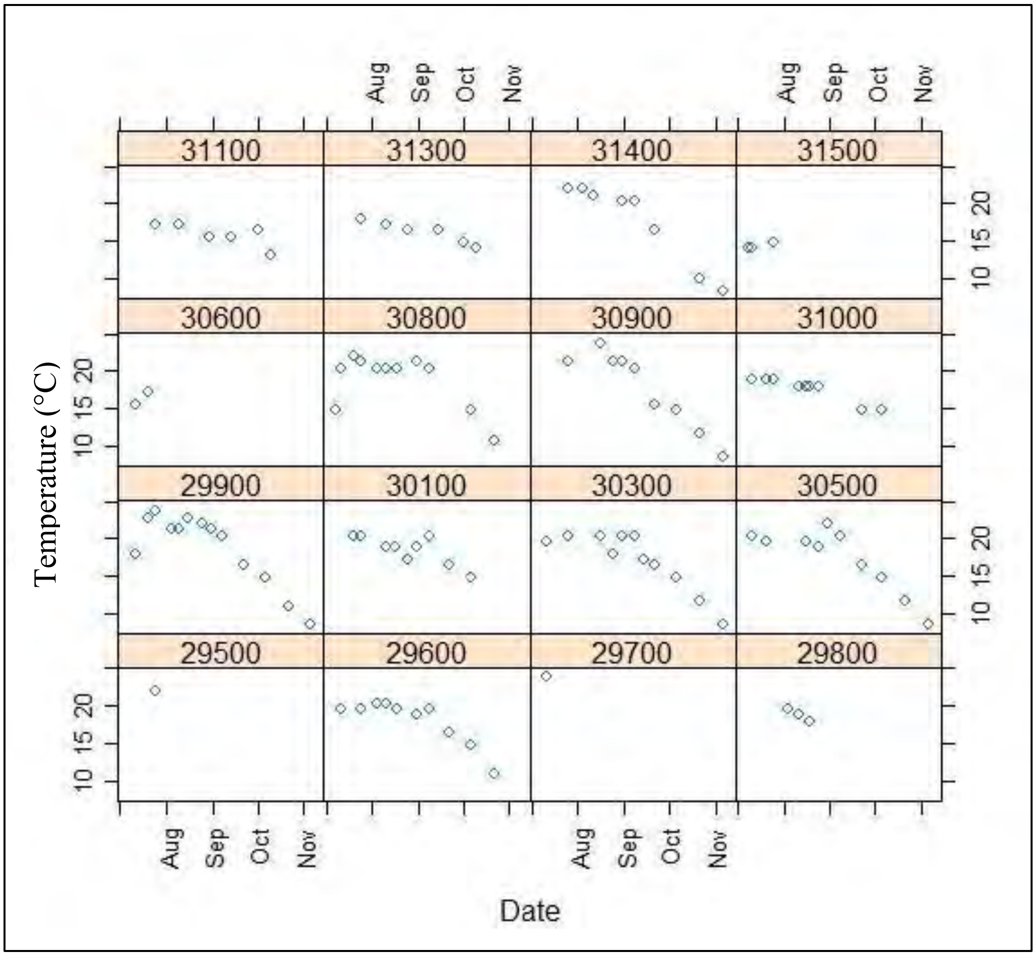

Figure 37. Temperature lattice graph showing temperature of the water at which the fish were found during the 2017 tracking events. The graph displays each individual fish, marked by its unique acoustic number (31100 through 29800). The date is grouped in months along the x-axis and temperature, in Celsius, increases along the y-axis. The cell below each unique number represents the temperature the fish was occupying when it was identified.

Twenty-one of the twenty-five fish tagged in 2018 were detected at some point in 2018, along with an additional six tags detected from fish that were tagged in 2017. The 2018 tracking season began on April 11. This early tracking season allowed for documentation of trout movements earlier in the season compared with 2017.

In 2018, individual fish depth selections did not vary substantially throughout the season with two patterns emerging. Rainbow trout were either found at less than 6 meters below the surface of the water or between 6 to 15.6 meters (Figure 38).

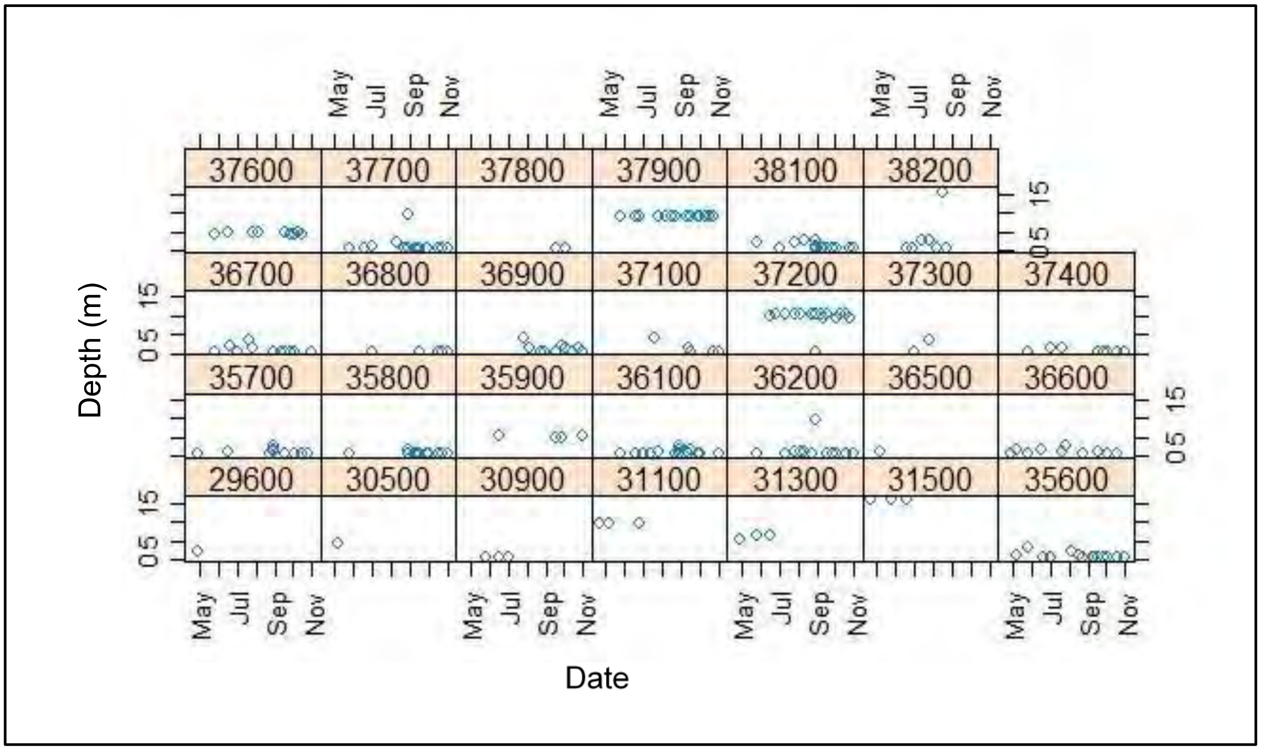

Figure 38. Depth lattice graph showing depth location of fish during the 2018 tracking events. This graph displays each individual fish, marked by its unique acoustic number (37600 through 35600). Fish on the bottom row were also tracked in 2017 with the exception of 35600. The cell below each unique number represents the fish's depth each time it was tracked throughout the 2018 season. Depth along the y-axis increases from surface water (0) to deeper segments (15 m). Date is grouped in months along the x-axis.

Fish that remained close to the surface in July and August experienced a temperature range of 18.0 to 20.4 °C (Figure 39). Three fish found deeper in the water column were found at temperatures averaging 15.6 °C. In September, water temperatures began to decrease, staying at or below 19.6 °C and falling to below 14.8 °C for the remainder of the season for the fish near the surface. Overall, in 2018, a majority of fish selected depths near the surface, in the epilimnion, resulting in the fish staying at much warmer temperatures than anticipated. The temperatures in the epilimnion during the warmer months of summer reach the rainbow trout upper limits of presumed preference, which corresponds with the trends seen in 2017.

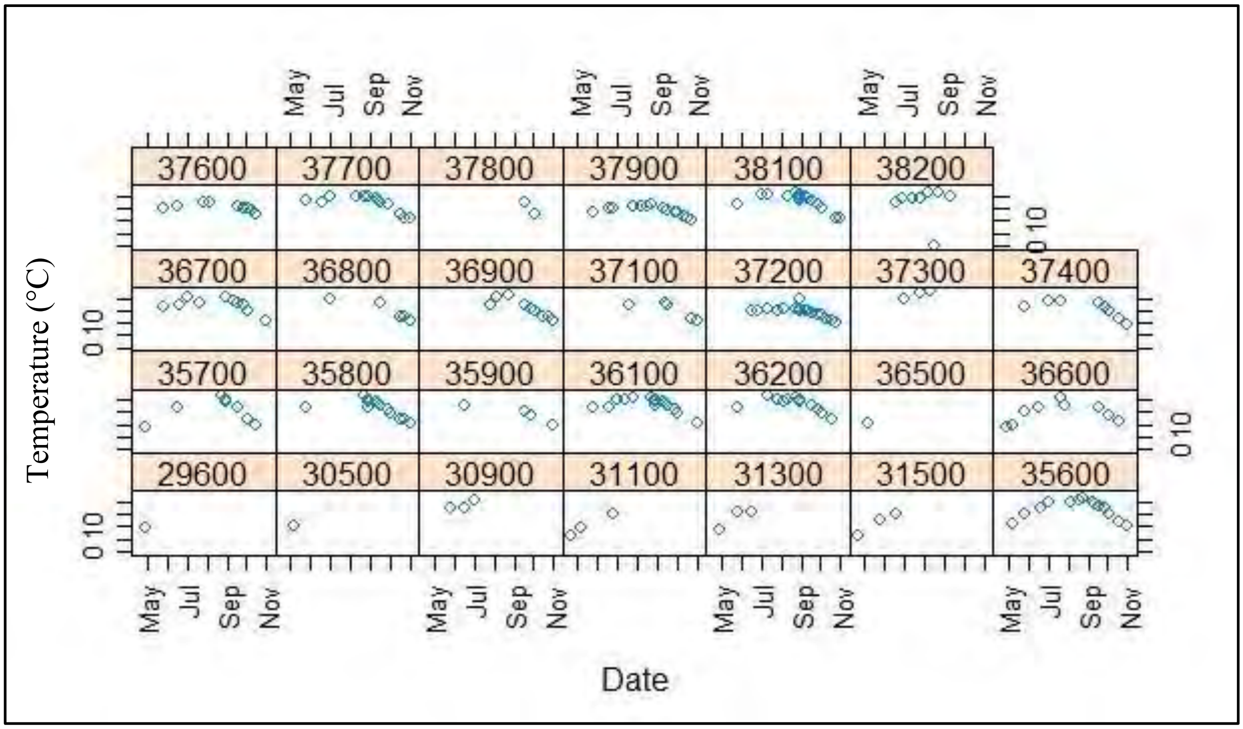

Figure 39. Temperature lattice graph showing temperature of the water at which the fish were found during the 2018 tracking events. The graph displays each individual fish, marked by its unique acoustic number (37600 through 35600). The date is grouped in months along the x-axis and temperature, in Celsius, increases along the y-axis. The cell below each unique number represents the temperature the fish was occupying when it was identified.

Fish Tracking Locations and Depths Compared with Baseline Water Quality Results

Recorded fish locations in 2017 and 2018 were spatially mapped by month to visually represent where fish may be grouping. Water quality monitoring locations were overlaid onto the kernel density maps to identify the closest monitoring location to where fish were located each month. Using the depth at which the fish were found, water quality parameters from the closest monitoring locations, at those depths, were summarized to approximate the water conditions (temperature and DO) that the tracked fish may have experienced. As described above, fish tracking was conducted weekly throughout summer months and water quality monitoring was conducted bi-monthly (Table 13).

Table 13. 2017 and 2018 water quality monitoring event dates and fish tracking dates

Year	Month	Water Quality Monitoring Dates	Fish Tracking Dates
2017	July	11 and 12 25 and 26	8, 11, 20, 25
	August	8 and 9 22 and 23	4, 10, 11, 16, 18, 25, 31
	September	12 and 13 26 and 27	8, 14, 22
	October	18 and 19	6 and 22
	November	none	6
2018	April	None	28
	May	16 and 17	6 and 26
	June	6 and 7 19 and 20	17, 20, 26
	July	10 and 11 23 and 24	2, 12, 20, 26
	August	7 and 8 28 and 29	6, 11, 17, 23, 29, 30
	September	12 and 13 25 and 26	9[t] 12, 17, 28,
	October	16 and 17	3, 10, 17, 24
	November	none	1

July 2017

In July 2017, tagged fish were mostly distributed in two specific locations in the lower reservoir (Figure 40). The highest density of tagged fish was observed in mid and late July just up reservoir of water quality monitoring station LL2 and down reservoir of the town of TumTum. Fish were observed within this area at depths ranging from 2.7 to 4.8 m. Another grouping of fish was observed near station LL1 in mid-July at depths ranging from 0 to 7.5 m.

The water column at station LL2 was strongly stratified during both monitoring events in July, with the epilimnion encompassing the top 6 m. All fish observed slightly up reservoir of LL2 were observed within the epilimnion of the water column. Water temperatures ranged from 23.3 to 24.1°C in the top 5 m of the water column and DO ranged from 8.6 to 8.8 mg/L (Table 14). Water temperatures at 15 m and deeper were generally around 18°C or colder. Dissolved oxygen concentrations were depressed at station LL2 from about 18 m and deeper however concentrations were above 6 mg/L for the majority of the water column. Only DO concentrations near the very bottom (24 and 25 m) were less than 6 mg/L.

The water column at station LL1 was also strongly stratified during the month of July, with the epilimnion extending to about 5 m. On July 11th two fish were observed near station LL1 at depths below the epilimnion (5.4 and 7.5 m). Water temperatures at these depths were slightly cooler than in the epilimnion but still greater than 20°C. Dissolved oxygen concentrations were slightly higher at these deeper depths than in the epilimnion and corresponded to a peak in concentrations just below the epilimnion. Similar to station LL2, DO throughout the water column at LL1 was mostly greater than 6 mg/L with concentrations falling below 6 mg/L at depths greater than 24 m. Temperatures and DO concentrations in the upper reservoir (LL3 and LL4) in July were similar to those at LL1 and LL2 with slightly warmer surface temperatures (24.7°C).

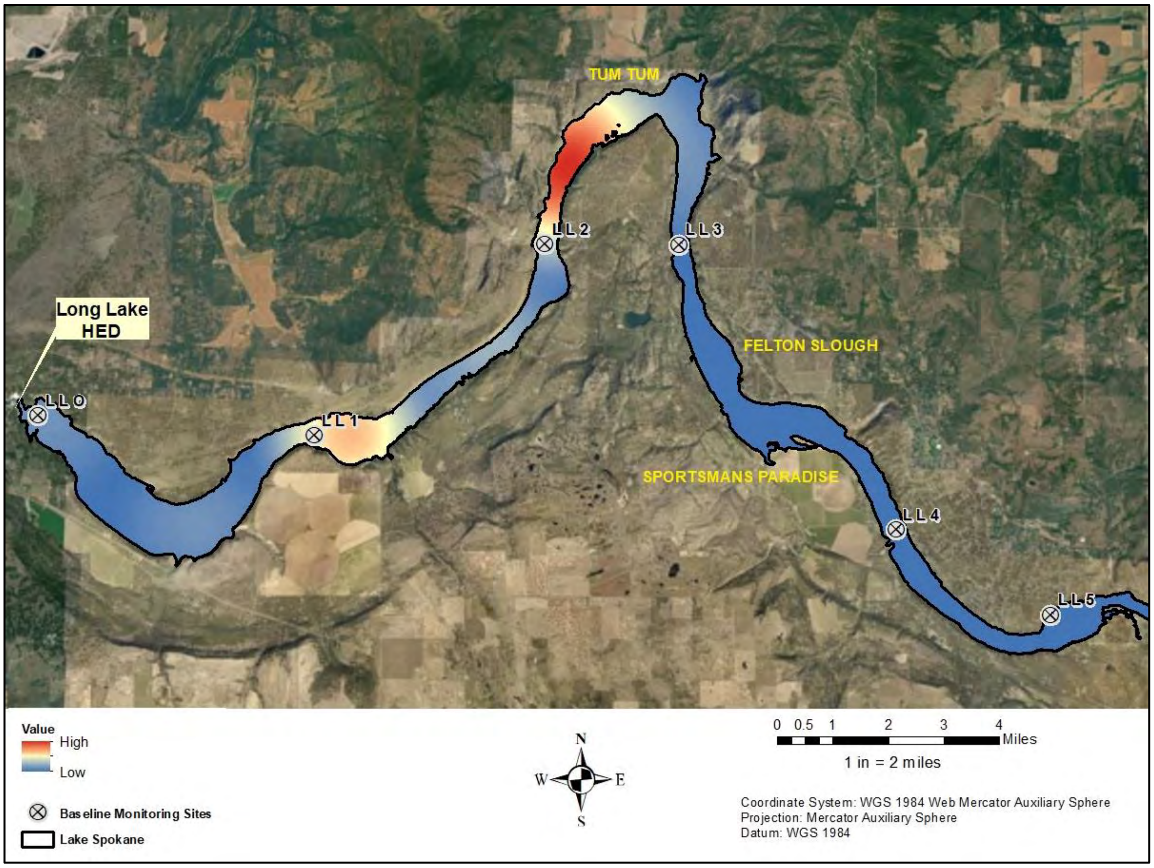

Figure 40. Fish density map, July 2017 (n = 22).

Table 14. Summary of recorded fish depths and select water quality measurements at LL1 and LL2 in July 2017.

Station	Depth (m)	Temperature (°C)	Dissolved Oxygen (mg/L)
Fish recorded at depths between 0 – 7.5 m near LL1			
LL1	0 – 8	20.2 – 23.5	8.4 – 9.2
Fish recorded at depths between 2.7 – 4.8 m near LL2			
LL2	0 – 5	23.3 – 24.1	8.6 – 8.8

August 2017

In August 2017, the tracked fish distribution was concentrated in the reservoir mostly between stations LL2 and LL3 in the vicinity of TumTum (Figure 41). Fish were also concentrated along the western shoreline across from Felton Slough between stations LL3 and LL4 (Figure 41). Throughout the reservoir and in the concentrated areas fish were observed at depths ranging from 0 – 8.2 m, with the majority between 1.4 to 4.8 m.

In early to mid-August, the bottom of the epilimnion at stations LL2 and LL3 was around 4 to 5 m, with slightly cooler temperatures and elevated DO (Table 15). At both stations a DO peak was observed at the bottom of the epilimnion most likely due to elevated levels of primary productivity. Also, higher conductivity values indicative of mixing with the interflow zone were observed at the same depths. Dissolved oxygen concentrations at LL2 were around 8 mg/L or higher through the top 21 m of the water column with depressed oxygen occurring only near the bottom at 24 and 25 m depths. At station LL3 DO was greater than 8 mg/L throughout the entire water column. Similar water quality conditions were also observed downstream at LL1 and upstream at LL4.

In late August, water quality conditions were similar to those in early to mid-August with slightly cooler temperatures in the epilimnion. There was a DO sag from about 6 m to 15 m, however all concentrations were above 6 mg/L. The bottom DO concentrations were greater than those observed early in the month. A similar pattern was observed at station LL3, however, the DO sag was much smaller, from 8 to 10 m. Again, nearby stations LL1 and LL4 had similar water quality conditions as LL2 and LL3, with the exception that LL1 had slightly higher DO concentrations in the top 5 m (11.3 – 11.4 mg/L).

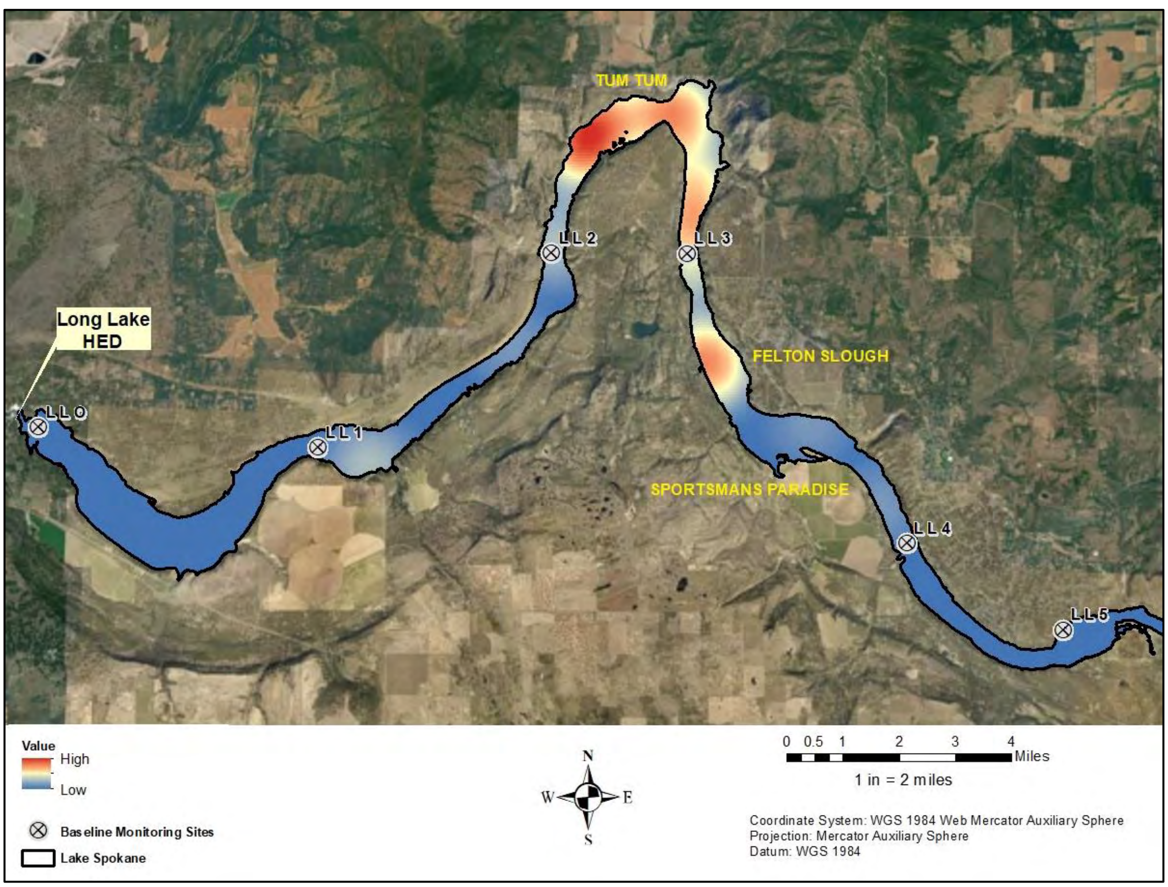

Figure 41. Fish density map, August 2017 (n = 36).

Table 15. Summary of recorded fish depths and select water quality measurements at LL2 and LL3 in August 2017.

Station	Depth (m)	Temperature (°C)	Dissolved Oxygen (mg/L)
Fish recorded at depths between 0 – 8.2 m near LL2 and LL3			
LL2	0 – 5	22.6 – 24.9	9.8 – 11.7
LL3	0 – 5	21.7 – 24.9	9.9 – 12.6

September 2017

Over the month of September, tracked fish were concentrated between Willow Bay and Sportsmans Paradise, with higher distributions just downstream of LL3 and across from Sportsmans Paradise (Figure 42). Fish were observed at depths ranging from 0 to 2.7 m over the course of the month with most fish being found near the surface.

The water column at LL3 was still stratified in mid-September with epilimnetic temperatures ranging from 20.6 to 20.8°C (Table 16). Dissolved oxygen in the epilimnion ranged from 9.5 to 10.1 mg/L and was high (> 8 mg/L) throughout the water column (Table 14).

Stratification was slowing breaking down in late September. Temperatures in the top 3 m of the water column where fish were most often found ranged from 17.1 to 17.2°C (Table 16). Dissolved oxygen concentrations in late September were similar to mid-September and ranged from 9.4 to 10.0 mg/L in the top 3 meters, with high (> 8 mg/L) throughout the water column (Table 16).

Water quality conditions at nearby station LL4 were similar in mid-September as observed at LL3. One fish was observed closer to LL4 on the 8 of September at a depth of 0.7 m (Figure 42). In late September, water temperatures were slightly colder at LL4 (15.1 to 16.9°C) than at LL3 and the epilimnion at LL4 was only 2 m deep. Dissolved oxygen was also slightly higher (10.1 – 10.4 mg/L) at LL4. Secchi disk transparency was lower at LL4 than LL3 in mid-September (3.6 vs. 4.2 m) but greater than LL3 in late September (4.8 vs. 4.2 m). No fish were observed upstream of Sportsmans Paradise in late September.

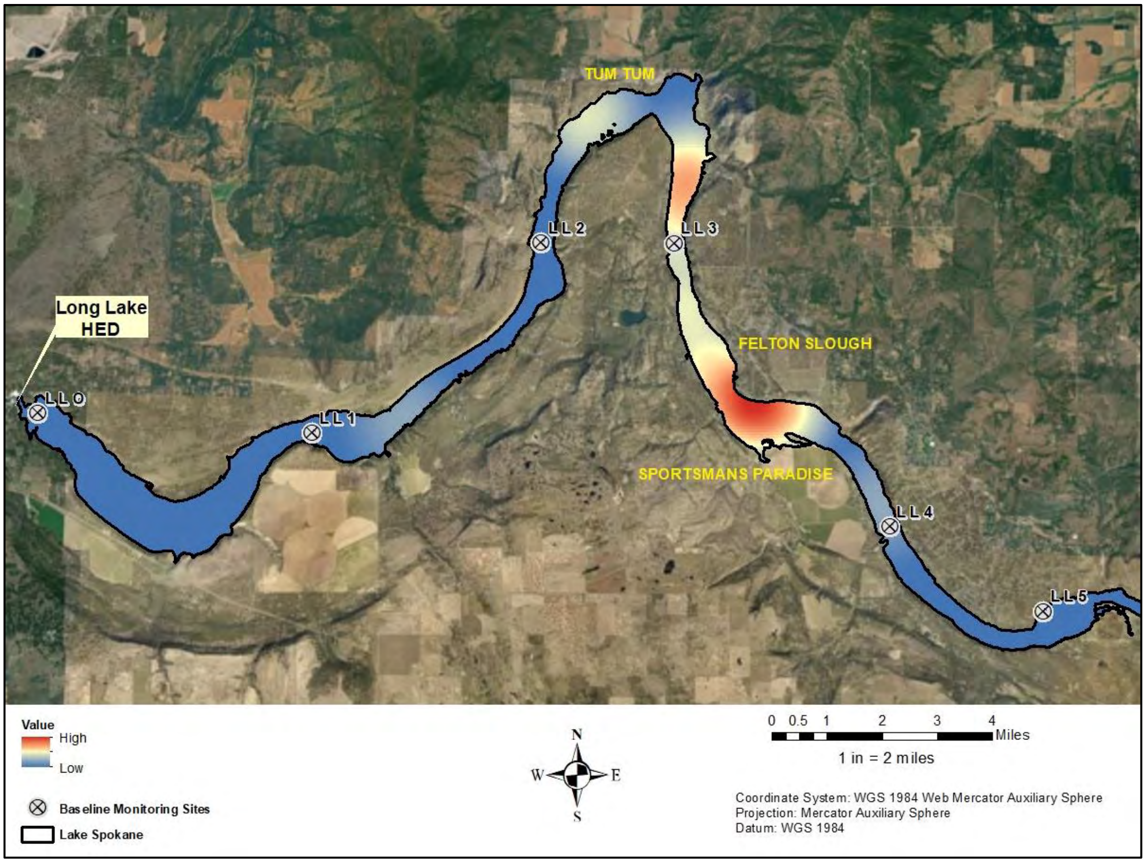

Figure 42. Fish density map, September 2017 (n = 17).

Table 16. Summary of recorded fish depths and select water quality measurements at LL3 and LL4 in September 2017.

Station	Depth (m)	Temperature (°C)	Dissolved Oxygen (mg/L)
Fish recorded at depths between 0 – 2.7 m near LL3			
LL3	0 – 3	17.1 – 20.8	9.4 - 10.1
Fish recorded at a depth of 0.7 m near LL4			
LL4	0 – 1	16.8 - 20.9	10.4 – 10.5

October/November 2017

Tracked fish were more widely distributed in October and November 2017 than was observed in September, although they were still concentrated between LL3 and LL4 near Felton Slough and Sportsmans Paradise in October (Figure 43). Fish were also observed downstream near TumTum in October and November and further downstream near station LL2, mostly in November (Figure 43). Fish observed in October were found at depths ranging from 0 to 2 m near Felton Slough and Sportsmans Paradise and at depth ranging from 3 to 3.4 m near TumTum.

The water column was still stratified at station LL3 during October with water temperatures just below 13°C in the epilimnion (Table 17). Temperatures in October were much cooler at station LL4, around 10.8 °C, and the water column was fully mixed. Further downstream at LL2, the water column was beginning to mix and the epilimnion had deepen to 15 m with temperatures around 13 °C. Dissolved oxygen was high (9.6 to 10.2 mg/L) and uniform throughout the water column at LL2, LL3, and LL4 during October monitoring.

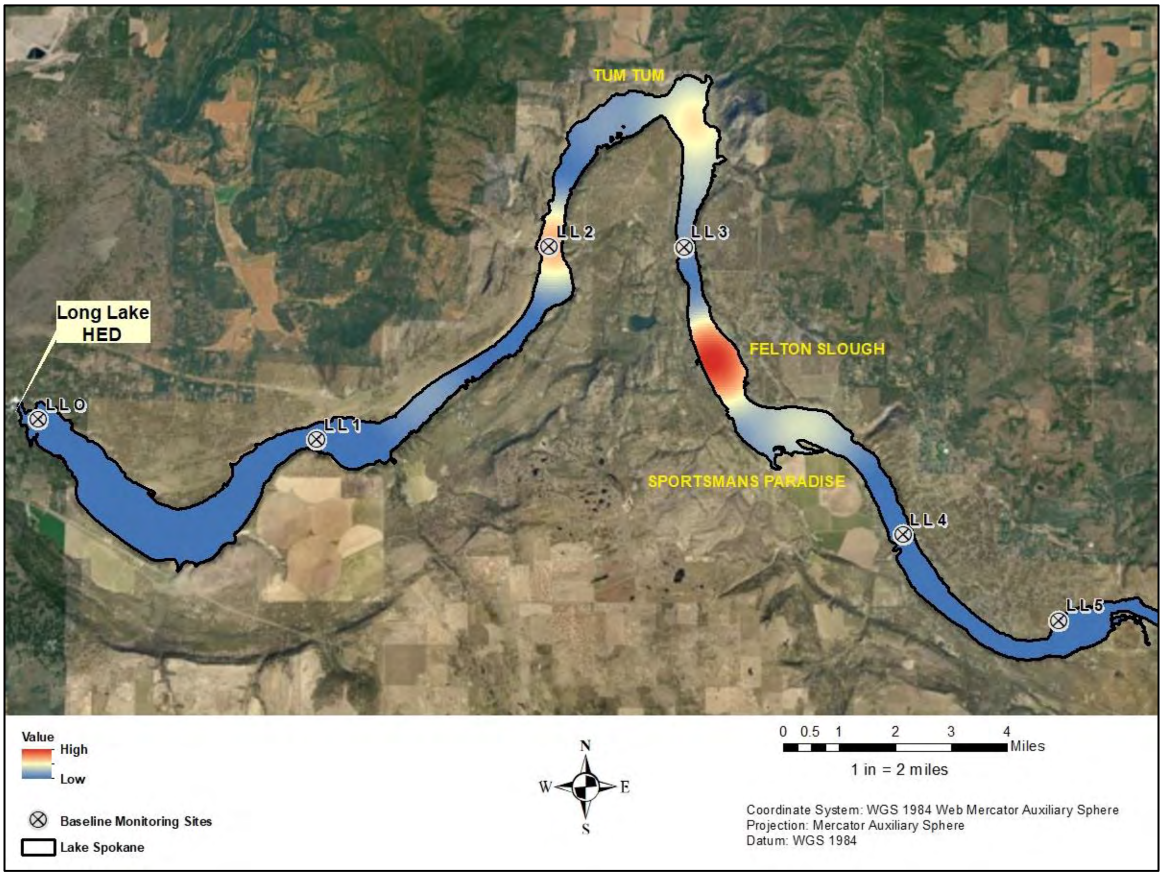

Figure 43. Fish density map, October/November 2017 (n = 20).

Table 17. Summary of recorded fish depths and select water quality measurements at LL2, LL3, and LL4 in October 2017.

Station	Depth (m)	Temperature (°C)	Dissolved Oxygen (mg/L)
Fish recorded at depths between 0 – 3.4 m near LL2, LL3 and LL4			
LL2	0 – 5	13.0 – 13.1	9.9
LL3	0 – 5	12.9	10.1
LL4	0 – 5	10.8	9.6 – 9.7

2018

Late April-May 2018

In late April and May 2018, tracked fish were mostly distributed in the lower parts of the reservoir near water quality monitoring stations LL1 and LL1a, with a few fish also located between LL0 and LL1 (Figure 44). Fish located nearest to LL0 and LL1 in late May were observed mostly at the surface with one fish at approximately 3.4 m. In early May it appears that fish utilized a wider depth range and were found at depths ranging from approximately 1.3 to 4 m. Fish nearest station LL1a were observed at depths ranging from 0 to just over 4 m.

Water quality measurements were recorded on May 16, 2018 at stations LL0, LL1, and LL1a. Water temperatures ranged from 13.9 to 15.0 in the top 4 meters and DO ranged from 11.7 to 12.9 mg/L (Table 18). Dissolved oxygen was high (> 10 mg/L) throughout the water column at all three locations. Water quality conditions further up-reservoir (LL2, LL2a, and LL2b) were similar to those in the lower reservoir. Slightly cooler temperatures were observed at LL3, LL4, and LL5 in May.

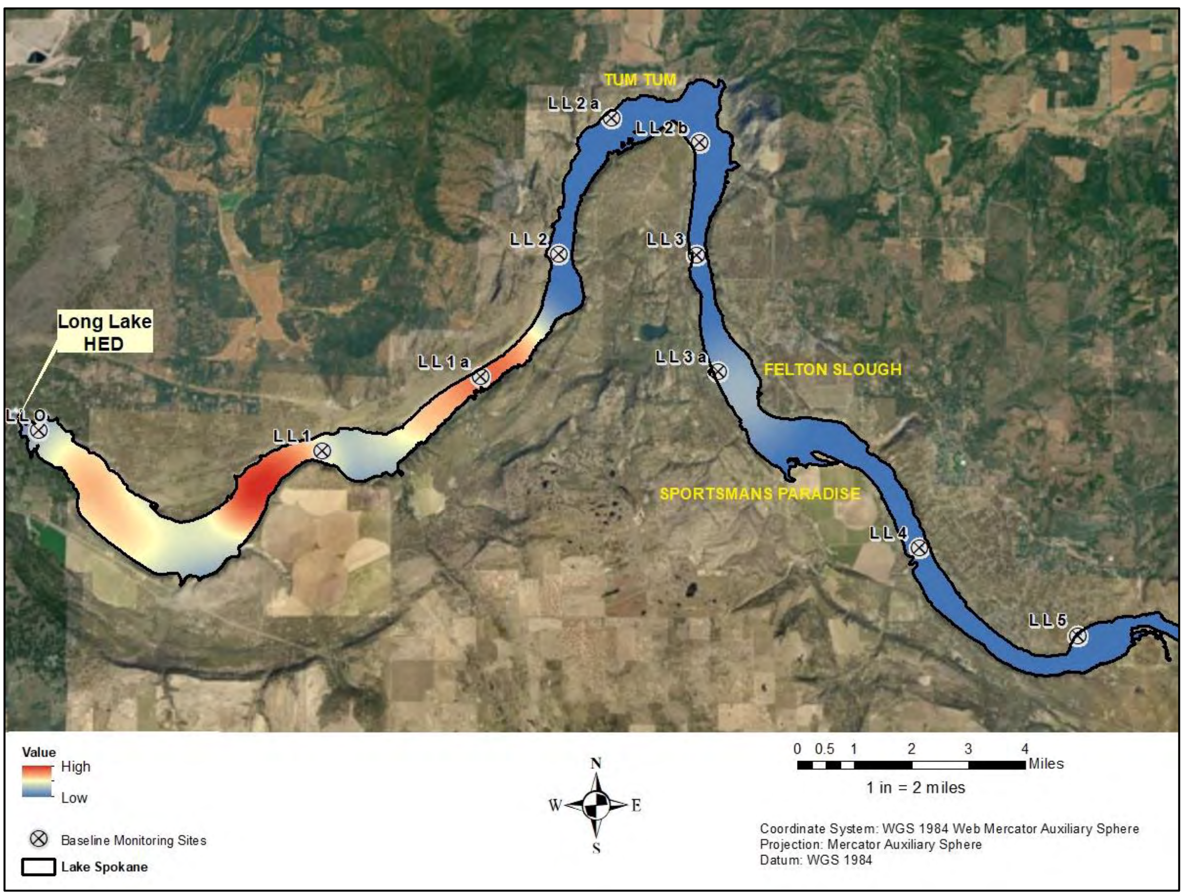

Figure 44. Fish density map, Late April – May, 2018 (n = 18).

Table 18. Summary of recorded fish depths and select water quality measurements at LL0, LL1, and LL1a in May 2018.

Station	Depth (m)	Temperature (°C)	Dissolved Oxygen (mg/L)
Fish recorded at depths between 0 – 3.4 m near LL0 and LL1			
LL0	0 – 4	13.9 – 15.0	12.6 – 12.9
LL1	0 – 4	14.2 – 15.0	11.7 – 12.2
Fish recorded at depths between 0 – 4 m near LL1a			
LL1a	0 – 4	14.3 – 14.8	11.7 – 11.9

June 2018

In June 2018, tracked fish were still utilizing the reservoir between monitoring stations LL1 and LL1a but were found at greater densities just downstream of TumTum near stations LL2a and LL2b (Figure 40). Fish located between monitoring stations LL1 and LL1a were found at depths ranging from 1.4 to 4.8 m, while fish located near stations LL2a and LL2b were found at the surface.

The water column of all four stations was weakly stratified in late June, with warmer temperatures observed in the top 6 to 10 m of the water column depending on the station (Table 19). Dissolved oxygen remained high (≥ 9 mg/L) throughout the water column at all stations, with maximums occurring in the top 5 m. Surface water temperatures in late June were slightly warmer up-reservoir at stations LL3 and LL3a, however, other water quality parameters were similar between stations.

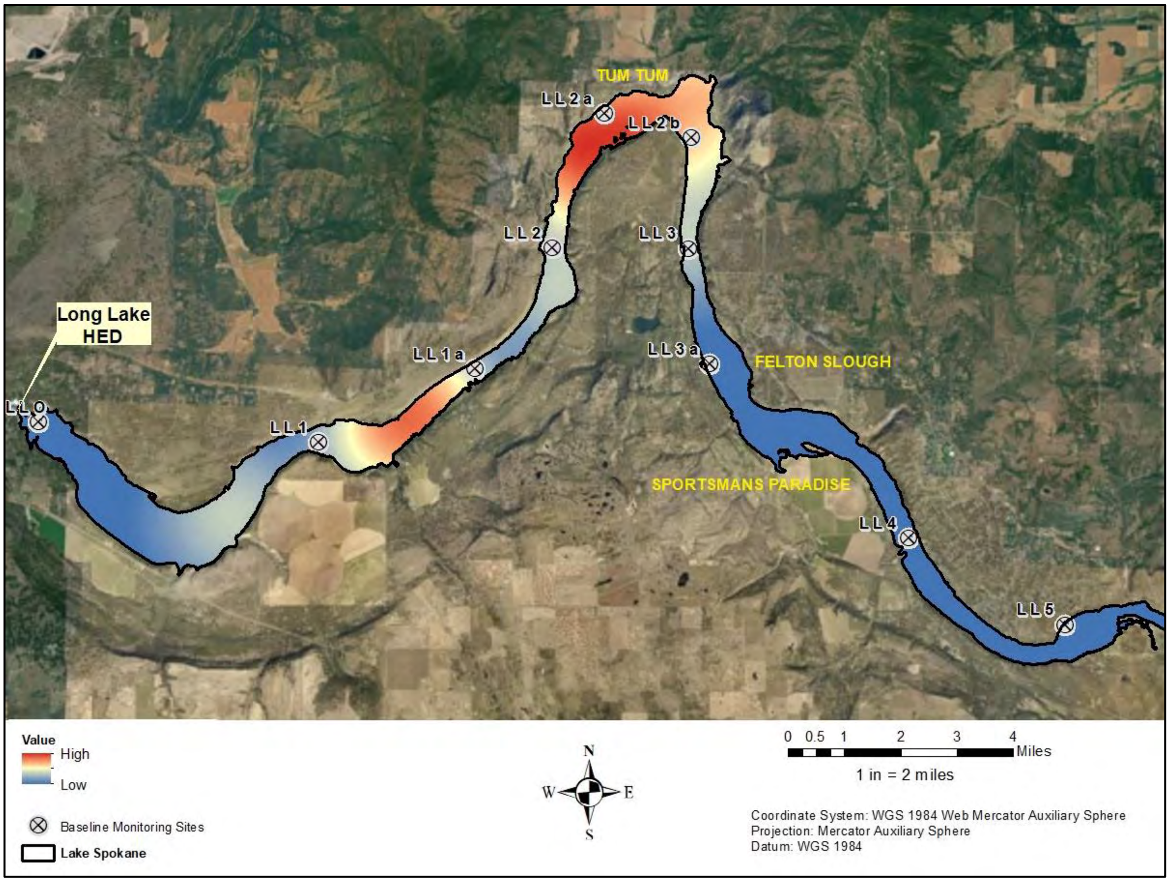

Figure 45. Fish density map, June 2018 (n = 11).

Table 19. Summary of recorded fish depths and select water quality measurements at LL1, LL1a, LL2a and LL2b in June 2018.

Station	Depth (m)	Temperature (°C)	Dissolved Oxygen (mg/L)
Fish recorded at depths between 1.4 to 4.8 m near LL1 and LL1a			
LL1	1 – 5	18.1 – 18.3	9.9 – 10.1
LL1a	1 – 5	17.8 – 18.3	9.8 – 10.0
Fish recorded at the surface near LL2a and LL2b			
LL2a	0.5	18.4	10.3
LL2b	0.5	19.0	9.8

July 2018

In July 2018, fish were more heavily distributed further upstream, near monitoring stations LL3 and LL3a (Figure 46). In early July, fish were observed at depths ranging from 0 to about 1.4 m, while in late July they were observed in deeper water, at depths ranging from about 1.4 m to just over 4 m. The water column at both stations was strongly stratified during July with thermoclines ranging from 4 to 8 m. Fish were observed in late July within the epilimnion. Water temperatures in the epilimnion ranged from about 22 to almost 25°C, while temperatures below 8 m were usually around 18°C (Table 20). Dissolved oxygen within the epilimnion in late July ranged from 9.6 to 10.8 mg/L at stations LL3 and LL3a (Table 20).

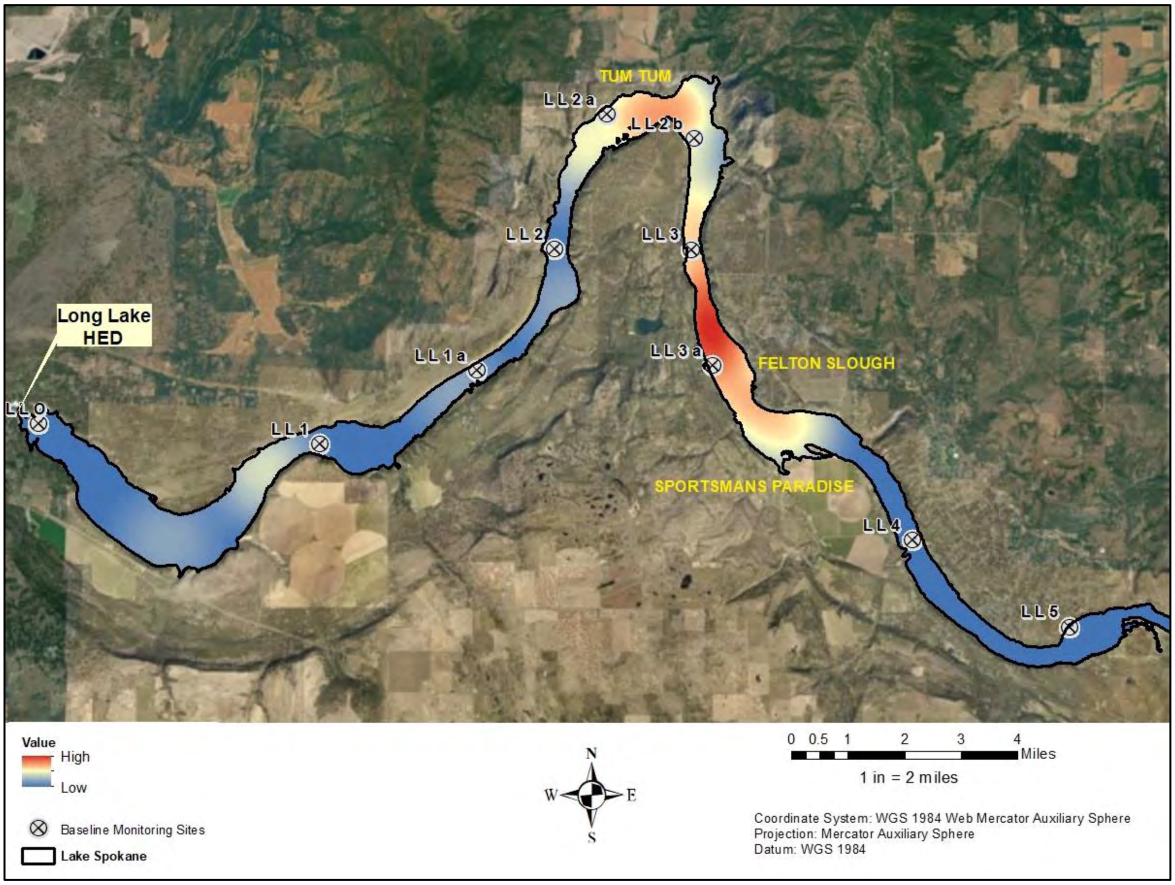

Figure 46. Fish density map, July 2018 (n = 26).

Table 20. Summary of recorded fish depth and select water quality measurements at LL3 and LL3a in July 2018.

Station	Depth (m)	Temperature (°C)	Dissolved Oxygen (mg/L)
Fish recorded at depths between 0 – 1.4 m near LL3 and LL3a in early July			
LL3	0 – 2	22.6 – 22.7	10.0 – 10.1
LL3a	0 – 2	22.4 – 22.6	10.3 – 10.4
Fish recorded at depths between 1.4 - 4 m near LL3 and LL3a in late July			
LL3	1 – 4	22.7 – 24.5	9.6 – 10.8
LL3a	1 – 4	22.9 – 24.4	9.8 – 10.6

In mid to late July, fish were also observed near monitoring stations LL2a and LL2b at depths ranging from 0 to 1.4 m. Fish observations in late July (July 26) were at deeper depths ranging from 1.4 to 2 m. Surface temperatures were cooler in mid-July than in late July at stations LL2b (22.5 vs. 24.3°C, Table 19). Dissolved oxygen however was similar at the surface throughout July, from 9.4 to 9.9 mg/L (Table 21). In late July, temperatures from 1 to 2 m ranged from 24.3 to 24.6°C and DO was about 9.5 mg/L (Table 21). Similar to stations LL3 and LL3a, the water column at both LL2a and LL2b was strongly stratified in late July. Dissolved oxygen was below saturation at both LL2a and LL2b below 7 m, however, concentrations were above 6 mg/L except at the very bottom of the water column.

Table 21. Summary of recorded fish depths and select water quality measurements at LL2a and LL2b in July 2018.

Station	**Depth (m)**	**Temperature (°C)**	**Dissolved Oxygen (mg/L)**
Fish recorded at depths between 0 – 2 m near LL2a and LL2b in mid-July			
LL2a	0 – 2 m	22.6	10.1 – 10.2
LL2b	0 – 2 m	22.4 – 22.5	9.9 – 10.0
Fish recorded at depths between 1.4 - 2 m near LL2a and LL2b in late July			
LL2a	1 – 2 m	24.6, 24.5	9.4, 9.5
LL2b	1 – 2 m	24.3	9.5

August 2018

In August the majority of tagged fish were clustered near TumTum, closest to stations LL2a and LL2b, at depths ranging from 0 to 1.4 m, with a few fish in deeper water (1.4 to 2.7 m) in mid-August (Figure 47).

The water columns at stations LL2a and LL2b were strongly stratified in late August but epilimnetic temperatures were much cooler than in July and early August (Tables 21 and 22). Similar to previous months, water temperatures below 8 m ranged from 15 to just over 18°C. Dissolved oxygen profiles at stations LL2a and LL2b were different than in previous months with higher concentrations in the epilimnion, depressed concentrations observed between around 6 and 12 m depth and then increased concentrations at the bottom of the water column. The depressed concentrations between 6 and 12 m were still greater than 6 mg/L.

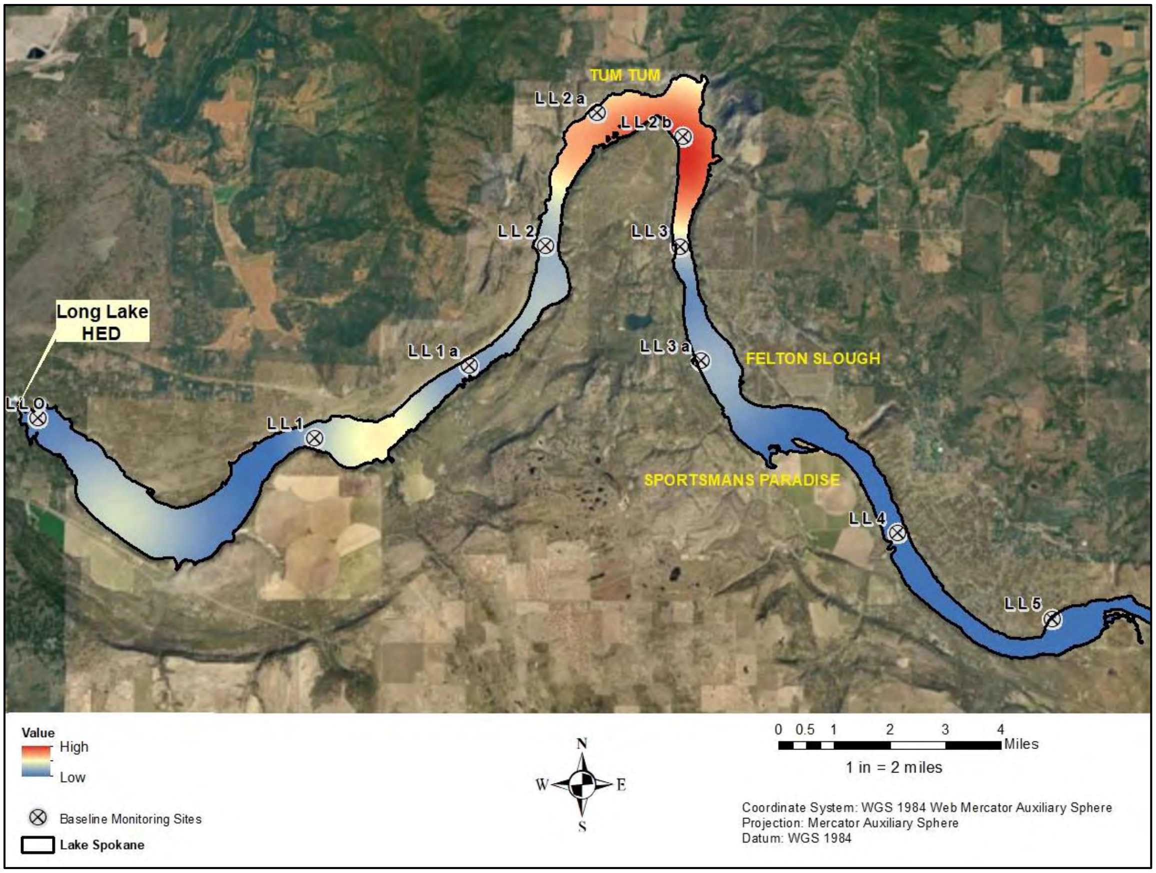

Figure 47. Fish density map, August 2018 (n = 31).

Table 22. Summary of recorded fish depths and select water quality measurements in late August at stations LL2a and LL2b.

Station	**Depth (m)**	**Temperature (°C)**	**Dissolved Oxygen (mg/L)**
Fish recorded at depths between 0 – 2.7 m near LL2a and LL2b			
LL2a	0 – 2	20.7 – 20.9	9.6
LL2b	0 – 2	20.6 – 20.7	9.7

A smaller cluster of fish was also observed in late August just upstream of LL1 at depths ranging from 0 to 0.7 m (Figure 47). Water quality near the surface of LL1 in late August was similar to that observed at stations LL2a and LL2b; water temperature around 20.3°C and DO around 9.8 mg/L. Water temperature and DO concentrations in the epilimnion of the reservoir were similar between stations in late August, however, colder water (14-15°C) occupied the bottom waters of LL4 and most of LL5.

September 2018

In September the distribution of tagged fish stretched from just upstream of Sportsmans Paradise (not quite to LL4) all the way down reservoir to LL1 (Figure 48). Within this stretch of reservoir, the most concentrated areas were near station LL3a and Sportsmans Paradise, near stations LL2a and LL2b by TumTum, and near station LL1 (Figure 48). Interestingly, fish that were observed up reservoir of station LL2 were at the surface with depths ranging from 0 to 0.7 m regardless of date within the month. Fish observed down reservoir of station LL2 were at depths ranging from 0 to 10.2 meters, with a large portion observed at depths between 2 and 4.8 m. On September 17th, two fish were observed between LL4 and LL5 at the surface. This was the furthest up reservoir observation of fish in 2018.

In September the water column at stations LL1 through LL3a remained stratified, however, epilimnetic waters had cooled substantially and the thermocline had deepened to about 10 m by the end of September (Table 23). There was a DO sag starting at about 8 m observed at stations LL1 through LL3a during the month of September. The depth of the sag varied from 10 to 21 m depending on the station. The magnitude of the sag was greater during the first monitoring event in September (12 and 13) than the event in late September. Dissolved oxygen concentrations within the sag were less than 6 mg/L only once, at station LL1 at 10 m (5.8 mg/L) on September 12. Otherwise, DO concentrations were, for the most part, 7.0 mg/L or greater throughout the water column during the month of September. There was also a DO sag measured at station LL0, down-reservoir of any fish distribution. The DO sag at LL0 resulted in lower DO concentrations (< 5.0 mg/L) between 10 and 15 m. However there was not much difference in temperatures between station LL0 and LL1.

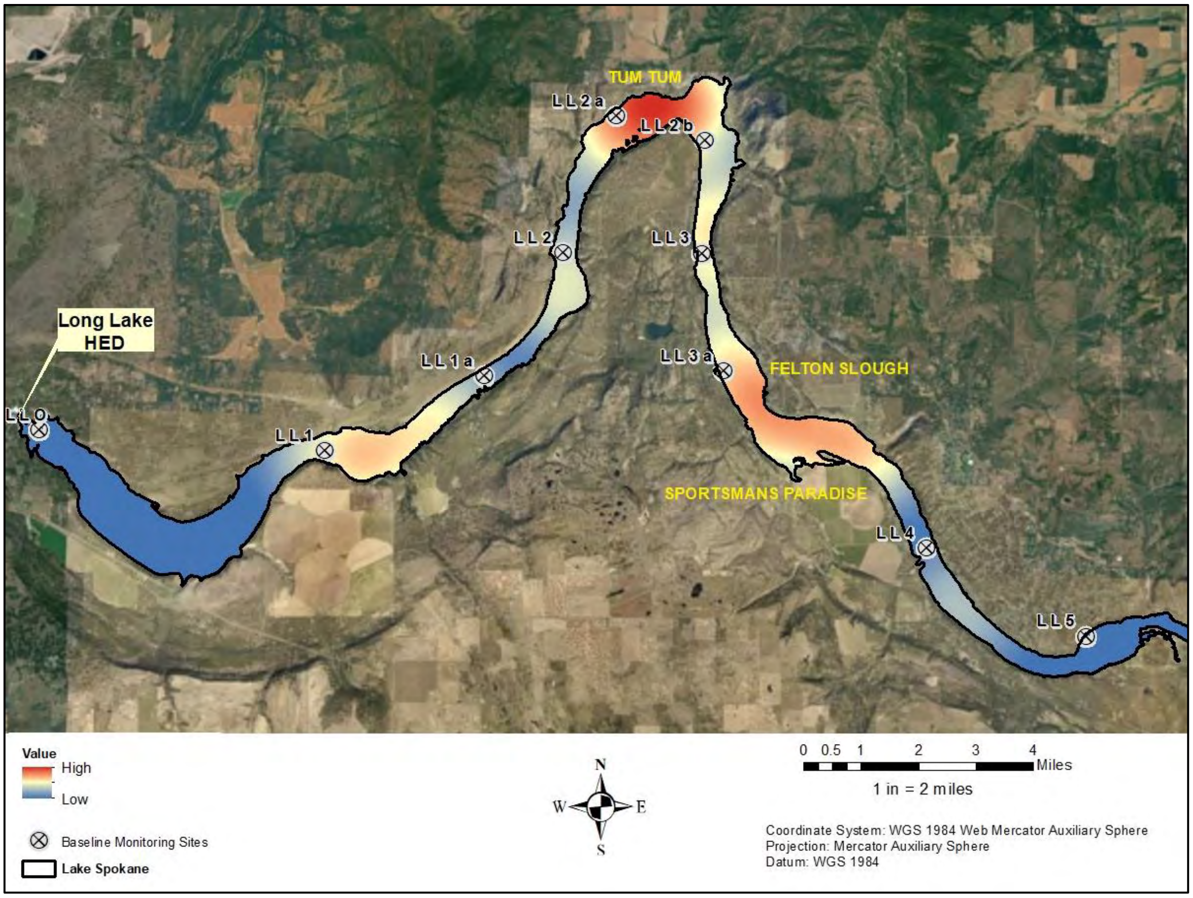

Figure 48. Fish density map, September 2018 (n = 40).

Table 23. Summary of recorded fish depths and select water quality measurements in September 2018 from LL1 through LL3a.

Station	Depth (m)	Temperature (°C)	Dissolved Oxygen (mg/L)
Fish recorded at depths between 0 – 10.2 m down reservoir of LL2			
LL1	0 – 10	17.0 – 19.2	5.8 – 9.4
LL2	0 – 10	16.1 – 19.7	7.2 – 9.2
Fish recorded at depths between 0 – 0.7 m up reservoir of LL2			
LL2a	0 – 1	17.7 - 20.0	9.2 - 9.3
LL2b	0 – 1	17.4 - 19.2	9.1 - 9.3
LL3	0 – 1	17.3 - 19.1	9.2 - 9.4
LL3a	0 – 1	17.4 - 19.0	9.5

October-November 2018

During October and early November 2018, tagged fish were observed mostly near TumTum (stations LL2a and LL2b) and again by Sportsmans Paradise (in between stations LL3a and LL4) (Figure 49). Most fish observations during October and early

November indicated fish were utilizing surface waters with depths ranging from 0 to 1.4 m. Four fish were observed at deeper depths (4.1 and 5.4 m) near stations LL1a and LL2.

Water quality monitoring occurred only once during October 2018. The water column at most stations in the reservoir, except LL4 and LL5, remained stratified in October, but had cooled dramatically from September (Tables 23 and 24). Dissolved oxygen concentrations throughout the reservoir were high in October with concentrations at the deeper stations (LL0, LL1, and LL1a) greater than 8.5 mg/L and concentrations at the rest of the stations greater than 10.0 mg/L.

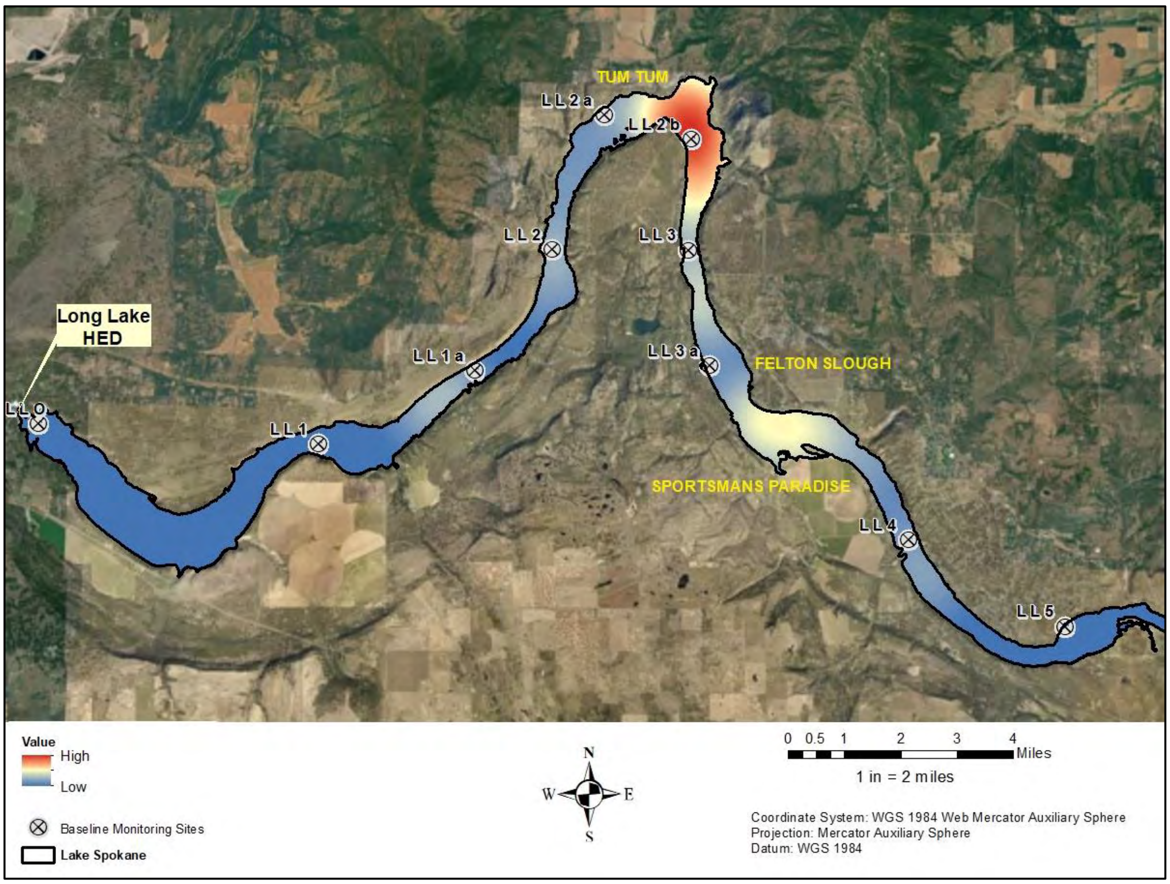

Figure 49. Fish density map, October-November 2018 (n = 20).

Table 24. Summary of recorded fish depths and select water quality measurements in October 2018 or stations LL2a, LL2b, LL3, and LL3a.

Station	Depth (m)	Temperature (°C)	Dissolved Oxygen (mg/L)
Fish recorded at depths between 0 – 1.4 m near TumTum			
LL2a	0 – 2	13.4 – 13.7	10.3 – 10.5
LL2b	0 – 2	13.2	10.3
LL3	0 – 2	13.0 – 13.1	10.4 – 10.6
LL3a	0 – 2	12.7	10.7 – 10.8

Summary

Data from fish tracking efforts in 2017 and 2018 indicate that stocked rainbow trout in Lake Spokane are utilizing warmer habitat than expected. In late August and September 2018, colder habitat was available in the upper portions of the reservoir but none of the tagged fish were found in those areas. The tagged fish appeared to mostly use the area of the reservoir from near the State Parks Riversideboat launch to Sportsmans Paradise and primarily were found within the epilimnion of the water column. More than likely rainbow trout within Lake Spokane are utilizing more of the reservoir than shown in Section 2.2.5 and that the suitable habitat is greater than depicted in Figures 30 through 35. Avista will continue to work with Ecology and WDFW to further evaluate the results of the Rainbow Trout Habitat Assessment, in conjunction with lake-wide water quality parameters, with the goal of obtaining a better understanding of Lake Spokane's core summer salmonid habitat.

3.2 2019 Implementation Measures

The following section highlights measures which Avista implemented, or assisted in the implementation of, in order to reduce phosphorus loading and improve DO concentrations in Lake Spokane.

3.2.1 Carp Removal

During 2019, Avista implemented the third year of its common carp (*Cyprinus carpio*) removal program on Lake Spokane. The removal effort was done in cooperation with WDFW and the Spokane Tribe of Indians (Figure 50), and completed under a Scientific Collection Permit issued by WDFW.

Figure 50. 2019 Lake Spokane carp removal effort.

The removal effort occurred during two, four day sampling events; May 20 through 23 and June 3 through 5, and focused on sampling carp during their spring spawning behavior. Removal efforts were focused in four areas of the upper portion of Lake Spokane between McLellan Slough and the Nine Mile Recreation Area (Figure 51). The four areas were broken into thirty-two, 400-meter long sections. In each 400-meter section, two 200-foot nets, combined together end to end, or separated as two individual nets were deployed. A total of 577 carp were collected along with 653 other fish considered by-catch (Table 25).

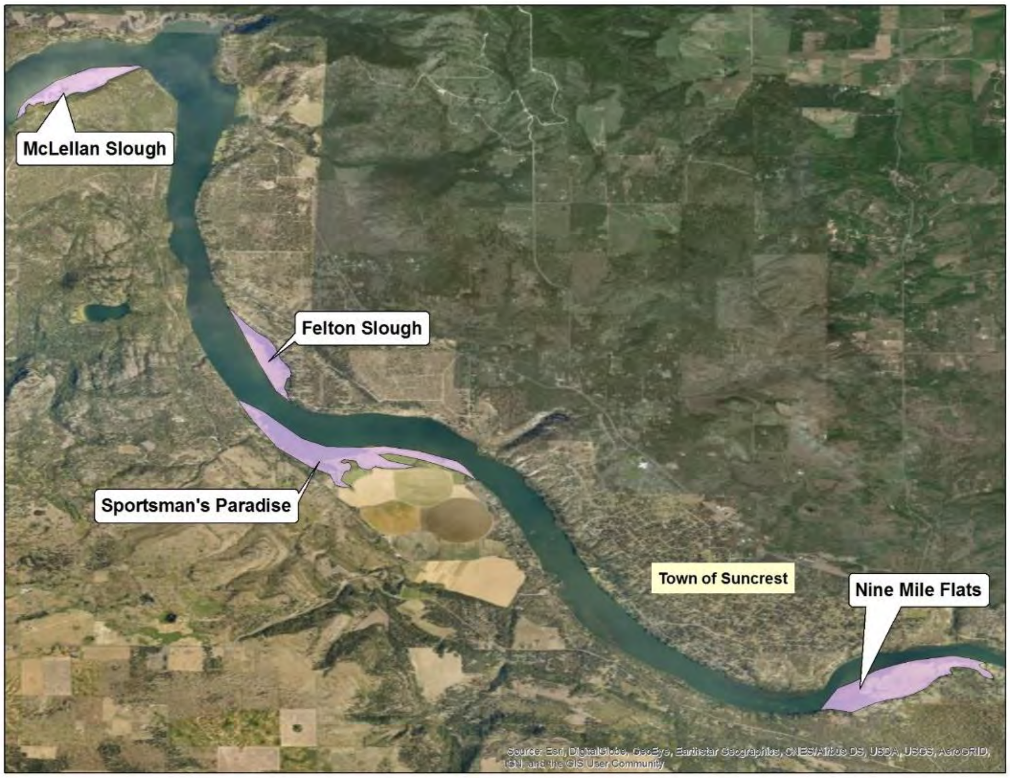

Figure 51. Lake Spokane carp removal locations (purple shaded area).

Table 25. Species, total number caught, and total number removed (per species) during the spring 2019 carp removal effort.

Species	Total Caught	Total Removed
Common carp	577	577
Brown bullhead	16	1
Black crappie	43	3
Largemouth bass	29	7
Largescale sucker	148	21
Longnose sucker	1	0
Northern pike	96	96
Northern pikeminnow	6	1
Rainbow trout	1	0
Smallmouth bass	8	0
Tench	251	1
Walleye	53	35
Yellow Perch	1	0
Total	**1230**	**742**

All carp were weighed, measured, and checked for sex and maturity. Carp ranged in length from 8.8 to 32.6 inches and averaged 25.6 inches. The average carp weighed 9.4 pounds (lbs) and ranged from 2.0 to 20.9 lbs. All carp were removed from the water and placed into a refuse bin and transported to the Greater Wenatchee Regional Landfill for disposal.

The 577 carp collected in 2019 totaled approximately 5,432 lbs of biomass being completely removed from the watershed. Using the average total phosphorus to weight ratio, provided in the ALS Environmental 2018 lab analysis, removal was calculated to be 28.9 lbs of total phosphorus in 2019 (Table 26). Combining the 2017, 2018, and 2019 carp removal sampling, a total of 143 lbs of total phosphorous has been removed from Lake Spokane by Avista's carp reduction program. That number does not quantify the amount of phosphorous that will no longer be re-activated in the water column by excretion or bioturbation (during the feeding and spawning behavior of these carp).

Table 26. Total number and weight of carp, along with the resulting total phosphorus, removed from Lake Spokane in 2017, 2018 and 2019.

	2017	**2018**	**2019**
Total carp collected	1,219	557	577
Total weight (lbs)	10,310	5,183	5,432
Total phosphorous removed (lbs)	86.6	27.5	28.9

3.2.2 Other Measures: Wetlands

Sacheen Springs

Avista acquired the 109-acre Sacheen Springs property, located on the west branch of the Little Spokane River (Figure 52). This property contains a highly valuable wetland complex with approximately 59 acres of emergent, scrub-shrub and forested wetlands and approximately 50 acres of adjacent upland forested buffer. Several seeps, springs, perennial and annual creeks are also found on the property. The property was purchased "in fee" and during 2017, Avista pursued a conservation easement in order to protect it in perpetuity. Avista completed a detailed site-specific wetland management plan and began implementing it upon Ecology and FERC's approval in 2014. Herbicide application to control terrestrial invasive weeds was completed in 2014, 2015, and 2016 which should help improve the overall biodiversity and function of the wetland property. Activities conducted during 2019 included: (a) monitoring the effectiveness of previous treatments on reducing the area occupied within two stands of reed canarygrass monocultures, (b) completing the Sacheen Springs Wetland Five-Year Monitoring Report 2014-2018, (c) constructing a new gate with a wing fence across the road along the Avista property boundary, (d) removing 600-feet of old 3-strand barbed wire fence along the property boundary, and (e) finalizing a conservation easement on the property with the Inland Northwest Land Conservancy in August 2019.

Figure 52. Sacheen Springs wetland property, 2019.

<u>Hangman Creek Wetlands</u>

Avista and the Coeur d'Alene Tribe have acquired approximately 1,022 acres on upper Hangman Creek since 2010, within the southern portion of the Coeur d'Alene Tribe Reservation in Benewah County, Idaho approximately 10 miles east of the Washington-Idaho Stateline. Site-specific wetland management plans are updated annually for approximately 500-acres of these properties and include establishing long-term, self-sustaining native emergent, scrub-shrub and/or forested wetlands, riparian habitat and associated uplands, through preservation, restoration and enhancement activities. These properties were all in agricultural use, including straightened creek beds prior to the acquisition. Given Hangman Creek is a significant contributor of sediment and associated phosphorus loading to the Spokane River, Avista anticipates a TP load reduction from the wetland mitigation work. Since 2013, approximately 14,649 native tree and shrub species have been planted on this wetland complex. Other wetland management activities included noxious weed herbicide treatment, protective fencing installation, and monitoring vegetative success as well as wetland functionality. In 2020 the Hangman Creek Site Management Plan will be revised to incorporate two additional properties acquired by the Coeur d'Alene Tribe. Additionally in 2019, the Hangman Creek Planting Plan was implemented, with a total of 2,071 seedlings planted.

<u>Little Spokane Natural Area Preserve</u>

As part of the Nine Mile Hydroelectric Development's Rehabilitation Program, Avista partnered with the Washington State Parks and Recreation Commission Parks (State Parks) to complete a wetland and shoreline restoration project on four acres within the Little Spokane Natural Area Preserve. The Natural Area Preserve is a popular location for recreation, however two invasive weed species, yellow flag iris and purple loosestrife, have severely constricted large sections of the river and adjacent shoreline. The mitigation project included herbicide treatments on four acres of yellow flag iris and purple loosestrife invasive weed species during 2014 and 2015. Additionally, in 2014 four trees were removed from the Nine Mile barge landing site and relocated to the Little Spokane River Mitigation Site for large woody debris habitat. After two consecutive years of herbicide applications the stands of invasive weeds greatly reduced by an estimated 90%-100%. Also, during 2015, Avista partnered with the Washington Department of Natural Resources to implement re-vegetation of the site which included planting 400 trees and shrubs (black cottonwoods, quaking aspens, chock cherry and red osier dogwood). Individual plants were enclosed with four foot welded wire fencing for protection from browsing and the base was wrapped with a protective sleeve for protection from small mammals, and herbicide spot treatments are completed as well. During 2018, Avista conducted several site visits to monitor site conditions and conduct maintenance activities such as, noxious weed control by mechanical and chemical means, and fence repair and removal. Avista transferred the long-term maintenance of this project back to State Parks (owner of the property) in 2019, having fulfilled the project components.

Lake Spokane Floating Wetlands

In 2017, Avista partnered with the Stevens County Conservation District (SCCD) and Spokane Community College (SCC) to install a floating wetland in the downstream portion of Lake Spokane, adjacent to Avista owned shoreline. This project is supported by an Ecology grant awarded to the SCCD, with the purpose to evaluate a floating wetlands' potential for TP removal and wave attenuation, water quality education for both SCC students and boaters, as well as to gain information on plant species growth and fish habitat.

The floating wetland was installed during the spring of 2018 and consisted of two 40-foot long log structures (each consisting of three logs bolted together), located approximately 100 feet from the shore. Twenty floating wetland platforms were anchored to the log structure, and were planted with approximately 240 plants of various water species. Throughout the summer season, SCC students monitored the site for plant survivability, presence of invasive plants, wildlife activity, fish habitat, and shoreline wave impacts. The floating wetland platform was removed in October and approximately 180 of the plants were planted along the adjacent shoreline. Minimal plant tissue samples were submitted for total phosphorus and total nitrogen analyses to get a rough estimate of total phosphorus and nitrogen removed by the plants. Additionally, basic field water quality parameters were collected, including the deployment of temperature logger arrays. The data collected from 2018 provided education opportunities for SCC students and was presented at the Eastern WA/Northern ID Regional Lakes Conference in February 2019.

Figure 53. 2019 floating wetland structures on Lake Spokane

In June 2019, SCC constructed and installed 30 wetland structures (Figure 53). Avista supplemented this effort with 12 additional wetland structures planted with 200 common rush and 400 beaked sedge seedlings. SCC conducted similar monitoring to 2018, including water quality monitoring, minimal plant tissue nutrient analysis and underwater video recording. Avista focused monitoring efforts in 2019 on both plant biomass changes and wave attenuation potential. To measure biomass changes, the above-ground biomass was collected on 8 random seedlings prior to planting, four rush and four sedge. Weight and moisture content was recorded. In October, during structure removal, the above-water biomass weight and moisture content was recorded (Table 27).

Table 27. Floating wetland plant species average mass from June and October 2019.

	Above-Ground Plant Mass Average	
Species	**June 2019**	**October 2019**
Common Rush	1.2 g	19.4 g
Beaked Sedge	1.0 g	12.5 g

A wave attenuation pilot study was conducted in October 2019 to measure any affect the floating wetland may have on dissipating wave energy. Two pressure transducers (Solinst

Leveloggers) were installed approximately five feet offshore, fifteen inches below the water's surface, to record water elevation at a rate of eight measurements per second both behind the floating wetland and approximately 50 feet downstream from the log booms (Figure 54). Waves were created using a boat passing perpendicular to the shoreline. Simultaneously, drone footage was recorded. Results for the wave tests indicate that waves behind the floating wetlands were slightly smaller in height and contain slightly fewer wave peaks per wave set. An example of a wave set is provided in Figure 55. It should be noted that differences in wave height are within the measurement error of the instruments (± 1.2 inches). Other factors that may have influenced these results are the topography of the lake bed along the shoreline and spatial variability in the waves. Without further testing no definite conclusion can be made regarding wave attenuation by the floating wetland.

Figure 54. Locations of levelogger sensors during the floating wetland wave attentuation testing.

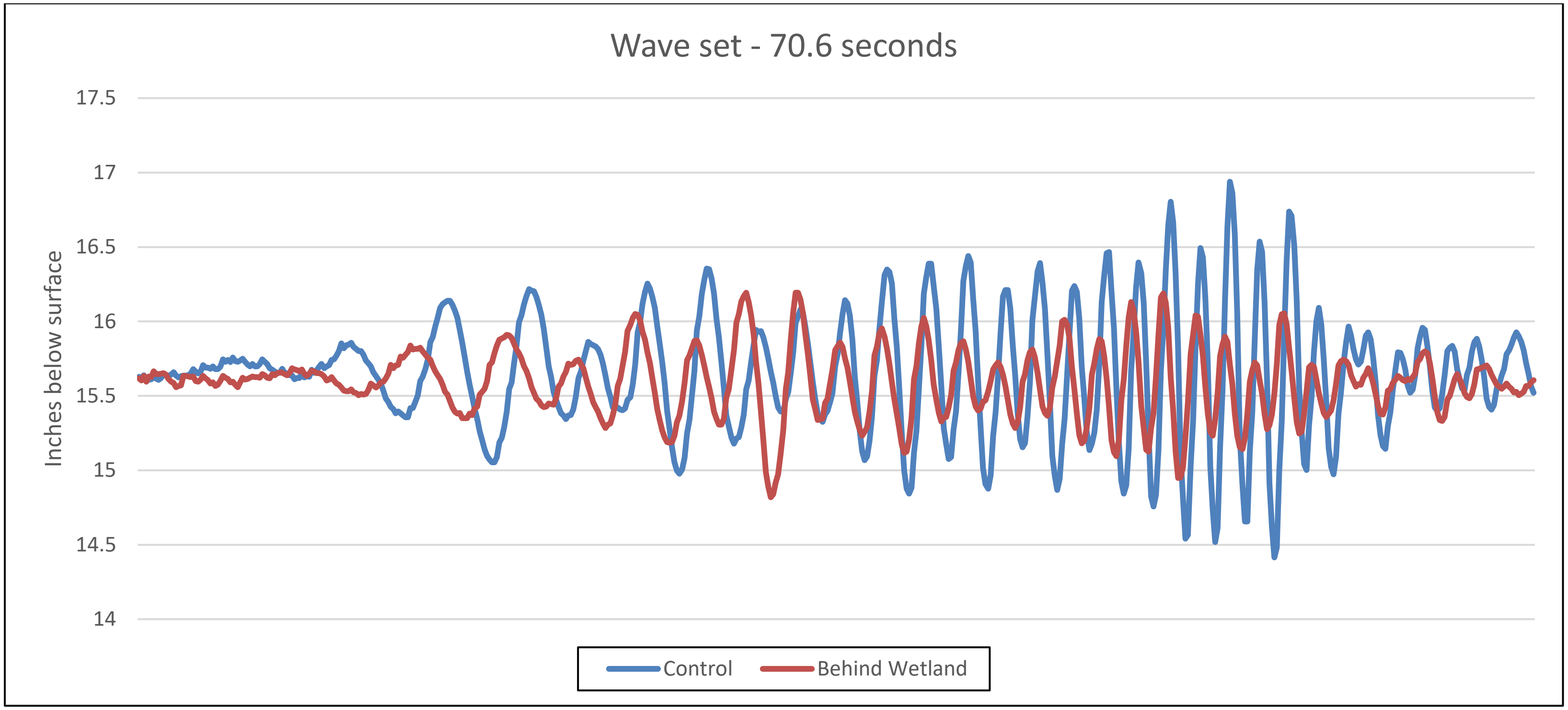

Figure 55. Example comparison of wave data from behind the floating wetland and a control site at the Lake Spokane floating wetland. The lines represent the peaks and troughs of the waves as they pass over the pressure transducers, located below that water's surface. Data is corrected for atmospheric pressure.

3.2.3 Other Measures: Land Protection

Avista owns over 1,000 acres of land, of which approximately 350 acres are located within 200 feet of the Lake Spokane shoreline in Spokane, Stevens, and Lincoln counties at the downstream end of the reservoir. This includes approximately 14-miles of Avista-owned shoreline that is managed in accordance with Avista's, FERC approved, Spokane River Project Land Use Management Plan (Avista 2016). For the most part this land is contiguous along the north and south shorelines and is managed primarily as Conservation Land. Specific details related to Avista's land use management activities are included in the Land Use Management Plan, a copy of which is available upon request. During 2019 Avista continued to protect this area and will pursue identifying the potential TP load that could be avoided by maintaining a 200-foot buffer along the Avista-owned lake shoreline. Avista will pursue the quantification of this activity along the wetland/restoration enhancements as the 200-foot buffer should create similar sediment-filtering effects.

3.2.4 Other Measures: Rainbow Trout Stocking

Avista began implementing a 10-year Lake Spokane rainbow trout stocking program in 2014. As part of the program, Avista annually stocks 155,000 triploid rainbow trout (approximately six inches in length) in the lake every spring. In 2019, approximately 111,000 catchable sized fish were stocked into the lake from the TumTum turnout in May and June. An additional 3,000 catchable sized fish were stocked on October 2.

To evaluate how the fish stocking program is effecting the lake's recreational fishery, Avista conducted biennial creel surveys during the fishing season (March – November) in 2016 and 2018, in accordance with its *Revised Lake Spokane Fishery Enhancement and Creel Survey Plan* (2013) (Revised Plan). Data from the 2016 survey indicated harvested rainbow trout ranged in length from 10 to 18 inches, with 40% being 15 to 16 inches. The 2018 survey results indicated that the largest proportion of rainbow trout harvested were 13 and 14 inches long. Prior to rainbow trout stocking in 2014 rainbow trout were not targeted or caught by angers (as reported in the 2011 baseline study). The 2018 survey results indicate that groups that targeted specific species of fish sought bass or rainbow trout and that their catching success improved by 5% from 2016 to 2018. Overall satisfaction was high among anglers on Lake Spokane, with 80 percent providing a satisfactory rating of their fishing experience. Future creel surveys will be conducted in 2020 and 2022, in accordance with the Revised Plan, and will contribute to the a 2023 comprehensive evaluation of the rainbow trout stocking efforts in Lake Spokane as a successful fishery.

3.2.5 *Other Measures: Bulkhead Removal*

During 2019 Avista worked with several Lake Spokane shoreline landowners in Spokane County to replace existing concrete, stacked rock, riprap, or other similar hardened bulkheads with natural shoreline materials or those that utilize bioengineered products that use native vegetation, when and where possible. The 2018/2019 winter drawdown allowed construction to begin on one of these bulkhead replacement projects, the Wright Project, located just downstream of Sportsman's Paradise, in Spokane County. Construction was completed in January 2019 and plantings were installed in April 2019. The Wright Project is intended to help reduce non-point source phosphorus loading into Lake Spokane and will be used as a prototype to educate other Lake Spokane shoreline homeowners about how they too can improve water quality in Lake Spokane by these types of projects.

3.2.6 *Other Measures: Education*

Avista participated with others to support passage of a Washington law[1], effective January 2013, limiting the use of phosphorus (except for certain circumstances) in residential lawn fertilizers, which includes those adjacent to Lake Spokane in Spokane, Stevens, and Lincoln counties. Although the new law legally restricts use of fertilizer containing phosphorus, homeowner education will be important in actually reducing phosphorus loads to the lake.

During 2019, Avista participated in the SCCD's Best Management Implementation Project. This project is funded through an Ecology grant and one component includes educating Lake Spokane high school students about the water quality in the watershed. This includes discussing best management practices around the lake, such as the benefits of natural shorelines with native vegetation buffers, proper disposal of lawn clippings and pet waste, use of phosphorus-free fertilizers, and regularly maintaining septic systems. Avista also managed an education table at the Lakeside School District's Science Night Out, using hands on experiments and displays to educate students and parents on water quality and fish habitat in Lake Spokane.

In addition, Avista supported a booth at the Northern Idaho/Eastern Washington Regional Lakes Conference to provide educational brochures with content ranging from shoreline best management practices, water quality improvement projects, aquatic weed management, eagles and fisheries habitat, and recreation opportunities in the Spokane River and Lake Spokane.

[1] Engrossed Substitute House Bill 1489, Water Quality – Fertilizer Restrictions, Approved by Governor Christine Gregoire April 14, 2011 with the exception of Section 4 which is vetoed. Effective Date January 1, 2013.

Avista actively participates with the Lake Spokane Association and periodically features articles regarding best management practices for shoreline homeowners in its annual Spokane River Newsletter which is distributed electronically to the Lake Spokane shoreline homeowners.

Lastly, Avista worked with WDFW and Ecology to design and create two educational videos focused on Lake Spokane best management practices and ways to improve water quality, riparian functionality, and manage aquatic weeds. These videos will be used as educational material during community events, conferences and on the Avista website (myavista.com/shorelinehealth).

4.0 EFFECTIVENESS OF IMPLEMENTATION ACTIVITIES

Quantification of the implementation activities including wetlands, land protection, and carp removal are in progress as described for each of these activities below. Avista is currently exploring the use of the STEPL modeling software, developed for EPA's Region 5 (Office of Water Grants Reporting and Tracking System) by Tetra Tech. According to EPA's STEPL website, the modeling software employs simple algorithms to calculate nutrient and sediment loads from different land uses and the load reductions that would result from the implementation of various BMPs (http://it.tetratech-ffx.com/steplweb/). While quantification of BMPs can be highly variable, STEPL may provide a pathway to quantify the cumulative effectiveness of Avista's various implementation activities and a pathway to guide future implementation activities. Avista will work with Ecology to determine if STEPL is the appropriate tool for quantifying phosphorus reductions from Avista's implementation activities.

- **Carp Removal**

  Avista has removed over 2,353 carp in the last three years, totaling approximately 20,925 lbs of biomass, from Lake Spokane. This equates to 143 lbs of total phosphorus removed from the Spokane watershed. The total amount of phosphorus removed from the lake is likely higher. Avista has not yet quantified the amount of phosphorous that will no longer be re-activated in the water column through bioturbation. Additionally, 728 of the total carp removed were mature females, collected during the spring removal effort before spawning, preventing the release of hundreds of thousands of eggs into the population.

- **Wetlands**

  Since 2012, Avista has purchased and enhanced over 500 acres of wetlands within the Spokane river drainage. Avista is in the third stage of implementing a Five-Year Wetland Plan with the Coeur d'Alene Tribe for Hangman Creek, Alder Creek and Benewah Creek properties within the Coeur d'Alene Reservation and will continue to monitor and improve the Sacheen Springs Wetland. As the wetland management plans are implemented, Avista will work with Ecology to explore appropriate total phosphorus load reduction quantification tools.

Initiated in 2018, Avista, SCCD and SCC plan to continue and further enhance the floating wetland study on Lake Spokane in 2020. This will include wave attenuation testing, plant biomass assessments, sampling for water quality parameters, and may also include phytoplankton and zooplankton sampling. Data collected as part of this study will be utilized to get a rough estimate of any impact on water quality and habitat in the near vicinity.

- **Land Protection**

  Avista and State Parks completed the 215 acre lease from DNR and eliminated grazing on this property in 2017. In addition, Avista owns over 1,000 acres of land, of which approximately 350 acres are located within 200 feet of Lake Spokane's shoreline in Spokane, Stevens, and Lincoln counties at the downstream end of the reservoir. During 2019 Avista continued to protect this area and will pursue quantifying TP load reduction for the 200-foot buffer and from the land protection, as these two activities should create similar sediment-filtering effects.

- **Other Cumulative Shoreline BMPs**

  Quantification of phosphorus reductions from Avista's shoreline BMPs, such as tree planting, shoreline encroachment restoration, and bulkhead replacements are difficult to describe quantitatively. However, efforts like these are the type of non-point source actions that will, over time, demonstrate and grow shoreline homeowner awareness of lake health.

5.0 PROPOSED ACTIVITIES FOR 2020

The following activities are proposed for implementation in 2020.

- **Carp Removal**

  Based on the success and lessons learned in 2017, 2018, and 2019 Avista plans to remove carp again in 2020. Avista has partnered with the WDFW to expand their carp efforts in 2020, increasing the number of weeks sampled and the number of gill nets used during each sampling event.

  At a minimum, length and weight will be measured on all carp to quantify the amount of total phosphorus removed during the 2020 efforts. All carp will be removed from Lake Spokane and transported to the Greater Wenatchee Regional Landfill for disposal.

- **Rainbow Trout Stocking**
  Avista will continue to stock 155,000 triploid rainbow trout (approximately six inches in length) in Lake Spokane on an annual basis. A creel survey was conducted on Lake Spokane in 2018, repeating the methods used for the 2016 creel survey, to assess trends in angler satisfaction and angling success associated with the stocking program. The third creel survey will be completed in 2020 and the data collected during this survey will be used to inform the future direction of the stocking program.

- **Rainbow Trout Habitat Assessment**
  Avista will continue to work with Ecology and WDFW to relate lake-wide water quality and habitat data to known rainbow trout occupancy data to help quantify and define available suitable habitat within the entire lake.

- **Wetlands**
  Avista will continue to implement the Wetland Plan with the Coeur d'Alene Tribe for the Hangman Creek properties and will continue to monitor and improve the Sacheen Springs wetland. Management actions likely to occur at the Sacheen Springs wetland property in 2020 include control of terrestrial and aquatic invasive weeds, brushing out roads on the property and revegetating the roads with native grass seed, creating a hiking trail along the perimeter of the island, and the installation of interpretive signage at the entrance to property.
  Additionally, Avista, SCCD and SCC plan to further continue and enhance the floating wetland study on Lake Spokane during 2020. This may include additional analysis of water quality parameters, shoreline wave impacts and attenuation, wildlife and fisheries habitat, and invasive weed infestations.

- **Native Tree Planting**
  Avista will assess survival of the trees planted to date along the Avista-owned Lake Spokane shorelines.

- **Land Protection**
  Avista permanently protected 894 acres along the south shore of Lake Spokane, including seven miles of shoreline through a conservation easement, with the help of the Inland Northwest Land Conservancy. Avista will begin the process to convert 200 acres of Avista-owned land on the north side of Lake Spokane to Conservation Land use. Avista will also continue to protect the 200-foot buffer on 350 acres of Avista-owned shoreline located in the lower portion of the reservoir.

- **Bulkhead Removal**

Avista will continue working with landowners on Lake Spokane who are currently in the construction and permitting phase of bulkhead replacement projects. Avista will also explore other removal projects as they arise.

- **Education**

  Avista will continue to participate and partner with Ecology, the Lake Spokane Association, the SCCD, and others to inform shoreline homeowners and local residents of best management practices they can implement to help protect the lake.

6.0 SCHEDULE

Avista's implementation schedule incorporates several benchmarks and decision points important in implementing the DO WQAP. As part of the 2015 Annual Summary Report and based on Ecology's recommendation, Avista revised the DO WQAP Implementation Schedule (Figure 1) to better sync with the compliance schedule of the DO TMDL, including point- and non-point source wasteload and load reductions. The revision consisted of changing the initial implementation dates that Avista would run the CE-QUAL-W2 model (2016/2017, 2019/2020, and 2021/2022). Avista will to work with Ecology during 2020 to continue developing a plan and timeline to run the CE-QUAL-W2 model, as further described below.

Benchmarks and important milestones completed to date, and extending into 2021 include the following.

2012

- Prepared the DO WQAP, which identified nine potentially reasonable and feasible measures to improve DO conditions in Lake Spokane. Approval of the DO WQAP was obtained from Ecology on September 27, 2012 and from FERC on December 19, 2012.

2013 (Year 1)

- Conducted the baseline nutrient monitoring in Lake Spokane (May through October).
- Conducted the Aquatic Weed Management Phase I Analysis and Nutrient Reduction Evaluation.
- Initiated the Lake Spokane Carp Population Abundance and Distribution Study.
- Planted 300 trees on Lake Spokane.
- Assisted with a bulkhead removal on the Staggs parcel and began designing the bulkhead removal for the second property on Lake Spokane.
- Protected approximately 14-miles of Avista-owned shoreline from future development.
- Acquired 109-acres of wetland property in the Little Spokane Watershed and 656-acres in the upper Hangman Creek Watershed.
- Continued education activities targeted at Lake Spokane shoreline homeowners.

2014 (Year 2)

- Completed and submitted the 2013 DO WQAP Annual Summary Report to Ecology and FERC.
- Conducted baseline nutrient monitoring in Lake Spokane (May through October).
- Completed the Lake Spokane Carp Population Abundance and Distribution Study.
- Planned and began permitting a bulkhead removal on an Avista Lake Spokane parcel.
- Protected approximately 14-miles of Avista-owned shoreline from future development.
- Implemented site-specific wetland plans on the Sacheen Springs and Hangman Creek properties.
- Stocked 155,000 triploid rainbow trout in Lake Spokane.
- Continued education activities targeted at Lake Spokane shoreline homeowners.

2015 (Year 3)

- Completed and submitted the 2014 DO WQAP Annual Summary Report to Ecology and FERC.
- Conducted baseline nutrient monitoring in Lake Spokane (May through October).
- Worked with WDFW and Ecology in planning a carp reduction effort for 2016.
- Continued planning and permitting the bulkhead removal on an Avista Lake Spokane parcel.
- Protected approximately 14-miles of Avista-owned shoreline from future development.
- Implemented site specific wetland plans on the Sacheen Springs and Hangman Creek properties.
- Stocked 155,000 triploid rainbow trout in Lake Spokane.
- Continued education activities targeted at Lake Spokane shoreline homeowners.

2016 (Year 4)

- Completed and submitted the 2015 DO WQAP Annual Summary Report to Ecology and FERC.
- Conducted the baseline nutrient monitoring in Lake Spokane (May through October). Following monitoring, evaluated the results and success of monitoring baseline nutrient conditions in Lake Spokane and worked with Ecology to define future monitoring goals for the lake.
- Initiated carp removal activities during spring spawning. Activities were rescheduled due to timing of the hydrograph and early aquatic weed growth.
- Stocked 155,000 triploid rainbow trout in Lake Spokane.
- Continued to implement site specific wetland plans on the Sacheen Springs and Hangman Creek properties.

- Protected approximately 14-miles of Avista-owned shoreline from future development.
- Planted 13,625 trees along Lake Spokane shoreline.

2017 (Year 5)

- Submitted the DO WQAP Five Year Report to Ecology and FERC on February 1 and April 1, respectively.
- Removed carp during winter aggregation and spring spawning.
- Continued baseline nutrient monitoring in Lake Spokane.
- Initiated the Rainbow Trout Habitat Assessment.
- Completed other mitigation measures as proposed in the DO WQAP Five Year Report.
- Avista continued to work with Ecology in regard to developing a plan to run the CE-QUAL-W2 model.

2018 (Year 6)

- Submitted the 2017 DO WQAP Annual Summary Report to Ecology and FERC by February 1 and April 1, respectively.
- Continued carp removal efforts.
- Continued the Rainbow Trout Habitat Assessment.
- Collected *in-situ* and zooplankton data at all 6, plus 4 additional, water quality monitoring stations.
- Completed other mitigation measures as proposed in previous years' Annual Summary Report.
- Continued discussions of timing, objectives, and data input of potential future CE-QUAL-W2 model runs with Ecology.

2019 (Year 7)

- Submitted the 2018 DO WQAP Annual Summary Report to Ecology and FERC by February 1 and April 1, respectively.
- Initiated analysis of the Rainbow Trout Habitat Assessment, relating identified occupancy information to lake-wide habitat and water quality parameters to quantify available habitat.
- Evaluated water quality monitoring needs in coordination with Ecology's proposed DO TMDL 10-year assessment monitoring.
- Continued carp removal efforts.
- Assisted with a bulkhead removal on the Wrights parcel and began the planning process for the Franks parcel, both on Lake Spokane.
- Completed other mitigation measures as proposed in previous years' Annual Summary Report.
- Continued discussions of timing, objectives, and data input of potential future CE-QUAL-W2 model runs with Ecology.

2020 (Year 8)

- Submit the DO WQAP Eight-Year Annual Summary Report to Ecology and FERC by February 1 and April 1, respectively.
- Will continue the evaluation of water quality monitoring needs in coordination with Ecology's proposed DO TMDL 10-year assessment monitoring.
- Continue carp removal program with extended removal timeframe.
- Continue analysis of Rainbow Trout Habitat Assessment in conjunction with lake-wide water quality parameters, including meeting with WDFW and Ecology to identify definitions or further data assessment.
- Avista will continue to work with Ecology to develop a plan for monthly 24-hour DO monitoring from June to September in Lake Spokane.
- Will continue working with shoreline homeowners interested in bulkhead removal projects.
- Will complete other mitigation measures as proposed in previous years Annual Summary Report.
- Will discuss timing, objectives, and data input of potential future CE-QUAL-W2 model runs with Ecology.

2021 (Year 9)

- Submit the 2020 DO WQAP Annual Summary Report to Ecology and FERC by February 1 and April 1, respectively.
- Will continue the evaluation of water quality monitoring needs in coordination with Ecology's proposed DO TMDL 10-year assessment monitoring.
- Evaluate benefit of carp removal program.
- Continue any bulkhead removals that are under construction and evaluate benefits of bulkhead removal program.
- Continue discussions with Ecology and WDFW to identify and define usable rainbow trout habitat in the lake.
- Will complete other mitigation measures as proposed in previous years Annual Summary Report.
- Will discuss timing, objectives, and data input of potential future CE-QUAL-W2 model runs with Ecology.

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APPENDICES

APPENDIX A

Agency Consultation

AVISTA
1411 East Mission Avenue
PO Box 3727
Spokane, WA 99220-3727

January 31, 2020

Chad Atkins, Water Quality Program
Washington Department of Ecology
Eastern Regional Office
4601 N Monroe Street
Spokane, WA 99205-1295

Subject: Lake Spokane Dissolved Oxygen Water Quality Attainment Plan, Eight-Year Report

Dear Chad:

I have enclosed the Lake Spokane Dissolved Oxygen Water Quality Attainment Eight-Year Report (Eight-Year Report) for your review and approval. The Eight-Year Report was completed in accordance with the Lake Spokane Dissolved Oxygen Water Quality Attainment Plan (DO WQAP), required by the Spokane River Hydroelectric Project License (License) Appendix B, Section 5.6.C of the Washington Department of Ecology (Ecology) Section 401 Water Quality Certification.

The Eight-Year Report assesses the progress made towards improving Lake Spokane's water quality through the implementation of the selected reasonable and feasible measures and includes monitoring results which address year to year variability and trend analyses. In addition the Eight-Year Report also includes a summary of the 2019 climatic conditions and hydrology, implementation activities, effectiveness of the implementation activities, and proposed actions for 2020.

As described in the Lake Spokane Dissolved Oxygen Water Quality Attainment Plan, 2018 Annual Summary Report, Avista has collected baseline data for nine years (2010 – 2018) over the full spectrum of flows that are likely to exist in the Spokane River under current license conditions. Avista will continue to focus on analysis of all collected data including zooplankton and fish habitat information. Along with analysis of the data, further focus can be placed on quantification of implementation activities and the associated phosphorus reductions.

We would appreciate your review of the Eight-Year Report by **March 2, 2020**. This will allow us time to incorporate your comments and recommendations, if you have any, and submit it to the Federal Energy Regulatory Commission by **April 1, 2020**.

Please feel free to call me at (509) 495-4651 if you have any questions about the Eight-Year Report.

Sincerely,

Monica Ott

Monica Ott
Water Quality Specialist
Enclosure (1)

cc: Karl Rains, Ecology
Chad Brown, Ecology
Cathrene Glick, Ecology
Meghan Lunney, Avista

From:	Ott, Monica
To:	Atkins, Chad (ECY)
Cc:	Cathrene Glick (cathrene.glick@ecy.wa.gov); Rains, Karl (ECY); Lunney, Meghan; Chad Brown (chad.brown@ecy.wa.gov)
Subject:	Lake Spokane Dissolved Oxygen Water Quality Attainment Plan, Eight-Year Report
Date:	Friday, January 31, 2020 4:30:07 PM
Attachments:	image001.png Cover Letter_Lake Spokane Eight Year Report_Ecology_1-31-20.pdf Avista_LakeSpokaneDOWQAP_8YearReport_1-31-2020.pdf

Chad,

I have attached the Lake Spokane Dissolved Oxygen Water Quality Attainment Plan, Eight Year Report (Report) for your review. The Report was completed in accordance with the Lake Spokane Dissolved Oxygen Water Quality Attainment Plan, required by the Spokane River Hydroelectric Project License, Appendix B, Section 5.6.C of the Washington Department of Ecology Section 401 Water Quality Certification. The Report includes assessment of progress made towards improving Lake Spokane's water quality through the implementation the selected reasonable and feasible measures and includes monitoring results which address year to year variability and trend analyses. The Report also includes a summary of the 2019 climatic conditions and hydrology, implementation activities, effectiveness of the implementation activities, and proposed actions for 2020.

We would appreciate your review of the Report by **March 2, 2020**. This will allow us time to incorporate your comments and recommendations, if you have any, and submit it to the Federal Energy Regulatory Commission by **April 1, 2020**.

Please let me know if you would like a hard copy of this report in addition to this electronic version and we would be happy to provide one.

Please feel free to call me at (509) 495-4651 if you have any questions or would like to discuss the contents of the report.

-Monica

Monica Ott, Water Quality Specialist
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AVISTA

STATE OF WASHINGTON
DEPARTMENT OF ECOLOGY
4601 N Monroe Street • Spokane, WA 99205-1295 • 509-329-3400

March 2, 2020

Monica Ott
Avista Corporation
1411 East Mission Ave
Spokane, WA 99220-3727

RE: Request for Ecology Review– *Lake Spokane Dissolved Oxygen Water Quality Attainment Plan - Eight Year Report*
Spokane River Hydroelectric Project No. 2545, Appendix B, Section 5.6C

Dear Monica Ott:

The Department of Ecology (Ecology) appreciates the opportunity to review the Lake Spokane Dissolved Oxygen Water Quality Attainment Plan Eight Year Report sent to Ecology in January 2020. Thank you for the work that has been accomplished to reduce nutrient loading and improve dissolved oxygen in Lake Spokane. Please see the attached comments from the Environmental Assessment Program. In addition to submitting these comments, Ecology would like to make two recommendations for 2020:

- Ecology recommends Avista perform diurnal monitoring of Lake Spokane for dissolved oxygen at two locations in the reservoir at two different times (early summer and fall) to characterize daily dissolved oxygen changes in the lake. Ecology is willing to provide monitoring support, including equipment and staff resources as available.

- Ecology remains unsure if implementation activities described in the Water Quality Attainment Plan are providing the nutrient reductions needed to achieve Avista's dissolved oxygen proportional responsibility described in Table 7 of the Spokane River and Lake Spokane Dissolved Oxygen Total Maximum Daily Load (and subsequently incorporated in the 401 certification for FERC project no 2545). Ecology recommends Avista participate with Ecology staff in a series of discussions in 2020. The purpose of these discussions will be to clarify the pathway for Avista to both implement and calculate dissolved oxygen improvements with an eye towards the ten-year compliance period.

Please contact me at (509) 329-3590 or catk461@ecy.wa.gov if you have any questions.

Sincerely,

Chad Atkins
Watershed Unit Supervisor
Water Quality Program

CA:red
cc: Meghan Lunney – Avista

Avista Corporation Lake Spokane Dissolved Oxygen Water Quality Attainment Plan Eight-Year Report Review Comments

Date: February 18, 2020

Reviewer: Cathrene Glick, EAP-ERO 509-329-3425

Documents: (1) Avista Corporation Lake Spokane Dissolved Oxygen Water Quality Attainment Plan Eight-Year Report, submitted January 31, 2020

Page, Paragraph, Line	Comment
Page 11, Figure 6 and Page 12, Figure 7	Yearly flow hydrographs indicate that seasonal flows are systematically arriving earlier in the year as compared to the 2001 and 2010-2011 flow hydrographs. Given the criteria for water quality to meet TMDL criteria in critical months March-October is Avista looking at operational modifications to permitted flows from the dam to allow for shorter retention times to reduce temperature increases and reduce algae blooms? What is controlling factor for water discharge (hydro power demands, minimum flow, downstream flow demands, lake water level, etc.) and how will these change to accommodate changes in inflow in the future?
Page 14, Tables 1 and 2	The tables reference residence time for the "whole reservoir" and for the "transition/riverine zone" using the same calculation of reservoir volume/outflow and produce differing values but there is no clarification for how the differentiation for the transition/riverine zone has been determined. Since you only have inflow (Nine Mile Dam and Little Spokane flows) and outflow at Long Lake dam how can you separate out unmetered flows within a specific section of the reservoir? Particularly as this data is further broken down to monthly daily residence time in Table 2 with no clarification on calculations.
Pages 15-18 including Figures 9, 10, and 11	Text in Section 2.2.1 and figures clearly indicate that the water temperature has increased over time particularly for depths shallower than 20m but there is no discussion or graphics to assess if any of the temperature increases are associated with through flow (residence time) from varying operation conditions. Seems once that there is an effect noticed, there should be an accompanying evaluation of causation rather than climate change. How much is operation of the lake having on water temperature? It is noted that you do attempt to correlate DO vs. Residence Time later on in report. Seems that in light of continued temperature increases there should be considerations for future operational flow adjustments.
Pages 19-21 including Figure 13	Text and figures indicate that there is a correlation of DO levels in the lake water compared to residence time although there is no specific text or data to clarify what seasonal and operational factors drive the residence time and how that may be altered in future operations given climatic changes.
Page 20, Figure 12	Text for figure title includes a statement "Inflow TP in 2018 was calculated as the flow-weighted average form observations at Nine Mile and Little Spokane River". I presume this is observation at Nine Mile Dam and for clarification is this data obtained from Ecology Ambient Monitoring Data or has Avista also collected samples at the two observation locations. Clarification of the source of the 2018 data should be provided.

Page, Paragraph, Line	Comment
Page 22, Figures 14 and 15 and Page 25-30 Figures 16-21	Comparison of Figures 14 and 15 provide strong indication of increases in water DO concentrations(mg/L) throughout the lake over time particularly for depths greater than 20 meters however the detailed information provided in Figures 16 thru 21 are reported in % Saturation not concentration (mg/L). Comparisons of "concentration" with "% Saturation" is not straight forward for interpretation from the data. It is confusing on page 23, second paragraph, where it references DO concentration is in excess of 100% saturation. Terms are not directly interchangeable. Would be a better correlation of Figures 14 and 15 with TMDL requirements if data were presented in concentration (mg/L) and not % Saturation (since I am not aware that the TMDL references % Saturation as a compliance component).
Pages 32-33 and Page 35, Figure 23	Text and Figure 23 identify elevated concentrations of Total Phosphorous for July thru August stations LL0, LL1, and LL2 in 2016 and 2017 but there is no discussion for possible causation for this TP spike. Was there an evaluation of what may have contributed to his TP spike?
Page 39, Figure 25	Is this data source Ambient Monitoring Data or other source? Clarification of the source of the data should be provided.
Page 50, Section 2.3	First paragraph includes the sentence "It was discussed that baseline monitoring would remain postponed until the upstream dischargers to the Spokane River have installed tertiary treatment and met their load allocations." I am not sure that this is a correct interpretation of the discussion which was more along the lines of waiting until the implementation phases of treatment upgrades (specifically the City of Spokane Wastewater Treatment Plant) are complete – not waiting until dischargers have met their load allocations. Please clarify sentence.
Page 50, Section 2.3	First paragraph includes the sentence "According to the DO TMDL Milestone Schedule, in 2021 all point source dischargers to the Spokane River will be meeting load allocations." Again, I am not sure this is the correct representation of the DO TMDL Milestone Schedule – which lays out the timeline for compliance to meet the specific load allocations. The TMDL schedule does not provide any assurance that each and all discharges will be meeting load allocations in accordance with the schedule. Please clarify sentence.
Page 50, Section 2.3	Regarding the proposed 24-hour DO monitoring study, further discussions between Water Quality and EAP led to considering monitoring at three (3) locations within the lake and at multiple depths throughout the upper 25m. These monitoring activities could occur independently (3 consecutive nights/days) or combined to occur in one 24-hour period if sufficient staffing/equipment resources allowed. EAP hydrolab equipment and staff could be made available to support these monitoring activities. Methodologies for "bottom anchorage" or "shoreline anchorage" can be addressed as the study develops.
Page 93, 2021 (Year 9) Schedule	Is this a good year to look at potential impacts to water quality over time compared to lake water levels and residence time associated with dam "operational practices" for hydroelectric production or from upstream/downstream water flows/demands?

From:	Ott, Monica
To:	Atkins, Chad (ECY)
Cc:	Lunney, Meghan; "Brown, Chad (ECY)"; Cathrene Glick (cathrene.glick@ecy.wa.gov); Rains, Karl (ECY)
Bcc:	Goloborodko, Yelena
Subject:	Revised Lake Spokane Dissolved Oxygen Water Quality Attainment Plan Eight-Year Report for Review and Approval
Date:	Monday, March 23, 2020 12:53:00 PM
Attachments:	Avista_LakeSpokaneDOWQAP_2019AnnualSummary-8YearReport_Revised.pdf Avista_LakeSpokaneDOWQAP_2019AnnualSummary-8YearReport_Redlines_03-23-20.pdf image001.png
Importance:	High

Hi Chad,

We have revised Avista's Lake Spokane Dissolved Oxygen Water Quality Attainment Plan (DO WQAP) Eight-Year Report (Report) in consideration of the Washington Department of Ecology (Ecology) comments, provided on March 2, 2020. Please find a redline version attached, showing changes to the document, as well as a Revised clean version. We agree that it would be beneficial for Avista and Ecology to meet this year regarding ongoing implementation of the DO WQAP. This would be a good setting to further discuss several of the comments attached to Ecology's March 2 letter. For example, in the comments attached to your letter, several include questions about hydro operations and river flows. During the relicensing process, Avista, Ecology, the Washington Department of Fish and Wildlife, the Idaho Department of Environmental Quality, the Idaho Department of Fish and Game and numerous other stakeholders engaged and evaluated operational options, as reflected in the relicensing record, including the Spokane River Project Federal Energy Regulatory Commission (FERC) License (June 18, 2009) and the Final Environmental Impact Statement Spokane River and Post Falls Hydroelectric Projects (July 2007). This, along with the Spokane River and Lake Spokane Dissolved Oxygen Total Maximum Daily Load (DO TMDL), may be a beneficial discussion topic in meetings this year, especially given there have been many transitions in staff and we appreciate the opportunity to rebuild institutional knowledge of the relicensing efforts.

Additionally, with regard to your comment concerning Table 7 of the DO TMDL, we understand it was identified as a proxy to identify Avista's proportional level of responsibility. Given the complexities with evaluating compliance to Table 7 we look forward to further discussing additional tools and different methods of evaluating nutrient impacts and DO sensitivities in Lake Spokane. Avista's efforts have appropriately focused on achievable water quality improvements by reducing non-point phosphorus inputs which supports beneficial uses. We look forward to clarifying a pathway to quantify phosphorus reductions and dissolved oxygen improvements in Lake Spokane as you suggested in your March 2 comment letter and during our March 19 conference call.

We would appreciate your expedited review and approval of the revised report, as reviewed during our March 19 conference call. This will allow us to file an Ecology-approved Report to FERC by April 1.

Thanks again for all your help!

Monica

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From:	Glick, Cathrene (ECY)
To:	Ott, Monica; Atkins, Chad (ECY)
Cc:	Lunney, Meghan; Brown, Chad (ECY); Rains, Karl (ECY)
Subject:	[External] RE: Revised Lake Spokane Dissolved Oxygen Water Quality Attainment Plan Eight-Year Report for Review and Approval
Date:	Thursday, March 26, 2020 4:07:20 PM
Attachments:	image001.png

Monica-

Thanks for the revised document, the red-lined version was quite helpful.

One comment is about the text on page 51, section 2.3 where you clarified discussions regarding future monitoring and you identify the City of Spokane WWTP upgrades and you state "…which is scheduled to be installed in 2021." My concern is that this work is actually underway (nearing completion) and not "to be installed". The text should more correctly reference the completion (?) and/or initiation and optimization (?) of the advance treatment system. Maybe someone at the city can give you some clarification for how to represent the status of this project or start up.

My second comment is regarding the figure on page 98 (formerly identified as Figure 56). I note that the figure title and reference to the figure in the preceding text has been deleted but the photo remains. Is there going to be a footnote or title for this photo?

Other than that, all good from my perspective.

Thanks

Cathrene D. Glick, LG, LEG, LHG, PG, CEG, CHG
WA State Department of Ecology
Environmental Assessment Program
Eastern Operations Section – Eastern Regional Office
Direct Ph: (509) 329-3425
Work Cell: (509) 209-7444

From: Ott, Monica <Monica.Ott@avistacorp.com>
Sent: Monday, March 23, 2020 12:54 PM
To: Atkins, Chad (ECY) <CATK461@ECY.WA.GOV>
Cc: Lunney, Meghan <Meghan.Lunney@avistacorp.com>; Brown, Chad (ECY) <CHBR461@ECY.WA.GOV>; Glick, Cathrene (ECY) <CGLI461@ECY.WA.GOV>; Rains, Karl (ECY) <KRAI461@ECY.WA.GOV>
Subject: Revised Lake Spokane Dissolved Oxygen Water Quality Attainment Plan Eight-Year Report for Review and Approval

Ott, Monica

Subject: FW: [External] Ecology Approval of the Avista Revised Lake Spokane DO Water Quality Attainment Plan - Eight Year Report

From: Atkins, Chad (ECY) [mailto:CATK461@ECY.WA.GOV]
Sent: Friday, March 27, 2020 4:47 PM
To: Ott, Monica <Monica.Ott@avistacorp.com>
Cc: Lunney, Meghan <Meghan.Lunney@avistacorp.com>
Subject: [External] Ecology Approval of the Avista Revised Lake Spokane DO Water Quality Attainment Plan - Eight Year Report

RE: Ecology Approval – *Revised Lake Spokane Dissolved Oxygen Water Quality Attainment Plan - Eight Year Report*
Spokane River Hydroelectric Project No. 2545, Appendix B, Section 5.6C

Hi Monica-

Ecology has reviewed Avista's *Revised Lake Spokane Dissolved Oxygen Water Quality Attainment Plan Eight-Year Report* (DO WQAP) provided to Ecology March 23, 2020. The purpose of this e-mail is to inform you that Ecology ***approves*** the DO WQAP as revised. We agree it would be beneficial for Avista and Ecology to meet this year regarding ongoing implementation of the DO WQAP and look forward to those discussions.

Sincerely,

Chad

Chad Atkins
Watershed Unit Supervisor
Water Quality Program
Eastern Regional Office
509-329-3590
