AVISTA CORPORATION

LAKE SPOKANE DISSOLVED OXYGEN WATER QUALITY ATTAINMENT PLAN 2014 ANNUAL SUMMARY REPORT

WASHINGTON 401 CERTIFICATION
FERC LICENSE APPENDIX B, SECTION 5.6

SPOKANE RIVER HYDROELECTRIC PROJECT
FERC PROJECT NO. 2545

Prepared By:

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1.0 INTRODUCTION

The Washington Department of Ecology (Ecology) has 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 water bodies 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).

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.

Avista Corporation (Avista) owns and operates the Spokane River Hydroelectric Project (Project), which consists of five dams on the Spokane River, including Long Lake Hydroelectric Development (HED) which creates Lake Spokane. 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 the ability of nutrients contained in those waters to reduce DO levels.

Avista received a new, 50-year license for the Project from the Federal Energy Regulatory Commission (FERC) on June 18, 2009 (FERC 2009). The license incorporates a water quality certification (Certification) issued by Ecology under Section 401 of the Clean Water Act (Ecology 2009). As required by 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 Lake Spokane. 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.

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 and 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 likely create an adverse effect 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.

In its 2013 Annual Summary Report, Avista concluded 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 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.

During 2013 and 2014 Avista completed a study which assessed the feasibility of reducing carp populations from Lake Spokane. The results are presented in Section 3.1.1 of this report.

As required by the DO WQAP, this report provides a summary of the 2014 baseline monitoring, implementation activities, effectiveness of the implementation activities, and proposed actions for 2015.

2.0 BASELINE MONITORING

Longitudinally, the lake can be classified as having three distinct zones which consist of a riverine, transition and lacustrine zone. 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 and temperature, change in storage, climate, 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 contains the thermocline and is the transition layer between the epilimnion and the hypolimnion that is influenced by both surface and interflow inflows. The hypolimnion is the deepest layer and is present throughout the lacustrine zone. **Figure 1** shows the locations of the six stations within Lake Spokane. Avista contracted with Tetra Tech to complete the baseline monitoring activities during 2014. Sample events were completed at the six lake stations, LL0 through LL5, during May through October.

Results of the monitoring are summarized in **Appendix A** (2014 Baseline Water Quality Monitoring Results, Tetra Tech 2014a) and include the water quality conditions in Lake Spokane as well as for its inflows and outflows, tables of water quality data collected for the DO WQAP, and a description of the general hydrologic and climatic conditions. Additionally, the report includes an analysis of the phytoplankton and zooplankton populations present during the 2014 sampling events. Highlights taken from the Tetra Tech Report are provided as follows.

- Weather conditions during 2014 varied slightly from the 30-year norms reported at the Spokane International Airport, with cooler than normal temperatures in the late winter, warmer than normal temperatures in May, July, August, September and October, and below normal precipitation for most of the year. Peak flows in 2014 (26,600 cubic feet per second [cfs]) were significantly smaller than peak flows observed in previous years (2011 and 2012), slightly greater than peak flows in 2013, and much greater than peak flows in 2010. The annual mean daily flow during 2014 was 7,452 cfs.
- The residence time for the lake as a whole (June through October) was longer in 2014 (31.3 days) compared with 2010 – 2012, but shorter than in 2013. By the early June sampling event, stratification had developed at the four downstream stations, but not at LL4 and LL5. The water column did not stratify at LL4 until July, and LL5 experienced a brief stratification in August.
- While the extent and depth of the hypolimnion varied throughout the summer, for most of the sampling dates the hypolimnion depth occurred at about 10 meters (m) from the surface, being shallow in June and deepening later in the summer.
- The maximum temperature reached at the surface was 25°C in the lacustrine zone and in the upper reservoir during August. Temperature was usually at or below 20°C at depths greater than 10 m in the lacustrine zone.
- Conductivity varied from about 69 to 270 µ Siemens/cm (µS/cm) throughout the reservoir. Water with increased conductivity (150 to 250 µS/cm), comprised the interflow zone that extended from about 4 to 12 m at stations LL3 through LL0 in June, and extended to 30 m in August as inflow volume decreased. The high conductivity water (250 – 270 µS/cm) in August moved along the reservoir bottom from LL5 to LL2, where depths were greater than or equal to 25 meters and entered the deeper reservoir portion between 10 and 25 m. Below 30 m, conductivity was usually less than 150 µS/cm. Much of the metalimnion in the lower reservoir is composed of a mixture of river inflow and bottom water from the transition zone that plunges to depths that approximate the density of that mixture. Conductivity in bottom waters at LL0 remained unchanged from late June until late September when river inflows increased enough to mix the deepest portions of the reservoir.
- The water column profiles for pH showed a range of 6.9 to 9.2 at the six stations during 2014 with the highest pH values occurred during August and September. Water column averages were much narrower, ranging from 7.6 to 8.2.
- Maximum epilimnetic DO concentrations ranged from 12.0 to 14.1 milligrams per liter (mg/L) at the six stations, with higher values occurring in the lacustrine zone. Average water column DO ranged from 8.3 to 10.3 mg/L. Minimum DO concentrations of 0.0 mg/L occurred near the bottom at the two deepest stations, LLO (~154 ft) and LL1 (~108 ft), most likely due to sediment demand. Minimum DO concentrations in 2013 and 2014 were the lowest observed of the five years sampled (2010-2014), most likely reflecting that 2013 and 2014 had the lowest inflows.
- Total phosphorus (TP) concentrations ranged from 4 to 70 micrograms per liter (µg/L) during 2014. Soluble reactive phosphorus (SRP) concentrations ranged from non-detect (1.0 µg/L) to 61 µg/L. TP and SRP were usually highest at stations LL0, LL1, and LL2 in the hypolimnion (15 m and deeper) with higher levels usually starting in July. One exception included the highest concentration (70 µg/L), which occurred at the bottom of LL0 in June when the water column was uniform with DO. Volume-weighted water column TP concentrations for all stations were below 35 µg/L and for most of the period were below 25 µg/L.

- Total nitrogen (TN) concentrations at all six stations ranged from 250 to 2,000 µg/L over the monitoring period, with most of the TN consisting of nitrate+nitrite. The average lacustrine epilimnetic TN and nitrate+nitrite concentrations during June through September were 606 and 480 µg/L, respectively. It should be noted, the TN and nitrate+nitrite concentrations measured at Ecology's Nine Mile and Little Spokane Stations (54A090 and 55B070) were high (1,100 to 1,700 µg/L), with most being nitrate+nitrate, roughly matched the levels in the metalimnion and hypolimnion of the lacustrine zone. This suggests that plunging river inflows were the source of the high summer N concentrations, with groundwater being an important factor.
- Chlorophyll (chl) concentrations at the six stations ranged from 0.5 to 25.4 µg/L in 2014. Maximums at most sites were higher than in 2012 and 2013. Chl was often highest at the 5 m depth, which was the case in 2012 and 2013. Transparency ranged from 1.6 to 7.7 m throughout the reservoir during 2014, and appears to be affected largely by phytoplankton (except during May and early June).
- The composition of the phytoplankton taxa showed diatoms (*Chrysophyta*) to be dominant at all the stations during spring, based on both cell counts and biovolume. Cyanobacteria (blue-green algae) increased numerically (cells/ml) at all sites in August, but were represented by significant biovolume at LL4 and LL5 only. The 2014 pattern is similar to 2012 when diatoms dominated during the spring at all sites, but cyanobacteria dominated cell counts at all sites in the late summer. Diatoms and green algae represented the greatest biovolume at all sites in 2014, although substantial cyanobacteria biovolume existed at LL4 and especially at LL5 in August.

Measures of Improvement

Tetra Tech used several standard limnological approaches to measure the lake's DO improvement since 1977. These approaches included comparing the minimum volume-weighted hypolimnetic DO over time, determining the lake's current trophic state index, and completing a cursory habitat evaluation for rainbow trout. Results of these analyses are discussed in **Appendix A**, and are summarized below. The approaches used by TetraTech provide valuable information. Avista anticipates these or other approaches, along with the goals of the DO TMDL, will be used to determine compliance with the surface water quality standards at the end of the 10-year compliance schedule.

- The minimum volume-weighted hypolimnetic DO has substantially increased since 1977. In 1978, the City of Spokane's wastewater treatment plant implemented an 85% reduction in point-source TP in their discharge water. Prior to the TP reduction, minimum volume-weighted hypolimnetic DO ranged from 0.2 to 3.4 mg/L (1972 – 1977). Following the TP reduction, minimum volume-weighted hypolimnetic DO ranged from 2.1 to 4.9 mg/L (1978 – 1985). The current (2010 – 2014) minimum volume-weighted hypolimnetic DO ranged from 5.9 to 7.8 mg/L, and averaged 6.5 mg/L with inflow TPs averaging 14.2 µg/L. While DO conditions have improved in Lake Spokane since 85% of point-source effluent phosphorus was removed in 1977, it is important to note data collected in 2014 indicate DO levels do not meet the surface water quality standard in the hypolimnion during portions of the summer critical season.

- The lake's tropic state, a general measure of biological production (utilizing concentrations of TP, chlorophyll, water clarity, etc.) is near borderline oligotrophic-mesotrophic, with the exception of the

TP concentrations in the transition and riverine zones. The trophic state of the lake is an important index to measure, especially when evaluating the lake's habitat. A eutrophic state indicates high biological production within the lake, an oligotrophic state indicates low biological production, and mesotrophic is between those two a state between the two.

- A cursory review of Lake Spokane's aquatic habitat specific to Washington's designated aquatic life use, core summer salmonid habitat was completed by Tetra Tech using the baseline nutrient monitoring data collected in 2014. Tetra Tech used a critical maximum temperature (18°C) and a minimum DO (6 mg/L) to compute the percent volume acceptable for growth for rainbow trout at the six stations for 2014 (Tetra Tech 2015a, Figures 97-102). Using this criteria, the results of the analysis indicated that trout would probably avoid the epilimnion during most of the summer due to temperatures that reached 25°C and prefer to seek cooler water deeper than 10 m. Between 10 and 20 m, DO was usually near or above 6 mg/L during August and September, but never less than the often cited required minimum of 5 mg/L. These data suggest that rainbow trout are most likely inhabiting cooler water in the metalimnion and upper portions of the hypolimnion. Additionally, the habitat volumes for temperature and DO together, as well as separately, were shown to indicate which factor appears most limiting. Tetra Tech Figures 98-103 show that habitat appears to be more restricted by temperature for rainbow trout. This evaluation provides a cursory review of fish habitat in Lake Spokane and how it might be affected by DO and temperature conditions, based upon select literature sources, as well as the data collected at the six lake stations. To obtain site specific water quality limitations on fish habitat in Lake Spokane, a more thorough analysis would need to be completed.

Monitoring Recommendations

Avista will continue conducting nutrient monitoring in Lake Spokane in accordance with the Ecology approved Quality Assurance Project Plan for Lake Spokane Nutrient Monitoring (Tetra Tech 2014).

3.0 IMPLEMENTATION ACTIVITIES

3.1 Studies

In accordance with the DO WQAP, Avista focused its initial efforts on analyzing two measures: reducing carp populations and aquatic weed management, which were identified as having a high potential for phosphorus reduction.

3.1.1 Carp Population Reduction Program

In order to investigate whether removal of 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 findings of the Phase I and Phase II Analyses are summarized below.

Phase I Analysis

Per the schedule identified in the Carp Population Study Plan (Appendix C of the DO WQAP), the Phase I Analysis included five components: quantifying carp abundance, investigating basic carp biological measures, identifying carp seasonal behaviors, testing whole-body TP concentrations, and estimating loads from carp excretions and bioturbation based upon a literature review. The results of the Phase I Analysis are summarized below, with a more thorough discussion provided in the Lake Spokane Carp Population Abundance and Distribution Study, 2014 Annual Report Phase I (Golder 2015), Phase II Analysis Carp Harvest Potential in Lake Spokane (Horner 2015), and the Technical Memorandum Literature Review of Phosphorus Loading from Carp Excretion and Bioturbation & Phosphorus Loading Estimates for Lake Spokane Carp (Tetra Tech 2015b), attached as **Appendices B, C, and E**, respectively.

All fish sampling activities conducted as part of the Phase I Analysis were completed under a Washington State Scientific Collection Permit (No. 13-276(a-c)) issued by the Washington Department of Fish and Wildlife (WDFW).

Quantify Carp Abundance

A rough population estimate of 125,000 carp in Lake Spokane was generated by WDFW prior to the start of this study (Donley 2011). Golder proposed refining the carp population abundance estimate by utilizing a Hierarchical Bayesian Model mark-recapture approach that utilized electrofishing from selected index sites, stratified by weed bed type, and extrapolating those results to the reservoir as a whole by using catch rates (catch per unit effort [CPUE]) associated with different habitat types.

The marking event was completed June 10 through June 13, 2014 utilizing electrofishing at 48 sites in the reservoir. No carp were captured downstream of the McLellan area of the reservoir (**Figure 2**). Electrofishing sites were guided by the distribution of combined acoustic/radio transmitter (CART) tagged carp and habitat types. A total of 616 carp were marked with a passive integrated transponder (PIT) tag and released near their capture location. Marking occurred during carp spawning to maximize the number of marked fish.

The recapture event occurred on September 28 and 29, 2014 utilizing electrofishing at 15 sites in the upper half of the reservoir. The timing and location of sampling for the recapture event was guided by the distribution of CART tagged carp and the relatively high catch per unit effort (CPUE) associated with the October 2013 collection of carp for CART tagging. However, at this same time period in 2014, the carp had already moved below the effective range of electrofishing. As a result only 26 carp were captured during the recapture effort, with none of those fish being PIT tagged, therefore a mark-recapture population estimate could not be made due to the lack of any marked carp.

CPUE is another measure of relative abundance. Electrofishing catch rates during the three sampling programs (CART tagging, mark effort and recapture effort) were highly variable in Lake Spokane ranging from 0 to 146 carp/hr on Lake Spokane. During the October 16-17, 2013 collection effort for CART tags, CPUE ranged from 3.4 carp/hr to 29.7 carp/hr. During the June 10-13, 2014 marking effort, the mean CPUE was 44 carp/hr (range 3 carp/hr to146 carp/hr). During the September 28-29, 2014 recapture effort mean CPUE was 6.7 carp/hr (range 0 carp/hr to 28.6 carp/hr).

Investigate Basic Carp Biological Measures

As part of the sampling events, basic biological measures were obtained from carp including: individual total lengths, fork lengths and length frequency distribution; individual weights and weight frequency distribution; condition factor; age and size at maturity. Maturity and ageing data were collected from 22 of the fish. Results from this component of the study are summarized as follows.

- **Distribution of length/weight** – The size of carp captured during the 2014 sampling were primarily large carp with very few small carp represented. Carp total lengths from all sampling efforts ranged from 168 to 810 millimeter (mm) with mean total length during the June marking event being 645 mm (25.4 inches [in]). Carp weights ranged from 60 to 10,450 grams (g) with a mean weight of 3,805 g (~4 kg or 8 pounds [lb]).

- **Age class/Growth/Size at Maturity** - Ages of the 22 carp captured ranged from age 5 to age 17 indicating successful spawning over multiple years rather than one or two dominant year classes. All carp examined were mature. The small number of fish aged is too small to draw meaningful conclusions about the dynamics of this population.

- **Condition Factor -** The relative weight (Wr) of carp sampled during the June 2014 carp spawning period ranged from 53.2 to 177.5, with a mean± SD of 109.2±18.6 and a median of 107.8 (Golder 2015, Figure 2-14). For comparison, the 22 fish with length and weight measurements in September 2014 had relative weights that varied much less, ranging from 91.7 to 119.2 with a mean±SD of 106.1 ± 9.0. The median relative weight for September 2014 fish was virtually the same as for June 2013 (105.0 September versus 107.8 for June).

Identify Carp Seasonal Behavior (movement and aggregation)

Twenty carp were captured at two locations in the Felton Slough area (approximately between river kilometer [RKM] 78-79) and Sportsman's Paradise (RKM 81-82) on October 17, 2013. These carp were surgically implanted with combined acoustic radio transmitters (CART) tags. Once tagged, they were redistributed into the reservoir. Locations of CART tagged carp were then recorded during 34 tracking events between October 30, 2013 and November 3, 2014 with more emphasis placed on fall and winter time periods. The entire reservoir was surveyed when not all tagged carp were located in the upper half of the reservoir. Throughout this time period, we were able to successfully track 15 of the carp, with 5 either dying or shedding their tags.

The carp telemetry data for Lake Spokane indicate that carp aggregate during the winter months (November through March) in an area of the reservoir adjacent to Sportsman's Paradise (RKM 79 to 81.5) (**Figure 2**). Water temperatures recorded by Ecology at their Spokane River at Nine Mile Bridge Station (54A090) during this timeframe ranged from 8.4°C to 3.7°C. Depth of where carp were aggregating during the winter months is not known precisely, but water depths recorded for the presumed location of the tagged carp indicate fish may be aggregating at depths from about 1.5 m (5 ft) to over 12 m (40 ft).

It appears that winter drawdown of Lake Spokane results in carp moving both up and downstream as water levels change, but that the Sportsman's Paradise area is a preferred winter aggregation area so long as water levels are relatively stable regardless of the winter pool elevation. In 2014, winter drawdown started in early December, however did not reach more than 2 feet below normal pool until January 6th and extended to March 13th. A maximum drawdown of 4.1 m (13.4 ft) was reached on January 29 and 30. The largest aggregations of tagged carp occurred in the Sportsman's Paradise area during tracking dates of 11/6, 11/21, 12/16, 2/4 and 3/22 when water levels were cold and stable. Tagged carp were more dispersed when the water elevation was decreasing (1/14) or increasing (2/21 and 3/12).

Tagged carp utilized shallow vegetated areas before and during the spring spawning period, but they were not as tightly aggregated as during the winter months. Carp spawning was documented at eight locations associated with shallow (depths of 2 m or less), vegetated flats in Lake Spokane primarily during the month of June (**Figure 2**).

It appears that the majority of tagged carp locations were between RKM 77 and RKM 84 regardless of the season and within that area, the Sportsman's Paradise area of Lake Spokane (about RKM 79 to 82) was the most frequently utilized area of the reservoir. This area is characterized by a deep (12-18 m or 40-60 ft) thalwag that represents the old river channel and a large (approximately 2 km long by 0.5 km wide) shallower floodplain flat with depths of 3-5 m at full pool. When carp were dispersed from Sportsman's Paradise, they were observed adjacent to other flooded flats like Willow Bay (RKM 74), Felton Slough (RKM 78-79), and the flats on both south and north banks around the Suncrest community (RKM 82-85). Telemetry locations were not precise enough to determine if the carp were using the flats or deeper areas adjacent to the flats. We also observed carp feeding on the surface film throughout the reservoir at different times of the year.

Test Whole-Body Carp Phosphorus Concentration

Three carp were collected from Lake Spokane in September 2014 during the recapture event and analyzed by ALS Environmental (Kelso, WA) for whole-body TP concentrations. Results of the analysis are summarized in Table 1 and the analytical report is included as **Appendix D.**

Table 1. Total Phosphorus Content of Lake Spokane Carp.

Carp ID	Wet Weight (kg)	Total Solids (%)	mg TP/kg carp (wet weight)	g TP/kg carp (wet weight)
Fish #658	2.82	25.5	4520	4.52
Fish #658-Dup	2.85	25.4	5910	5.91
Fish #656	3.93	27	10300	10.3
Fish #659	6.14	31.5	3940	3.94
Average (n = 4)	3.94	27.4	6198	**6.2**
Average (n = 3, without Fish # 656)	3.94	27.5	4790	**4.8**

This analysis indicates the TP content of Lake Spokane carp range from 4.8 to 6.2 g TP per kg of carp. Should Avista harvest carp out of Lake Spokane, this range could be simplified by estimating carp to have a TP content of 5 g TP per kg carp.

As an example, if 25,000 carp were harvested out of Lake Spokane, with the average carp weighing 4 kg, and each carp containing 5 g TP per kg of carp, the total amount of TP removed would be 500 kg or 1,102 pounds.

$$25{,}000\ carp\ x\ 4\ kg\ x\ \ 5\frac{g\ TP}{kg\ carp}\ = 500{,}000\text{ g TP (500kg or 1102 pounds TP)}$$

Estimated Loads from Carp Excretions and Bioturbation

A literature review was completed by Tetra Tech to determine a range of TP loadings from carp nutrient-pump excretions and bioturbation and is attached as **Appendix E**. Highlights from the literature review are provided below.

Phosphorus loading from excretion assumes carp are feeding extensively on bottom sediments, providing a new source of phosphorus to the overlying water column. Excretion rates decrease with carp size; largely due to decreased growth rates based on size, feeding habits and diet shifts. Assuming carp are located in the upper portion of Lake Spokane, which equates to 1,024 hectares (ha) (2,530 acres), excretion rates would be between 8 and 30 kg/day of phosphorus, based upon the literature review. This assumes a carp density ranging from 60 kg/ha (8 kg/day) to 250 kg/ha (30 kg/day). Based upon the results of the Phase I Analysis, Lake Spokane's carp density is likely closer to the 60 kg/ha (8 kg/day) loading factor. For perspective, external loading during June through October, the period of algal growth and abundance, was about 100 kg/day in 2014, as was loading estimated from sediment release in the riverine and transition zones.

Bioturbation is the result of feeding activities, where carp root around into the sediment up to 5 inches in depth. This suspends particulate sediment phosphorus which may be released as soluble phosphorus (a form of phosphorus more biologically available to plants and algae) to the overlying water column. Bioturbation could be slightly more significant than excretion, with a loading estimate ranging from 42 to 147 kg/day, especially given the average size of carp in Lake Spokane (4 kg). However, given the carp density in Lake Spokane is likely closer to 60 kg/ha, the loading from bioturbation is likely closer to the 42 kg/day (assuming particulate phosphorus is bioavailable).

It should be noted that while we evaluated loading estimates, phosphorus concentration is likely more important than loading. The inflow concentration from external loading averaged only 11.5 µg/L in 2014, while sediment released phosphorus from carp bioturbation and/or diffusion in shallow water would likely result in higher phosphorus water column concentrations producing denser algal blooms than the whole area estimate presented for the 1,024 ha.

To summarize, based upon the literature review, the density and area in which carp are inhabiting, phosphorus loading from carp excretion in Lake Spokane is estimated at 8 kg/day whereas loading from bioturbation is estimated at 42 kg/day.

Phase II Analysis

A Phase II Analysis, included as **Appendix C**, was completed (Horner 2015) which evaluates the feasibility of carp harvesting methods providing the technical and economical practicality for each removal method, and the expected reduction in phosphorus mass for Lake Spokane. The carp harvesting methods evaluated included a combination of chemical (ex. Rotenone), biological (ex. disrupting carp recruitment, predation of carp juveniles and eggs), and mechanical controls (ex. nets, electrofishing, and angling). The results of this evaluation indicate the most biologically effective and cost efficient methods of removing carp in Lake Spokane appear to be a combination of several mechanical methods including, but not limited to, spring electrofishing, passive netting (trap, trammel, or gill nets), winter seining as described below (Horner 2015).

Winter Seining

Winter aggregations of carp in Lake Spokane may provide an opportunity to harvest large numbers of carp (potentially 10,000 or more) in a relatively short amount of time with commercial seining gear. However, this effort should be guided by good telemetry data and a site visit from a commercial fisherman to determine both the feasibility and logistics of the effort. Lake Spokane is unlikely to get thick enough ice for long enough, so boat seining will be required. Boats could be equipped with hydraulic winches to pull the nets and the seines can be bagged either from operating off the shore, or from anchored boats. Typical seine hauls from Midwest lakes can result in hundreds of thousands of pounds of fish, so efficient transferring of fish from the net to trucks is essential. Shoreline access for removing carp from the seine with a tractor mounted dip net and transferring carp to trucks with a conveyor belt is desired, but not essential. The biggest limitation to an efficient commercial seining operation is identifying the presence of aggregated carp and ensuring a snag free bottom. A typical seining operation would take two large boats and a minimum crew of 5-6 experienced people. The potential bycatch of other fish species during a winter seining operation in Lake Spokane is unknown, but live release of non-target species is common. Assuming 10,000 carp were removed with this method this would equate to approximately 200 kg TP (441 lbs TP).

Spring Electrofishing

Carp were vulnerable to electrofishing during spring spawning, but catch rates were highly variable (mean CPUE of 44 carp/hr and range of 3 carp/hr to146 carp/hr). Larger diameter dip nets and focusing efforts on carp concentrations will improve catch rates of carp, as compared to the 2014 marking effort. Assuming that a four person crew could achieve an average CPUE of 50 carp/hr and a fishing time of 8 hr/day, it is anticipated a minimum of 400 carp could be captured daily. If the electrofishing crew fished during the peak two weeks of the spawning season (middle two weeks in June), an estimate 4,000 to 5,000 carp, or 16,000-20,000 kg of carp could be removed with one four person crew. This would equate to approximately 80 to 100 kg TP (176 to 220 lbs TP).

The bycatch of game fish species was relatively low during the June 2014 electrofishing marking event. A few largemouth bass, smallmouth bass, walleye, black crappie, yellow perch and black bullhead were captured, but all were released alive. The shallow, turbid, weedy areas where carp prefer to spawn do not appear to be preferred habitat for game fish species. Spring electrofishing would be a good selective removal technique with minimal effects on game fish species.

Bycatch of adult largescale suckers was high, with numbers of suckers captured equal to or greater than the capture of carp. Adult tench were also encountered while electrofishing, but in far fewer numbers than carp or suckers. If WDFW approved removing adult largescale suckers and tench encountered during spring electrofishing for carp, the total biomass of fish removed for phosphorus reduction would increase significantly. If approved, suckers and tench would be analyzed for phosphorus content to determine the overall benefit in TP removal.

Passive Netting

Passive netting could include gill nets, trammel nets and different types of trap nets (hoop and fyke nets). Depths for setting passive gear should be guided by sonar locations of fish concentrations associated with known telemetry “hot spots”. The most efficient use of passive netting may be to strategically place gill or trammel nets in shallow spawning areas while simultaneously electrofishing. Carp are notorious for avoiding passive gear once they have encountered it. CPUE could be enhanced due to the relatively turbid water where carp are actively spawning, constantly moving carp, and the effect of electrofishing activity driving carp into the nets. The same electrofishing crew could periodically check the nets reducing personnel needs. Gill or trammel nets could also be set in likely spawning areas prior to active spawning (starting in May) when weed beds are not as dense. The use of gill and/or trammel nets in conjunction with spring electrofishing could double the estimated 4,000-5,000 capture of carp from electrofishing alone during the spring spawning period. Assuming 4,000 to 5,000 carp were removed with this method this would equate to approximately 80 to 100 kg TP (176 to 220 lbs TP).

Due to the tangling issue of carp dorsal and anal spines in the fine mesh portion of trammel nets and the increased effort it would take to remove carp, gill nets of the correct mesh size and monofilament diameter would be preferred over trammel nets. Bycatch of game fish species would increase with the use of gill and trammel nets. Netting within the boundaries of the weedy, turbid carp spawning beds and when daylight electrofishing operations are occurring should reduce bycatch of game fish species.

Avista estimates the combination of these efforts could capture from 10,000 to 20,000 carp. Based upon data obtained in 2014, the average carp weighs 4 kg/fish with about 5 g of TP/kg carp (wet weight), removing 10,000 to 20,000 carp would equate to removing approximately 200 to 400 kg (440 to 882 lbs) of TP from Lake Spokane. If largescale suckers can be added to the total biomass of fish removed, the amount of TP would increase. Removal of carp would also reduce bioturbation and resuspension of TP in sediments as discussed in the previous Section, *Estimated Loads from Carp Excretions and Bioturbation.*

These methods appear to provide the greatest chance of achieving the objective of removing carp from Lake Spokane with minimal impacts to non-target species. As such, Avista recommends implementing a series of pilot study efforts utilizing a combination of these mechanical methods in order to identify which is the most effective to remove carp from Lake Spokane.

Avista will work with Ecology and WDFW during the planning of these pilot efforts and will obtain all required permits prior to implementation.

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). Avista evaluated whether harvesting of these aquatic weeds, prior to their senescence, could prevent a substantial load of phosphorus from being released back into the water column, as well as prevent the reduction of dissolved oxygen through the decomposition of these weeds. In order to evaluate this, 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 macrophytes in Lake Spokane at senescence, would not be a reasonable and feasible mitigation measure to reduce 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 Lake Spokane. Avista may also, through adaptive management, reassess opportunities to harvest macrophytes to control phosphorus in the future.

3.2 2014 Implementation Measures

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

3.2.1 Wetlands

Avista acquired the 109 acre Sacheen Springs property, located on the west branch of the Little Spokane River. 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 Avista will pursue 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.

In addition, Avista and the Coeur d'Alene Tribe have acquired approximately 656 acres on upper Hangman Creek, 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 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 3,700 native tree and shrub species have been planted on this wetland complex.

3.2.2 Land Protection

Avista has identified approximately 215 acres of land that is currently used for grazing under lease from Washington State Department of Natural Resources (DNR). This land is located within the south half of Section 16 in Township 27 North, Rand 40 E.W. M. in Stevens County. Avista will continue pursuing a lease for the 215 acres of land from DNR with the intent of placing the land in conservation use.

In addition, 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. During 2014 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.

3.2.3 Rainbow Trout Stocking

Avista stocked 155,000 triploid rainbow trout (approximately six inches in length) in Lake Spokane during June 2014 as part of a FERC License requirement. Initial reports from fisherman indicated the stocked fish were on average 14 inches long with some as long as 16 inches by late fall 2014.

3.2.4 Bulkhead Removal

During 2014, Avista continued to work with the Stevens County Conservation District (SCCD) to plan and permit a design for an additional bulkhead removal project on an Avista-owned shoreline parcel located in TumTum. The project would consist of replacing of an approximate 90 foot bulkhead with native rocks and vegetation to provide a more naturalized shoreline. We anticipate this project taking place during winter 2015/2016, after all permits have been obtained and when the lake is drawn down.

3.2.5 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 2014, 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.

In addition, during 2014 Avista managed a booth at the Northern Idaho/Eastern Washington Annual Lakes Conference to provide education materials for lakeshore owners and community members.

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

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[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.

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.

- **Wetlands**
  Given Avista is in the initial stages of implementing site-specific wetland management plans for the Sacheen Springs and Hangman Creek properties, along with the lack of trading ratios associated with the DO TMDL, Avista is currently unable to quantify a TP load reduction for these properties. Avista will more thoroughly evaluate TP reduction once the site-specific wetland management plans have had a few years of implementation.

- **Land Protection**
  Avista will continue pursuing leasing the 215 acres of land from DNR with the intent of placing the land in conservation use. Once this has been completed, Avista will provide a quantification of the estimated TP loading removed from eliminating, or limiting, grazing activities.

  In addition, 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. During 2014 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 TP load reduction of the 200-foot buffer of the Avista owned Lake Spokane shoreline in the downstream portion of the reservoir along with the quantification of TP load reduction from the wetland/restoration enhancements as these two activities should create similar sediment-filtering effects.

- **Carp**
  If Avista is allowed to remove carp from the lake it will quantify the associated TP reduction based upon the results of the Phase I Analysis as well as any new information pertaining to loading estimates for Lake Spokane.

5.0 PROPOSED ACTIVITIES FOR 2015

The following activities are proposed for implementation in 2015.

- **Carp**

  Avista proposes to conduct carp removal activities in Lake Spokane utilizing several different methods, such as spring electrofishing, passive netting and winter seining. These methods will be evaluated for their effectiveness.

- **Habitat Evaluation**

  Avista will continue to stock 155,000 triploid rainbow trout (approximately six inches in length) in Lake Spokane on an annual basis. Initial responses to the program indicate it is successful and the stocked trout are doing well. This program will assist Avista, Ecology and WDFW in the ongoing effort to evaluate suitable salmonid habitat in Lake Spokane. Additionally, Avista and WDFW will evaluate the success of the stocking program after ten years of implementation.

- **Wetlands**

  Avista will continue to implement site-specific wetland management plans for the Sacheen Springs and Hangman Creek properties.

  Additionally, Avista will continue to work with the SCCD to plan the placement of a floating treatment wetland in Lake Spokane. The purpose of the floating treatment wetland would be for wave attenuation outside a community swim area as well as potential TP removal.

- **Native Tree Planting**

  Avista and the SCCD anticipate planting native tree species along Lake Spokane's shoreline on Avista-owned property in 2015. The tree planting will completed as part of the Long Lake Dam Reservoir and Tailrace Temperature Water Quality Attainment Plan. Once mature, the trees will help reduce water temperature and improve habitat along the lake shoreline.

- **Land Protection**

  Continue to pursue the 215 acre lease of land from DNR with the intent of placing the land in conservation use. Avista will also continue to protect the 200-foot buffer of Avista-owned shoreline located in the lower portion of the reservoir.

- **Bulkhead Removal**

  During the 2015/2016 winter, once all permits have been obtained, Avista will work with the SCCD to replace approximately 90 feet bulkhead with a more natural shoreline on the Avista-owned shoreline parcel in TumTum.

- **Education**

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

6.0 SCHEDULE

The implementation schedule, as presented in **Figure 3**, incorporates several benchmarks and decision points important in implementing the DO WQAP. Benchmarks and important milestones completed to date, and extending into 2017 include the following.

In addition, Avista and Ecology discussed the possibility of revising the overall compliance schedule to better sync it with the DO TMDL compliance schedule. As such, Avista plans to work with Ecology this year to reassess the compliance schedule and to revise it accordingly.

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 16-miles of Avista-owned shoreline.
- 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.
- 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)

- Will submit the 2014 DO WQAP Annual Summary Report to Ecology and FERC by February 1 and April 1, respectively.
- Will conduct the baseline nutrient monitoring in Lake Spokane (May through October). Following monitoring, will evaluate the results and success of monitoring baseline nutrient conditions in Lake Spokane and work with Ecology to define future monitoring goals for the lake.
- Will initiate carp removal activities.

- If obtain permits and drawdown, will begin the TumTum bulkhead replacement project.
- Will stock 155,000 triploid rainbow trout in Lake Spokane.
- Will continue to implement site specific wetland plans on the Sacheen Springs and Hangman Creek properties.
- Protected approximately 16-miles of Avista-owned shoreline.
- Will plant trees along Lake Spokane shoreline.

2016 (Year 4)

- Will submit the 2015 DO WQAP Annual Summary Report to Ecology and FERC by February 1 and April 1, respectively.
- May conduct the baseline nutrient monitoring in Lake Spokane (May through October), dependent upon 2015 evaluation of monitoring program.
- Will complete other mitigation measures as proposed in previous years Annual Summary Report.
- Will discuss the CE-QUAL Model with Ecology.

2017 (Year 5)

- Will submit the 2016 DO WQAP Annual Summary Report to Ecology and FERC by February 1 and April 1, respectively.
- May conduct the baseline nutrient monitoring in Lake Spokane (May through October), dependent upon 2015 evaluation of monitoring program.
- Will complete other mitigation measures as proposed in previous years Annual Summary Report.
- Will discuss the CE-QUAL Model with Ecology.

7.0 REFERENCES

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TetraTech. 2015b. Technical Memorandum, Literature Review of Phosphorus Loading from Carp Excretion and Bioturbation & Phosphorus Loading Estimates for Lake Spokane Carp. January.

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FIGURES

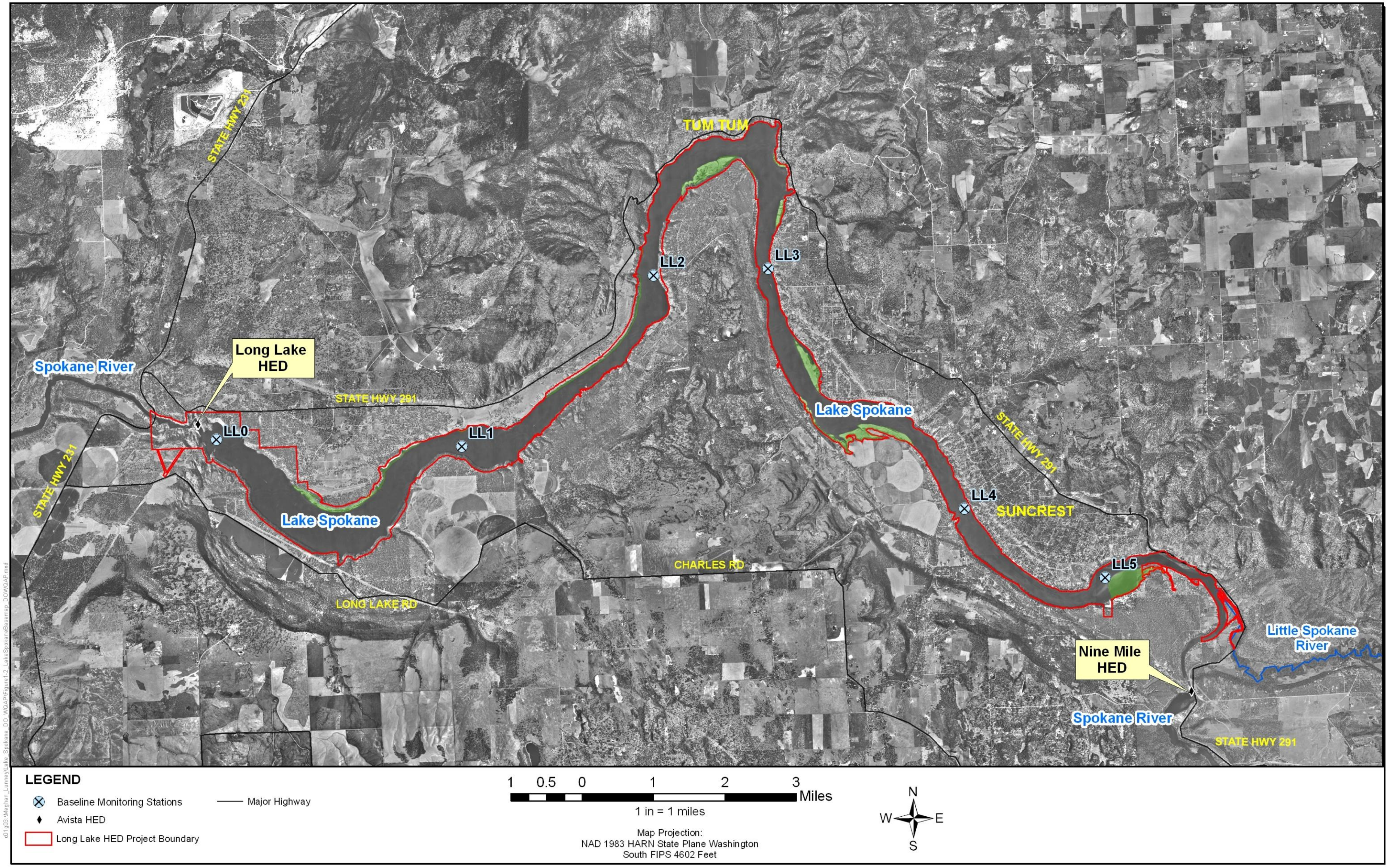

Figure 1. Lake Spokane Baseline Monitoring Stations

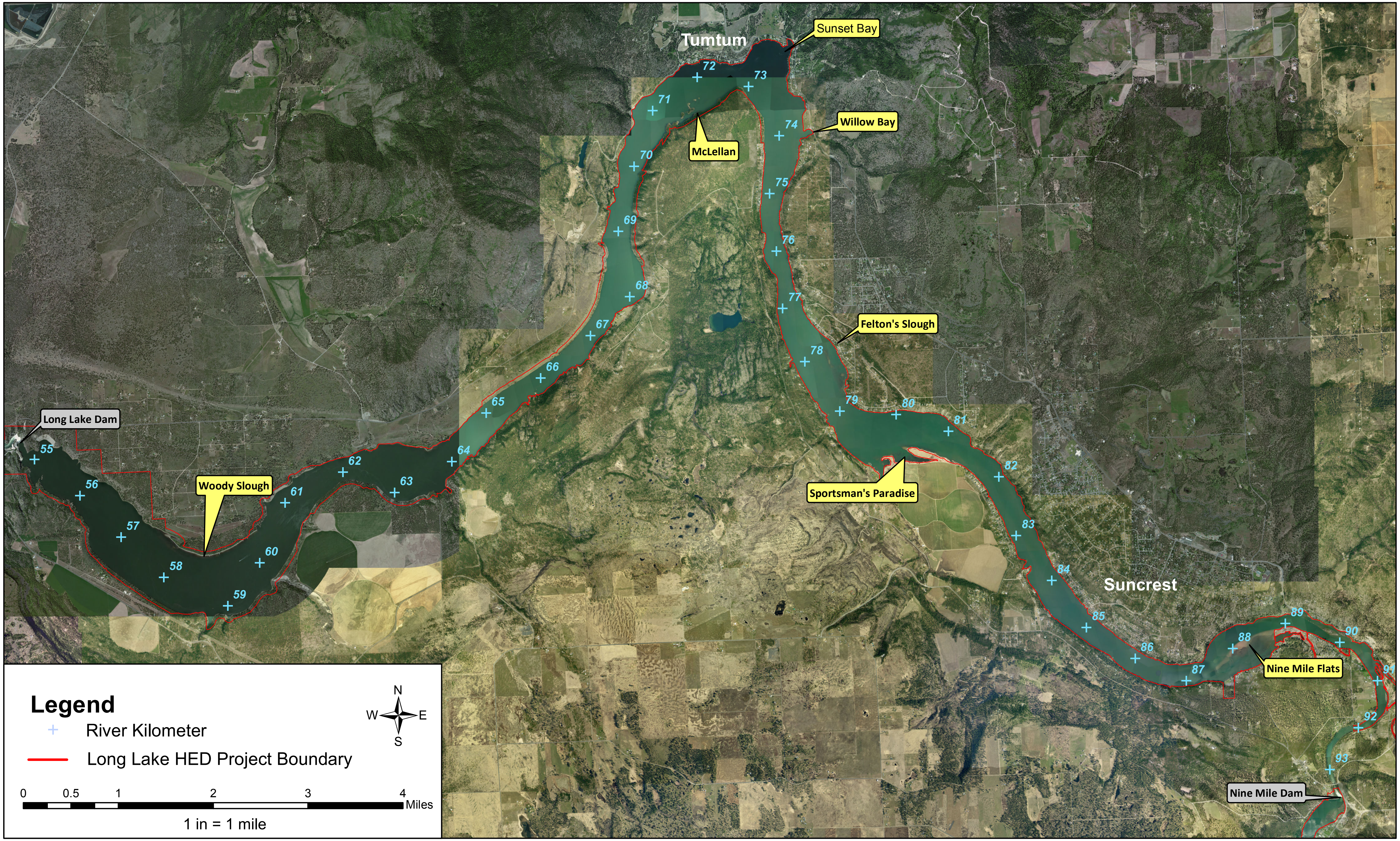

Figure 2. Lake Spokane Carp Study Vicinity Map

		Implementation Year[1]																																									
						Year 1				Year 2				Year 3				Year 4				Year 5				Year 6				Year 7				Year 8				Year 9				Year 10			
		2012				2013				2014				2015				2016				2017				2018				2019				2020				2021				2022			
Activity		Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	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	x	x	x	x																								
	If implemented, monitor for nutrient reductions															x	x			x	x			x	x			x	x			x	x			x	x			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			x	x			x	x			x	x			x	x			x	x			x	x				
	If implemented, monitor for nutrient reductions											x	x			x	x			x	x			x	x			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			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	x	x	x	x	x	x	x	x				
Monitoring & Modeling	Baseline Monitoring[4]		x	x	x		x	x	x		x	x	x		x	x	x		x	x	x																								
	Ongoing Habitat Analysis[5]										x	x			x	x			x	x			x	x			x	x			x	x			x	x			x	x					
	Site Specific Nutrient Reduction Analysis[6]																																												
	CE-QUAL Modeling																				x	x											x	x						x	x	x			
Compliance Reporting	DO WQAP Annual Summary Report*									x				x				x								x				x								x							
	Five, Eight, and Ten-Year Reports*																					x												x								x			

Notes:

(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.

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

APPENDICES

APPENDIX A

2014 Baseline Water Quality Monitoring Results (TetraTech 2015a)

LAKE SPOKANE ANNUAL SUMMARY REPORT

2014 Baseline Water Quality Monitoring Results

Prepared for

AVISTA

SPOKANE, WASHINGTON

PREPARED BY:

Tetra Tech, Inc.

316 W. Boone Avenue, Suite 363
Spokane, WA 99201

May 2015

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ACRONYMS AND ABBREVIATIONS

µg/L	micrograms per liter
µS/cm	micro Siemens per centimeter
AHOD	areal hypolimnetic oxygen deficit
Avista	Avista Utilities
chl	chlorophyll a
DNR	Department of Natural Resources
DO	dissolved oxygen
Ecology	Washington Department of Ecology
EWU	Eastern Washington University
HED	Hydroelectric Development
N	nitrogen
N+P	nitrogen plus phosphorus
ND	non-detect
NO_3+NO_2	Nitrate+nitrite
P	phosphorus
QAPP	Quality Assurance Project Plan
RM	river mile
SRP	soluble reactive phosphorus
TMDL	total maximum daily load
TN	total nitrogen or total persulfate nitrogen
TN:TP	total nitrogen to total phosphorus ratio
TP	total phosphorus
TSI	trophic state index

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1. INTRODUCTION

Water quality problems in Lake Spokane due to eutrophication have been investigated on several occasions since the 1960s. Studies by the Washington Department of Ecology (Ecology) and Eastern Washington University (EWU) provided much of the background data for a waste allocation analysis by Harper-Owes in the 1980s (Patmont 1987). The EWU studies defined the extent of algal blooms and hypolimnetic anoxia, which led to phosphorus removal (85%) from the City of Spokane wastewater starting in 1977. That phosphorus removal greatly improved water quality in the reservoir. During the 1970s to 1980s, the EWU group, headed by Dr. R.A. Soltero, produced 14 reports documenting water quality problems before and after wastewater phosphorus removal. This work showed the direct links between phosphorus input and algal blooms on the one hand, and the effect of that algal production on reservoir dissolved oxygen (DO) on the other (Soltero et al. 1982).

The degree of water quality improvement that occurred in the past is important to recognize in assessing the reservoir's water quality today. For example, chlorophyll a (chl) decreased from an average of 20.5 micrograms per liter (µg/L) before phosphorus removal (5 years of data) to 11.1 µg/L after (7 years of data). Minimum hypolimnetic DO increased from an average of 1.4 mg/L before (5 years of data) to 3.6 mg/L after (7 years of data) (Patmont 1987).

Improvement in water quality continued during the subsequent 15 to 20 years; minimum DO has nearly doubled and chl has about halved. These improvements were probably attained during the 1990s. These long-term improvements will be discussed in perspective with current water quality conditions determined in 2014.

This report describes the monitoring effort by Tetra Tech in 2014 that includes *in situ* profiles of temperature, DO, pH, and conductivity, as well as, discrete sampling for nutrients, chl, phytoplankton and net zooplankton.

1.1. Report Purpose

Avista Corporation (Avista) owns and operates the Long Lake Hydroelectric Development (HED) on the Spokane River. Long Lake Dam created a reservoir, Lake Spokane, in a 23-mile stretch of the Spokane River that was, at one time, free flowing. Portions of the river, including Lake Spokane, experience seasonal patterns in DO concentrations, some of which do not meet Washington State's water quality standards.

Table 1 lists the state water quality criteria for dissolved oxygen that apply to the Spokane River and Lake Spokane. In addition, the Spokane River has the following specific water quality criteria, per WAC 173-201A-130, from Long Lake Dam (RM 33.9) to Nine Mile Bridge (RM 58.0), which encompasses all of Lake Spokane:

> The average euphotic zone concentration of total phosphorus (TP) shall not exceed 25 µg/L during the period of June 1 to October 31.

Table 1. Designated Aquatic Life Uses and DO Criteria for the Spokane River as Defined in the 2006 Water Quality Standards.

Portion of the Waterbody	Aquatic Life Uses	DO Criteria
Spokane River (from Nine Mile Bridge to the Idaho Border)	Migration/Rearing/Spawning	DO shall exceed 8.0 mg/L. If "natural conditions"[a] are less than the criteria, the natural conditions shall constitute the water quality criteria.
Lake Spokane (from Long Lake Dam to Nine Mile Bridge)	Core Summer Habitat	No measurable (0.2 mg/L) decrease from natural conditions.

[a]Washington water quality standards (WAC 173-201A-020) defines "natural conditions" or "natural background levels" as "surface water quality that was present before any human-caused pollution. When estimating natural conditions in the headwaters of a disturbed watershed, it may be necessary to use the less disturbed conditions of a neighboring or similar watershed as a reference condition."

Ecology has been working, along with several stakeholders, to address these impairments through the development and implementation of a water quality improvement plan, or Spokane River and Lake Spokane Dissolved Oxygen Total Maximum Daily Load (DO TMDL) (Ecology 2010).

The DO TMDL relies on the CE-QUAL-W2 hydrodynamic and water quality modeling to assess the capacity of the Spokane River and Lake Spokane to assimilate oxygen-demanding pollutants (i.e., phosphorus, carbonaceous biological oxygen demand, and ammonia) under varying conditions (DO TMDL, page vi). Unlike point- and non-point source discharges, since Avista does not discharge nutrients to either the Spokane River or Lake Spokane it was not assigned a wasteload allocation or a load allocation. However, since the presence of the Long Lake HED increases the residence time (average amount of time it takes water to flow through Lake Spokane) the DO TMDL assigned Avista a "proportional level of responsibility" for depressed DO levels in Lake Spokane through a water quality modeling scenario. This responsibility is reflected in Table 7 of the DO TMDL, which was subsequently corrected (Ecology 2010e; Appendix B). Table 7 in the TMDL is based on a comparison of CE-QUAL-W2 model runs for the 2001 model year.

Ecology, with Avista, conducted a 2-year baseline sample collection effort that began in May 2010 and extended through October 2011 at six lake stations and two river stations. The main purpose was to gather more recent data to verify the baseline water quality conditions in 2001, which were used in the TMDL development process, and to account for any changes in water quality in the lake. Ecology and Avista collaborated on a monthly sampling routine extending from June through September in 2010 and 2011 in order to expand the frequency of observations at the six lake monitoring stations. To do that, Avista contracted with Tetra Tech.

Beginning in 2012, Avista took over monitoring of the six lake stations in Lake Spokane and will continue that effort until 2016. Ecology will continue to provide water quality data for the three river stations (54A090, 55B070, and 54A070). In 2016, Avista will evaluate the results and success of monitoring baseline nutrient conditions in Lake Spokane and will work with Ecology to define future monitoring goals for the lake. This may include assessing whether the monitoring parameters, locations, duration, and frequency should be modified.

2. MONITORING PROGRAM

Water quality samples were collected and *in situ* profiles were determined once per month in May and October and twice per month from June through September 2014 at the six in-lake locations (LL0, LL1, LL2, LL3, LL4, and LL5) (Figure 1). Station LL0 is located farthest downstream in the reservoir with a depth of 48-50 m. Station LL1 is located across from the Lake Spokane Campground and Boat Launch (formerly operated by the Department of Natural Resources (DNR)) at a depth of about 34 m. Station LL2 is down-reservoir from the City of TumTum and Sunset Bay at a depth of about 26 m. Station LL3 is just up-reservoir from Willow Bay at a depth of about 19-20 m. Station LL4 is across from Suncrest Park and boat launch at about 9 m depth. Station LL5 is the farthest up-reservoir, slightly up-reservoir from the Nine Mile Recreation Area on the north side of the river at about 6 m depth.

Longitudinally, the reservoir can be divided into three zones representing varying morphometric characteristics. The upper portion of the reservoir is considered to be the riverine zone where depths are shallow and the reservoir has morphological characteristics similar to a large river. Station LL5 is within this riverine zone. Stations LL4 and LL3 are located within the transition zone of the reservoir, where the reservoir is changing from a riverine environment to a more lacustrine environment. Within the transition zone, depths are greater than in the riverine zone but the littoral areas are still similar to that seen in the riverine zone. Station LL3 is approximately 19-20 m deep and has a very small hypolimnion during stratification. Stations LL0, LL1, and LL2 are located in the lacustrine zone of the reservoir where there is both littoral and pelagic (shallow and deep water) environments. Water depths in the lacustrine zone are much deeper than the rest of the reservoir and stratifies into three layers; the epilimnion, metalimnion, and hypolimnion.

The vertical structure of Lake Spokane is set up by thermal stratification, largely determined by its inflow rates and temperature, change in storage, climate, 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 contains the thermocline and is the transition layer between the epilimnion and the hypolimnion that is influenced by both surface and interflow inflows. The hypolimnion is the deepest layer and is present throughout the lacustrine zone.

The 2014 sampling schedule is summarized in Table 2. Discrete depth samples were collected at each lake sampling location (see Table 3) and were shipped to Aquatic Research Inc. for analyses. In 2013 an additional sample depth at Station LL4 was added at 4 m. This additional depth was also sampled in 2014. Analyses were for nitrate plus nitrite, total persulfate nitrogen (TN), soluble reactive phosphorus (SRP), total phosphorus (TP), and chl. Samples were collected in accordance with methods and procedures outlined in Avista's *Quality Assurance Project Plan for Lake Spokane Baseline Nutrient Monitoring* (QAPP), which was approved by Ecology and submitted to FERC in February 2014. This QAPP is a revised version of an earlier QAPP written by Ecology for the 2010 and 2011 monitoring efforts and amended in 2012.

Water temperature, DO, pH, and conductivity were determined *in situ* at each of the six sampling locations by lowering a Hydrolab® multi-parameter water quality meter from the boat. The *in situ* measurements were determined at prescribed depths through the water column. The measurements were determined in accordance with the methods and procedures outlined in the QAPP (Tetra Tech 2014). The water quality meter was calibrated according to manufacturer's directions and standard measurement procedures were followed.

Volume-weighted DO and TP concentrations for each station were determined for sampling dates using CE-QUAL-W2 model segment volumes, which corresponded to 2014 monitoring stations. Volumes for model segments were obtained from Avista and Golder Associates. The monitoring stations correspond to model segments as follows:

- Station LL0: Model Segment 188, Reservoir Zone: Lacustrine
- Station LL1: Model Segment 181, Reservoir Zone: Lacustrine
- Station LL2: Model Segment 175, Reservoir Zone: Lacustrine
- Station LL3: Model Segment 168, Reservoir Zone: Transition
- Station LL4: Model Segment 161, Reservoir Zone: Transition
- Station LL5: Model Segment 157, Reservoir Zone: Riverine

Water samples for phytoplankton were collected at 0.5 m depth at each of the six sampling locations. These samples provided information on phytoplankton dynamics seasonally and also longitudinally at several locations throughout the reservoir. In 2014 during late July and late August, additional phytoplankton samples were collected at Stations LL0, LL1, and LL2 at depths of 5 and 15 m depths and 5 m at LL3. The additional samples allowed for further evaluation of the phytoplankton community composition and dynamics throughout the reservoir. Zooplankton were collected with a vertical haul at each of the six sampling locations from 1 m off the bottom through the water column. Both phytoplankton and zooplankton samples were sent to WATER Environmental Services, Inc. for analysis.

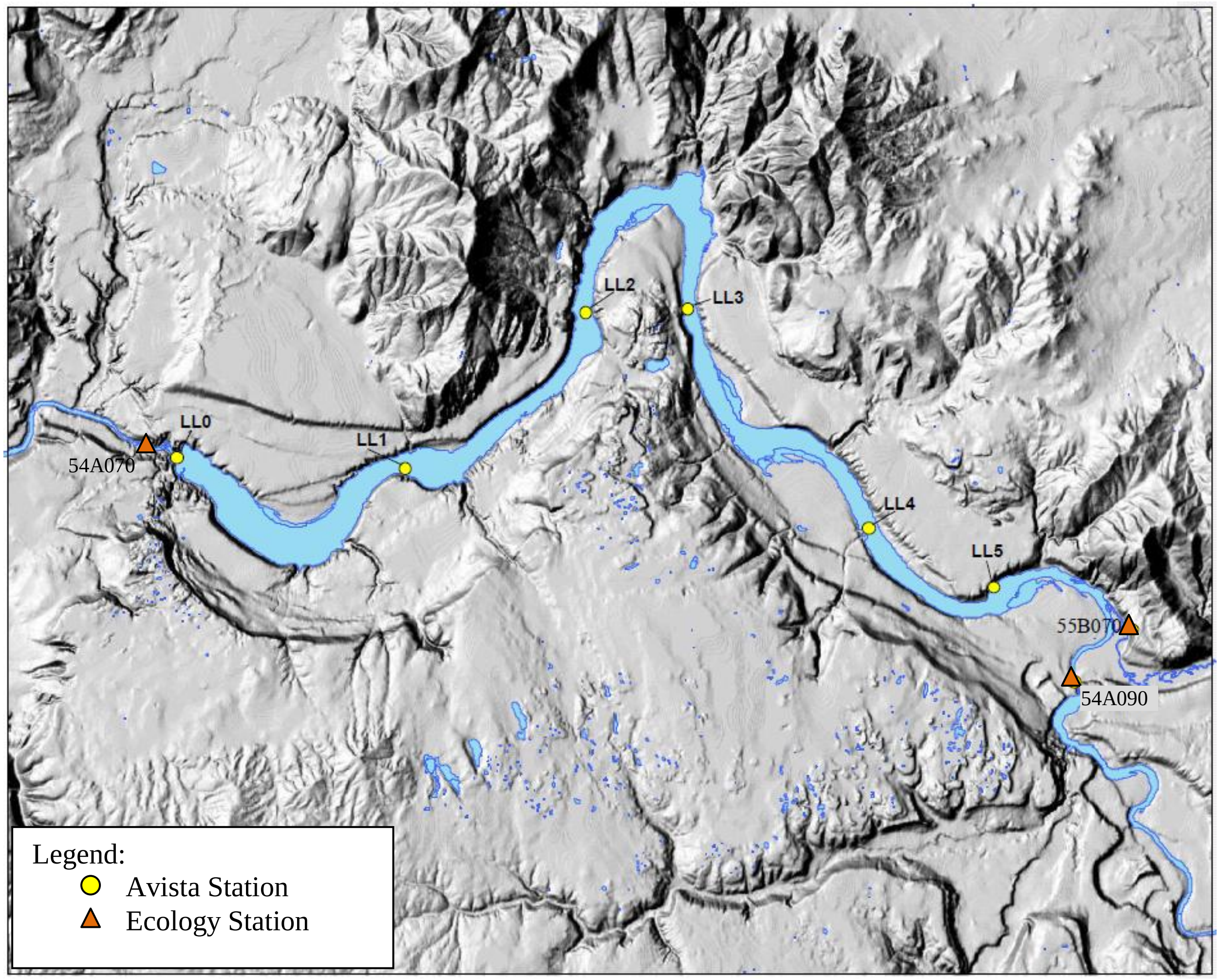

Figure 1. Lake Spokane Sampling Locations

Table 2. Lake Spokane Monitoring Schedule during 2014

Sample Date	Type of Samples Collected
May 14 – 15, 2014	Discrete Depth, *In situ*, Phytoplankton, and Zooplankton
June 10 – 11, 2014	
June 24 – 25, 2014	
July 8 – 9, 2014	
July 23 – 24, 2014	
August 5 – 6, 2014	
August 20 – 21, 2014	
September 9 – 10, 2014	
September 23 – 24, 2014	
October 14 – 15, 2014	

Table 3. Discrete Depth Samples for Stations Monitored in Lake Spokane during 2014$^{(1)}$

	LL0	LL1	LL2	LL3	LL4	LL5
Depths (m)	0.5	0.5	0.5	0.5	0.5	0.5
	5	5	5	5	4	B-1
	15	20	15	10	B-1	
	30	B-1	B-1	B-1		
	B-1					

(1) B-1 is 1 m off the bottom.

3. RESULTS

This section presents a summary of water quality constituents determined *in situ*, as well as nutrient, chl, phytoplankton, and zooplankton data from grab samples at discrete depths. The *in situ* data are presented in tabular form in Appendix I. All data from water samples collected in 2014 are presented in tabular form in Appendix II. Phytoplankton results are presented in Appendix III, and zooplankton results are in Appendix IV.

The section also presents a brief summary of the water quality conditions of the primary inflows and outflows to/from Lake Spokane as well as a description of general hydrologic and climatic conditions for 2014.

3.1 Hydrologic and Climatic Conditions

Weather conditions during 2014 varied slightly from the 30-year norms reported at Spokane International Airport, with cooler than normal temperatures in late winter, warmer than normal temperatures in May, July, August, September, and October, and below normal precipitation for most of the year. Temperatures ranged from a high of 100°F (37.8°C) on July 29 to a low of -5°F (-20.5°C) on February 6 as shown in Figure 2. The annual cumulative rainfall total was 14.99 inches (38.1 cm), which is well below the normal for the Spokane International Airport (Figure 2). The year began with drier than normal conditions which continued until the end of February. Precipitation in March was well above normal with a total of 2.88 inches (7.3 cm), which is 1.27 inches (3.2 cm) greater than normal. This is in contrast to early spring conditions in 2013 when March rainfall was only 0.82 inches (2.1 cm). June had above normal precipitation with the maximum recorded in one day; 1.01 inches (2.6 cm) on June 17. July was the driest month of the year with only 0.18 inches (0.46 cm) of precipitation. July was also the hottest month of the year with an average temperature of 75.7°F (24.3°C), which was the second hottest July on record. Several large and damaging wind storms occurred in August which brought much needed precipitation to the Inland Northwest. October was much warmer than normal with an average temperature of 53.3°F (11.8°C) which is 5°F (2.7°C) above the normal average temperature of 48.3°F (9.1°C). Temperatures at the Airport did not reach the freezing mark for the entire month of October, the first time since 2005. November started and ended with much warmer temperatures than normal but had a period of cold in the middle of the month when temperatures finally dropped below the freezing mark for the first time this year. Precipitation in November was well below normal. December was much like November with warmer and drier than normal conditions.

Figures 3 and 4 show inflows and outflows, respectively, for Lake Spokane during 2014.. Inflows include all incoming water as calculated by Avista using midnight to midnight lake elevation and day average outflow at midnight as recorded at Long Lake Dam. As expected, the inflows and outflows of Lake Spokane are very similar, with only slight differences occurring during the early part of the year during the annual drawdown. Maximum inflows in Lake Spokane typically occur during March, April, and May due to spring runoff. Peak flows in 2014 were significantly smaller than peak flows observed in 2011 and 2012, but slightly greater than peak flows in 2013 and much greater than peak flows in 2010 (Figure 5).

Both the Spokane River and the Little Spokane River had average to higher than average flows during March, April, and early May (Figures 6 and 7). The peak flow in the Spokane River occurred much earlier in the year than historically recorded (Figure 6). During the historical peak in May, flows in the Spokane River were very similar to average flows; however the peak flow in 2014 occurred in March and was well above the historical 90th percentile daily mean flow for that period (Figure 6). Flows in the Spokane River from the middle of May through the middle of June were slightly below average, while flows during the summer were also slightly below the historical median (Figure 6). Summer flows in the Little Spokane River, were also slightly below or very similar to the historical median (Figure 7).

Whole lake water residence time during June – October in Lake Spokane was relatively short, ranging from 14 to 37 days for the whole lake during 2010-2014 (Table 4). The average for the past five years was 25 days, slightly less than 29 days during 1972-1985. Residence times in the transition and riverine zones were much shorter, averaging 4.7 days (Table 3). Bloom development would be limited in these zones, especially in the spring, but are able to develop during low flow in August – September of most years. Table 5 provides inflows and water residence times in Lake Spokane during 2010-2014, however utilizes the seasonal timeframes consistent with the DO TMDL.

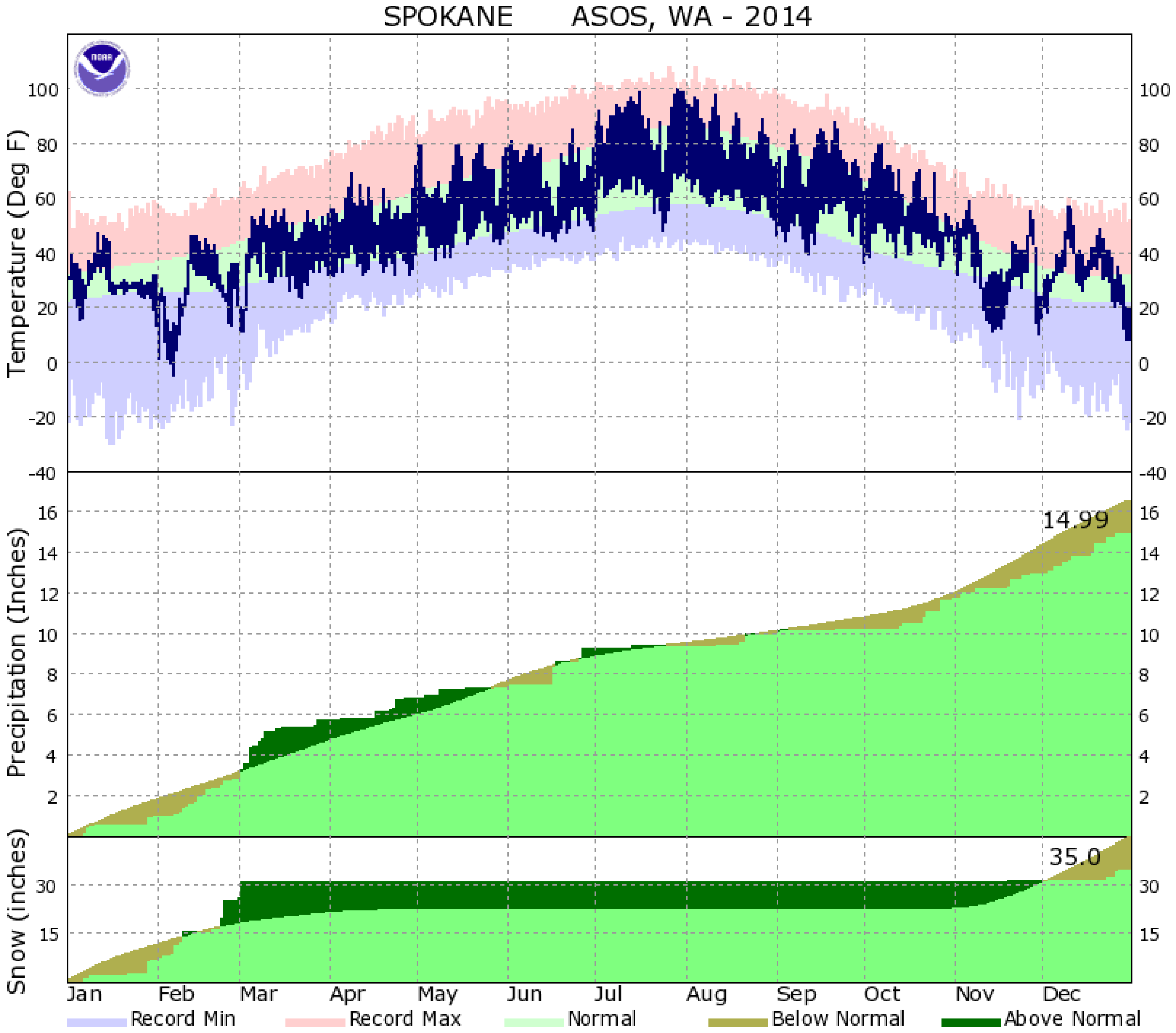

Figure 2. Temperature and Precipitation at Spokane International Airport for 2014

Table 4. Inflows and water residence times in Lake Spokane during 2010-2014

Year	Total Annual Flow Volume (cf x10^6)	Annual Mean Daily Flow (cfs)	Mean Daily Summer (June-Oct) Flow (cfs)	Residence Time[1] Whole Lake (June-Oct, days)	Residence Time[1] Transition/Riverine Zones (June-Oct, days)
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

[1] residence time = lake volume/outflow

Table 5. Daily flows and water residence times in Lake Spokane during 2010-2014, using DO TDML seasonal timeframes.

Year	Mean Daily Summer Flow (cfs)				Residence Time[1] Whole Lake (days)				Residence Time[1] Transition/Riverine Zones (days)			
	May	June	July – Sept.	Oct.	May	June	July – Sept.	Oct.	May	June	July– Sept.	Oct.
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

[1] residence time = lake volume/outflow

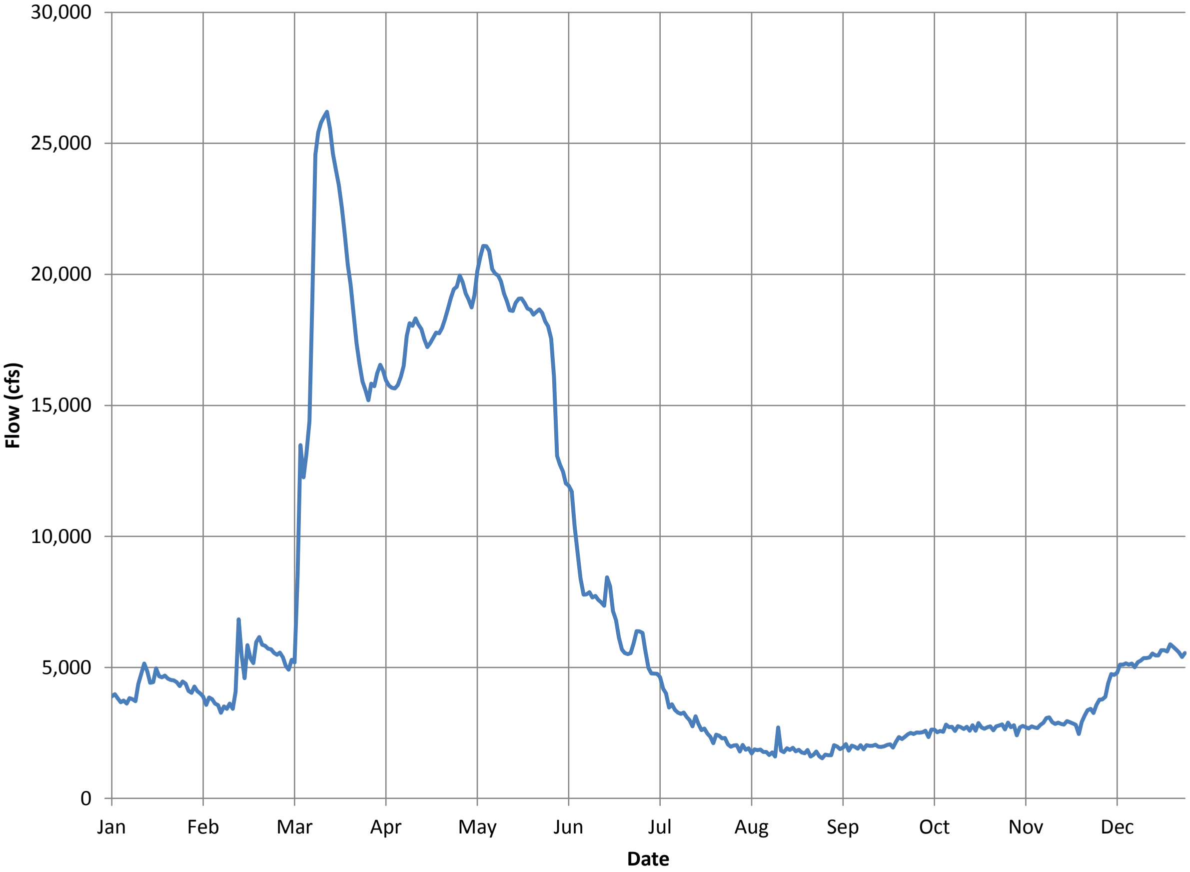

**Figure 3. Total Inflow into Lake Spokane, 2014
(Inflows calculated based on midnight to midnight lake elevation and day average outflow at midnight as recorded at Long Lake Dam)**

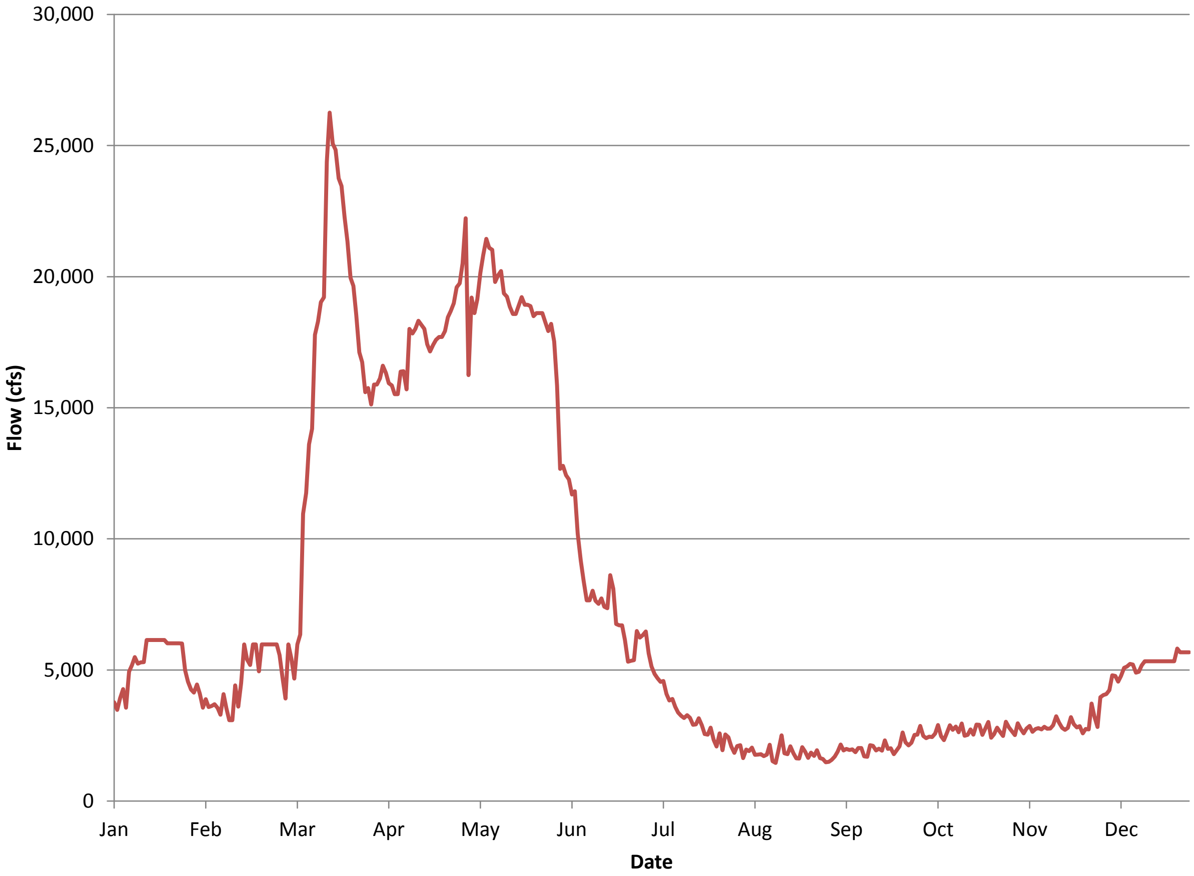

Figure 4. Total Outflow from Lake Spokane, 2014
(Outflows as reported at Long Lake Dam at midnight daily)

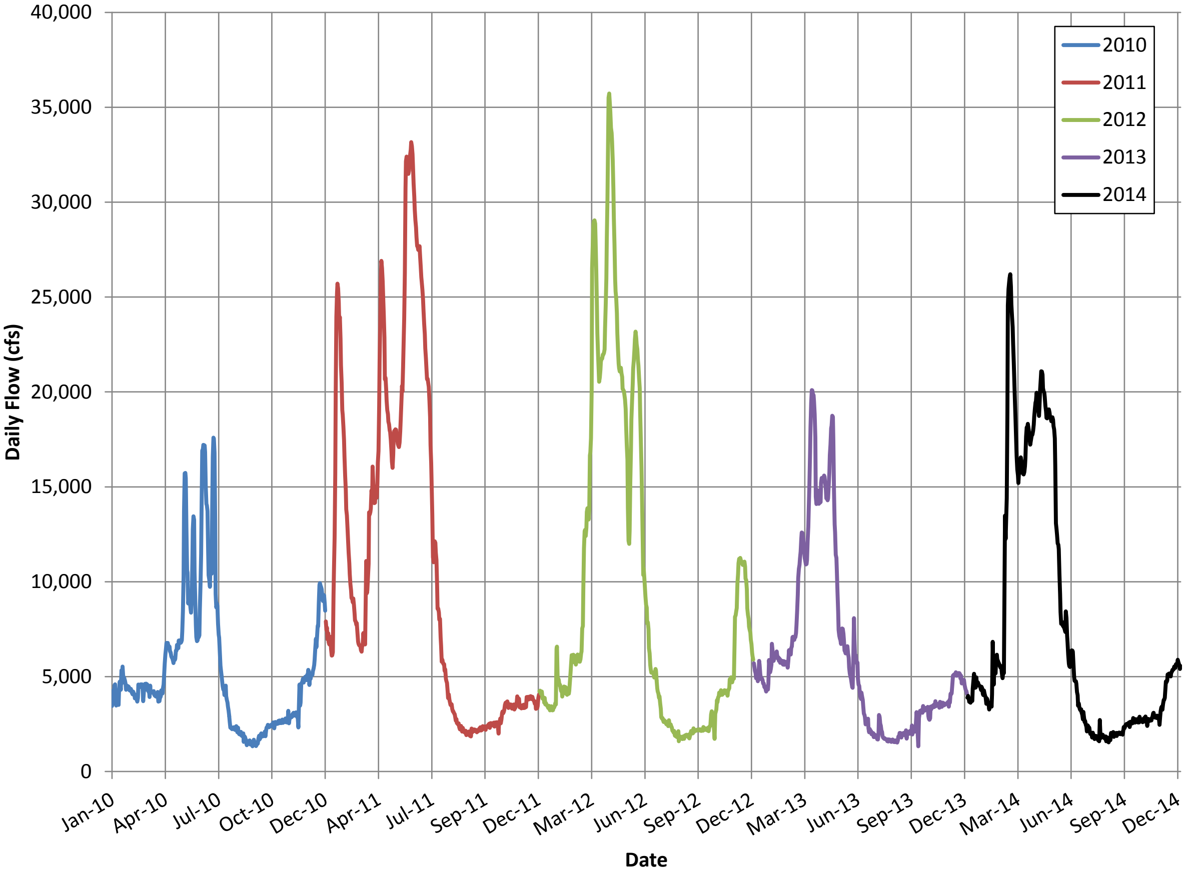

Figure 5. Total Inflows into Lake Spokane 2010-2014
(Inflows calculated based on midnight to midnight lake elevation and day average outflow at midnight as recorded at Long Lake Dam)

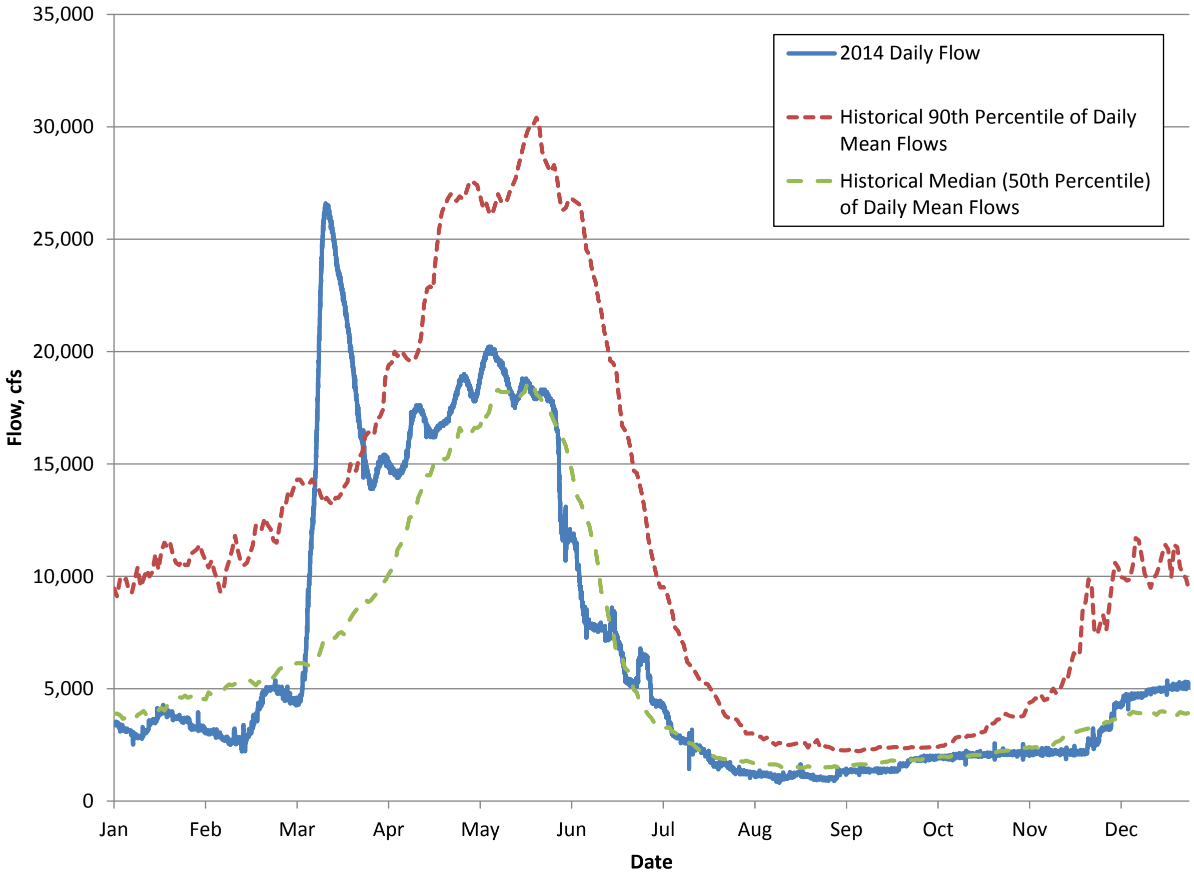

Figure 6. Spokane River at Spokane (USGS Gage # 12422500) Daily Flows, 2014 compared to Historical Daily Mean Flows

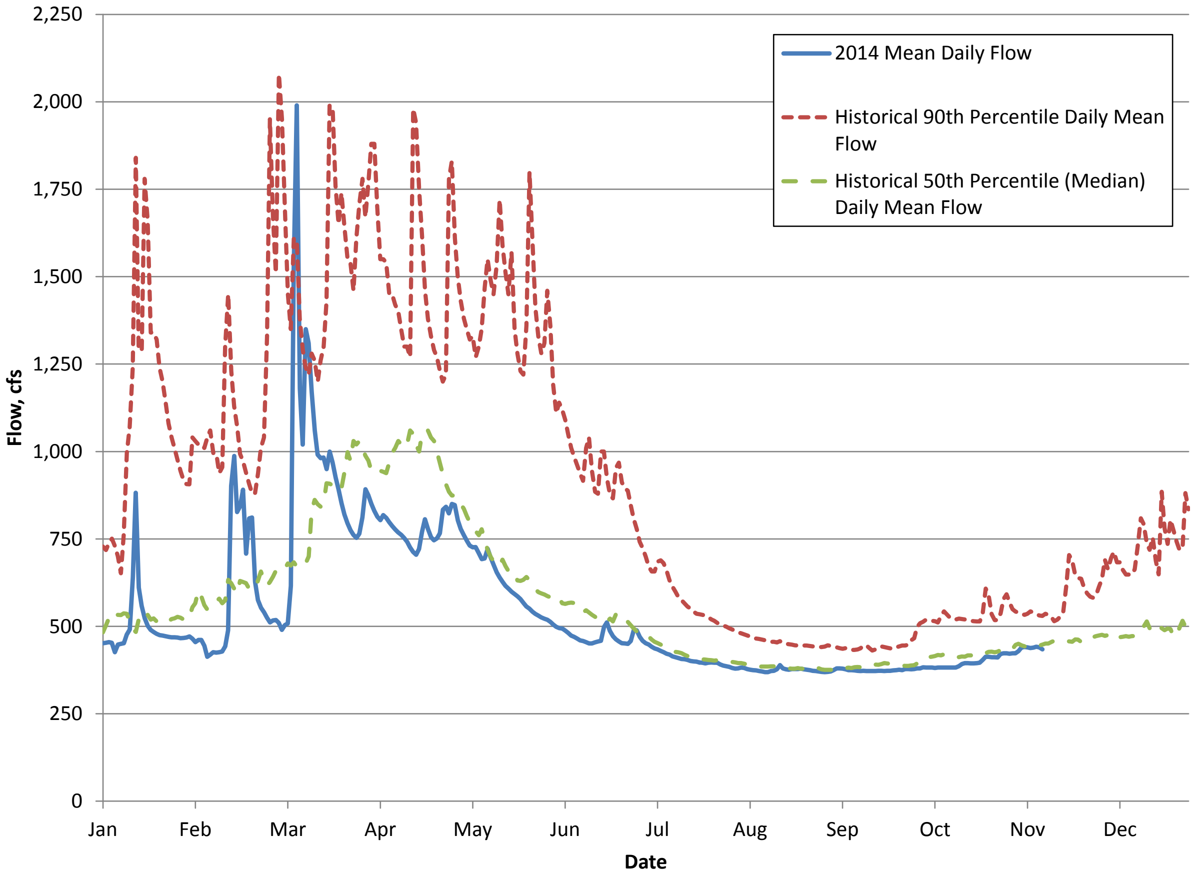

Figure 7. Little Spokane River near Dartford (USGS Gage # 12431500) Daily Flows, 2014 compared to Historical Daily Mean Flows (Data is through November 12th, 2014)

3.2 Water Quality Conditions

3.2.1 TEMPERATURE

The maximum temperature reached at the surface was 25°C in both the lacustrine zone and in the upper reservoir during August (Figures 8 through 13); the same maximums also occurred in 2013 but in July. Surface water was slightly cooler in July 2014. Temperature was usually at or below 20°C at depths greater than 10 m in the lacustrine zone during 2014, as in 2013.

Thermal stratification was evident in May during the first sampling event at stations LL0 and LL1, and weakly so at LL2. Temperatures near the bottom at these stations were higher than in 2013 (10.5 vs. 9°C). Complete mixing after winter stratification was more evident in 2014 than 2013 given temperature profiles were nearly vertical. Temperatures at the surface in May were cooler by about 2°C in 2014 than in 2013, which had an unseasonably warm spring. By the first sampling event in June, stratification had developed at all deep stations, but not at shallower LL4 and LL5. The water column at LL4 did not stratify until July. Some stratification occurred, briefly, during August at the shallowest station (LL5).

Depth of mixing in the surface layer, which defines the epilimnion, varied through the summer, being around 4 to 5 m at the three most down-reservoir stations with the exception of July when it deepened a few meters and then rose back to 4 to 5 m in August. The deepening in July may have been a response to windier conditions. Mixing depth did not increase again until October, except it deepened to 8 m at LL2 when surface water cooled in September. A similar pattern of rather shallow mixing depth occurred at stations LL3 and LL4 in July and August. Mixing depths at LL3 varied from 4 to 6 meters in July and August and remained so into October, similar to the pattern at LL2. Mixing depths at LL4 were more consistent over the summer at 3 to 4 meters.

The extent of the metalimnion and depth of the hypolimnion varied throughout the summer, which is typical in reservoirs that are strongly affected by river inflow and plunging interflows. The metalimnion is the layer with greatest temperature change with depth – typically 5 to 10 meters in Lake Spokane. Depth of the hypolimnion can be taken roughly at below the inflection point where rate of temperature change with depth begins to slow, - about 10 m during the summer months (Figures 8 through 10). For most dates the hypolimnion depth occurred at about 10 m, being shallower in June and deepening later in the summer. That variation is due to the river inflow plunging to different depths consistent with inflow density (temperature and conductivity). Conductivity profiles show the pattern of plunging inflows, which cause much of the temperature variation in the reservoir.

The water columns at stations LL0, LL1, and LL2 during the October sampling event were still slightly stratified. The deepening of the epilimnion at these stations in October indicates that the turnover process had begun. This pattern was similar to that observed in 2013; however surface temperatures in October 2014 were much warmer than in 2013.

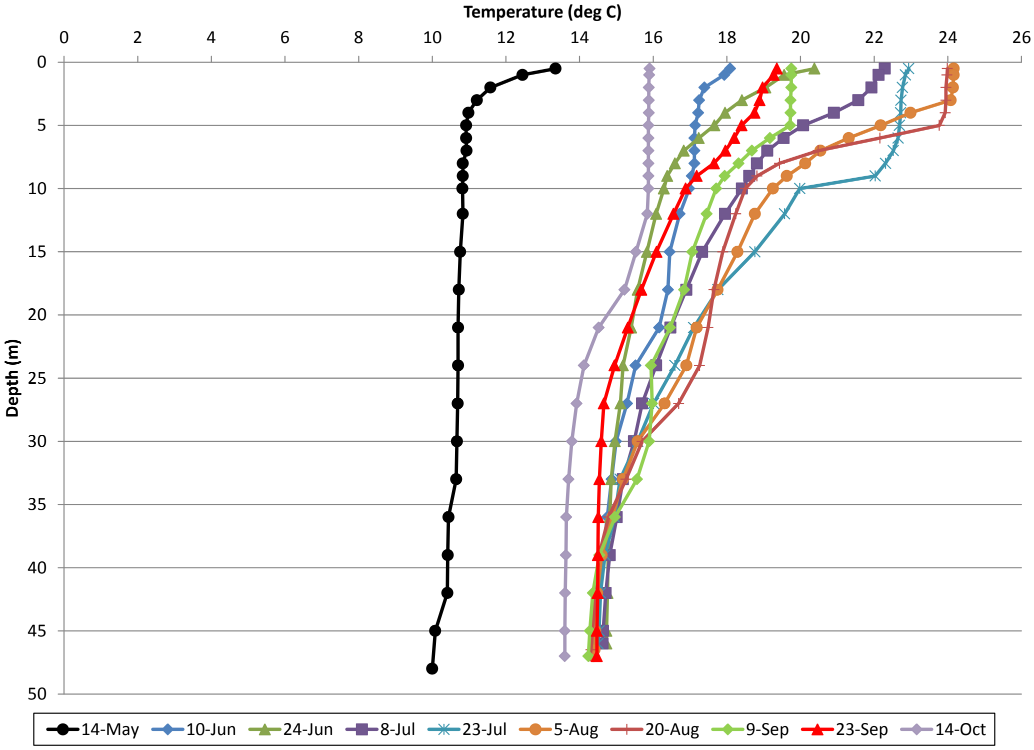

Figure 8. Temperature Profiles for Station LL0, May-October 2014

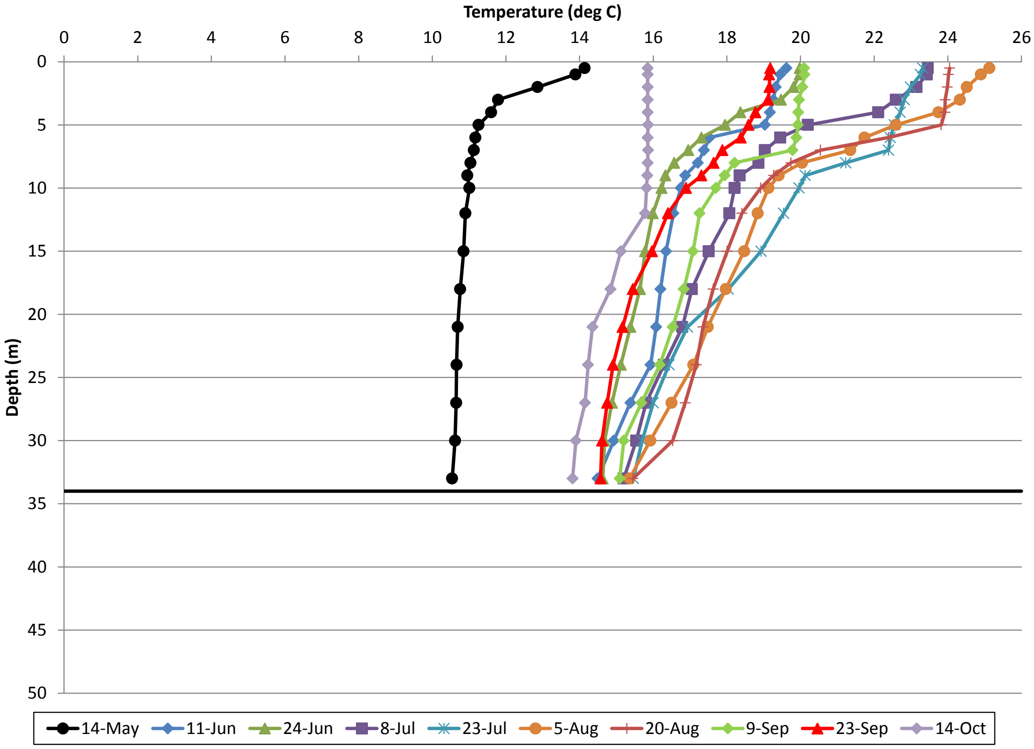

Figure 9. Temperature Profiles for Station LL1, May-October 2014

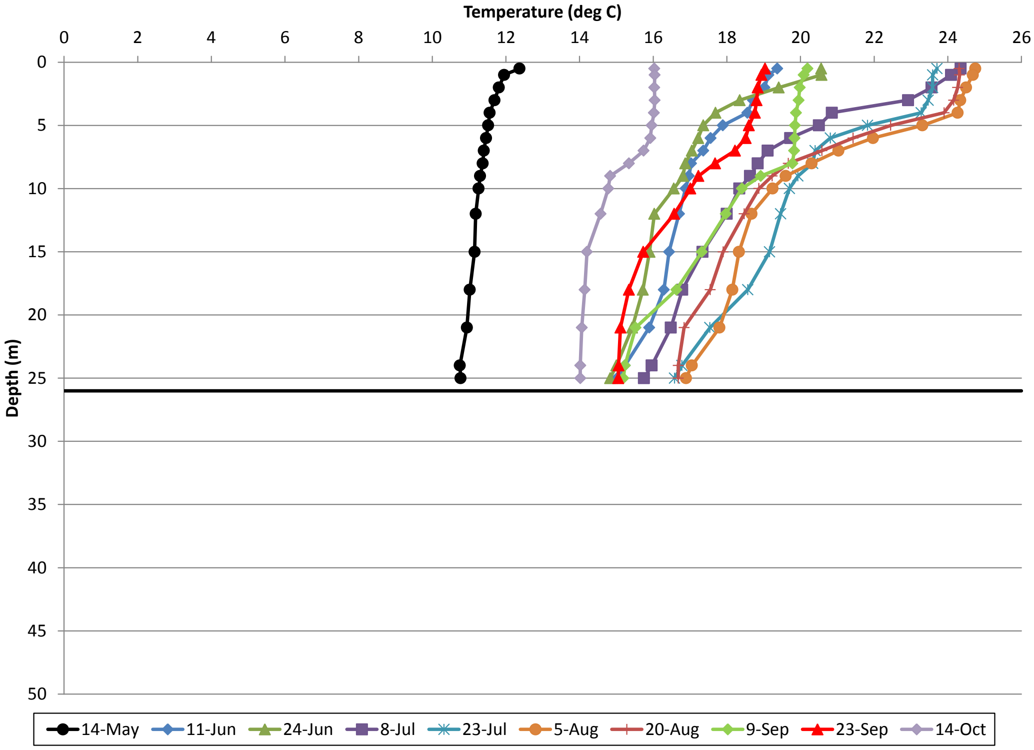

Figure 10. Temperature Profiles for Station LL2, May-October 2014

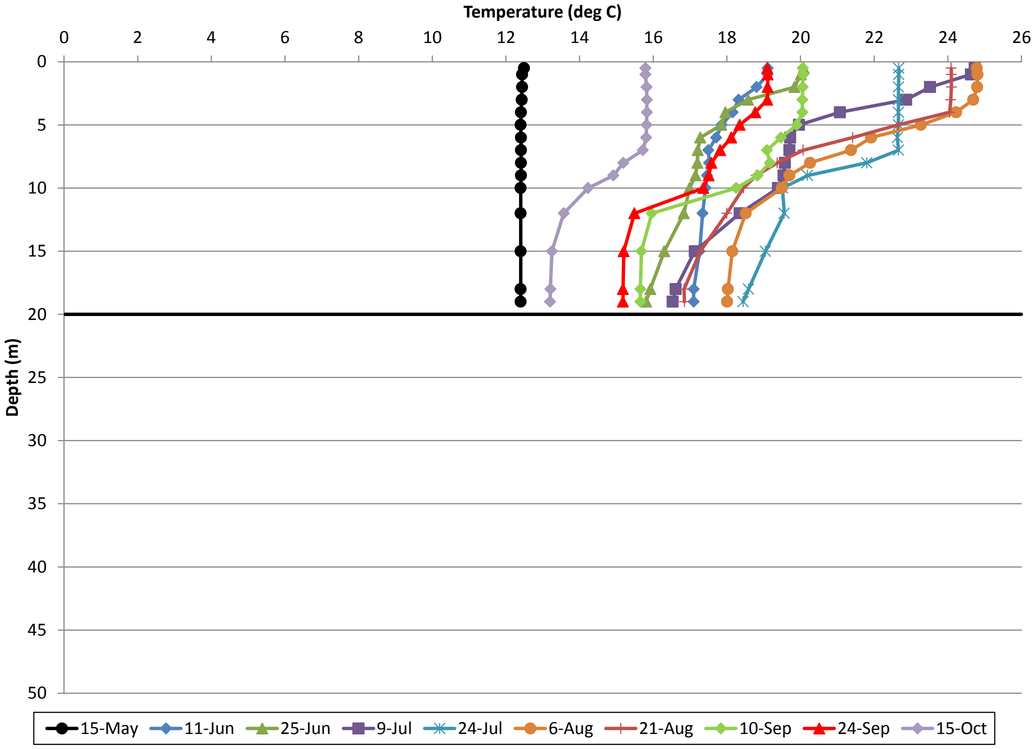

Figure 11. Temperature Profiles for Station LL3, May-October 2014

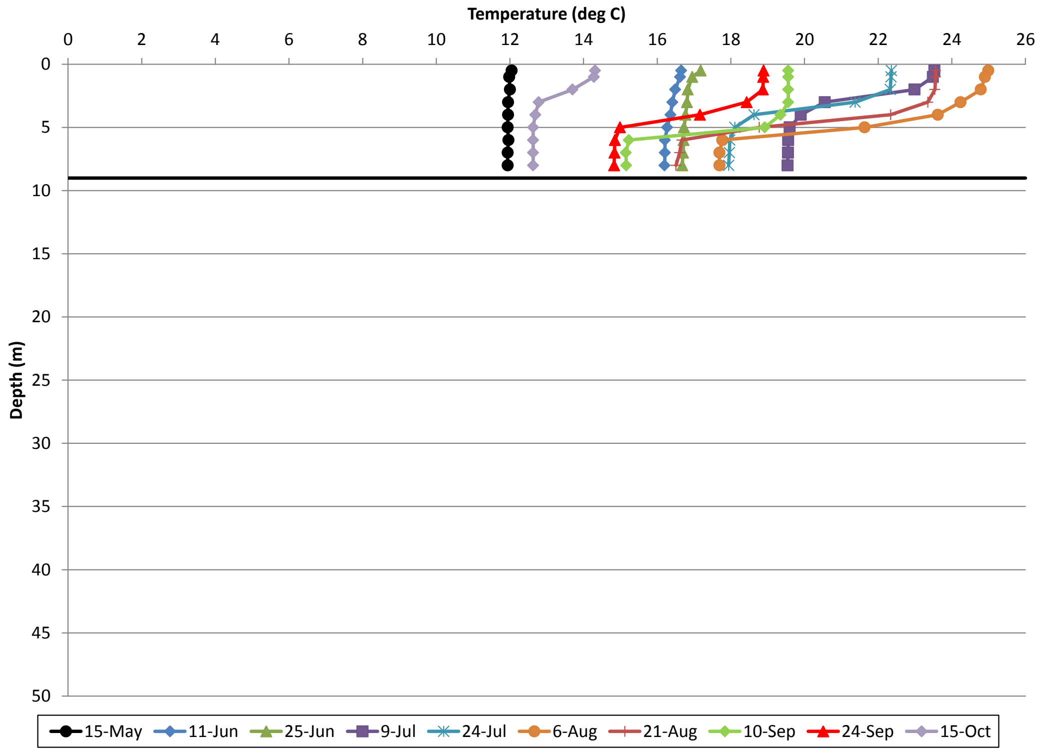

Figure 12. Temperature Profiles for Station LL4, May-October 2014

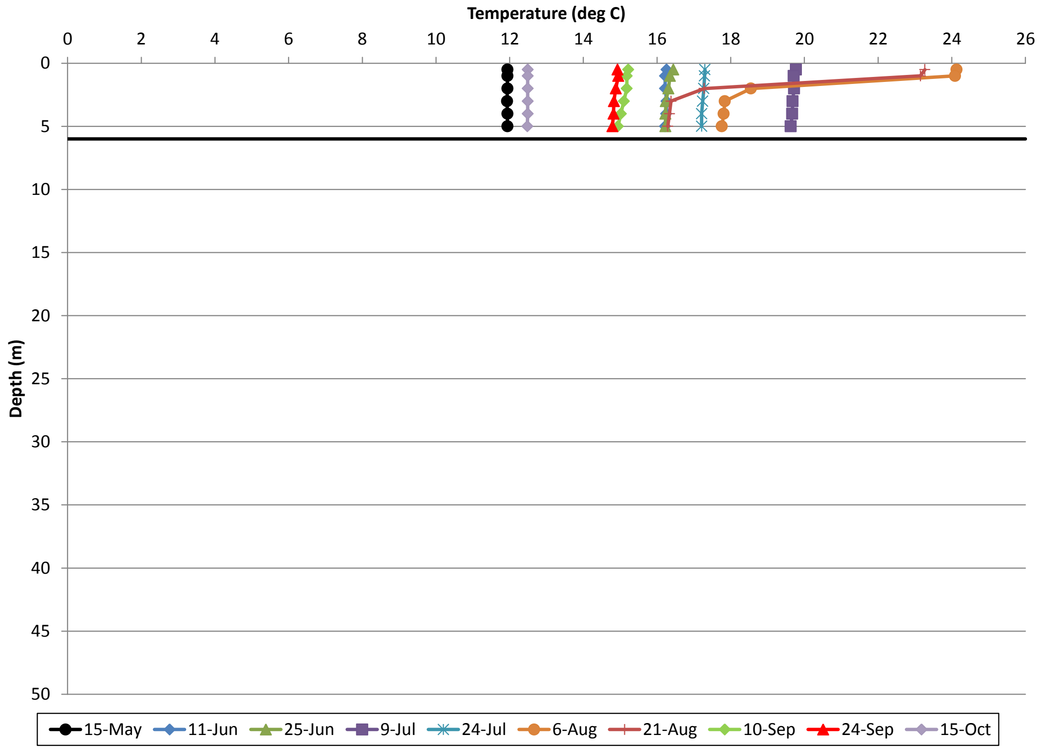

Figure 13. Temperature Profiles for Station LL5, May-October 2014

3.2.2 CONDUCTIVITY

Conductivity varied from about 69 to 270 micro Siemens/cm (µS/cm) throughout the reservoir (Figures 14 to 19). Conductivity is a conservative constituent, because it largely represents the major ions (Ca, Mg, etc.) that are usually not influenced by gains and losses due to physical (sedimentation) or biological processes. During May and early June, when river flow was relatively high, conductivity was low due to dilution with inflow of low conductivity, which was uniform, top to bottom, at all stations in May and at shallower stations in early June. As river flow decreased, inflow conductivity increased to 225 µS/cm on July 24 at LL5 (Figure 19). Water with increased conductivity, starting in June at around 150 µS/cm, reaching a maximum of 250 µS/cm, comprised the interflow zone that extended from about 4 to 12 m at stations LL3 to LL0 in June and expanded to 30 m in August as inflow volume decreased and inflow conductivity (and density) increased.

The high conductivity water (250-270 µS/cm) in August moved along the reservoir bottom from LL5 to LL2, where depths were greater than or equal to 25 meters and entered the deeper reservoir portion between 10 and 25 m. Below 30 m, conductivity was usually less than 150 µS/cm. This pattern results in much of the metalimnion in the lower reservoir being composed of interflow. Conductivity in bottom waters at LL0 remained unchanged from late June until late September when river inflows increased enough to mix the deepest portions of the reservoir.

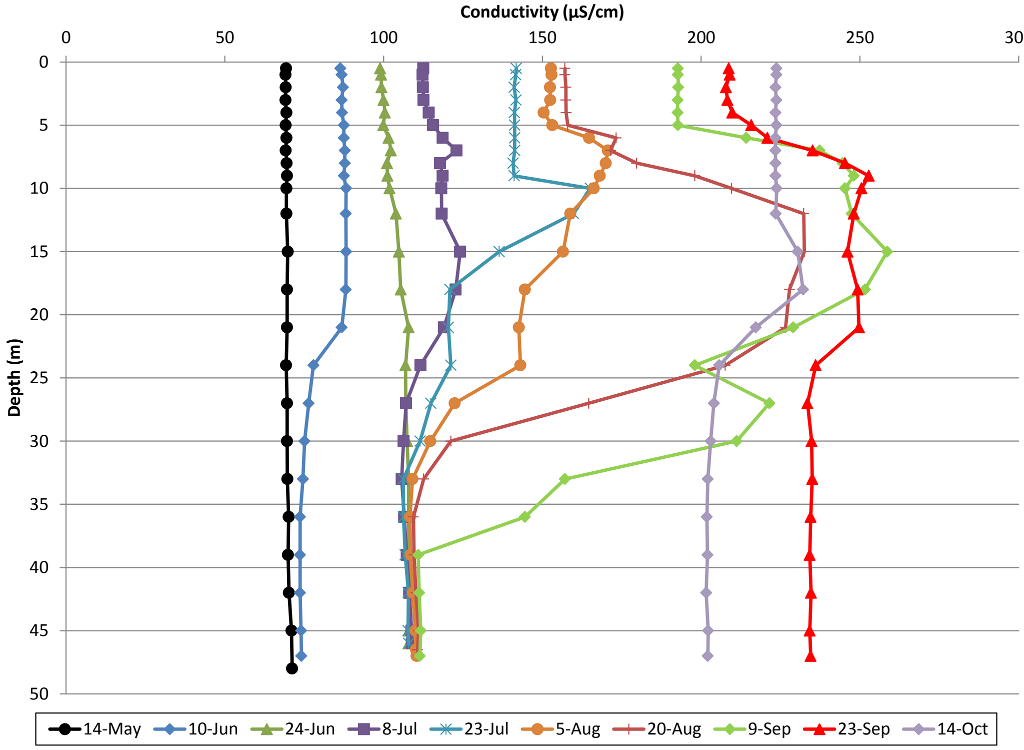

Figure 14. Conductivity Profiles for Station LL0, May-October 2014

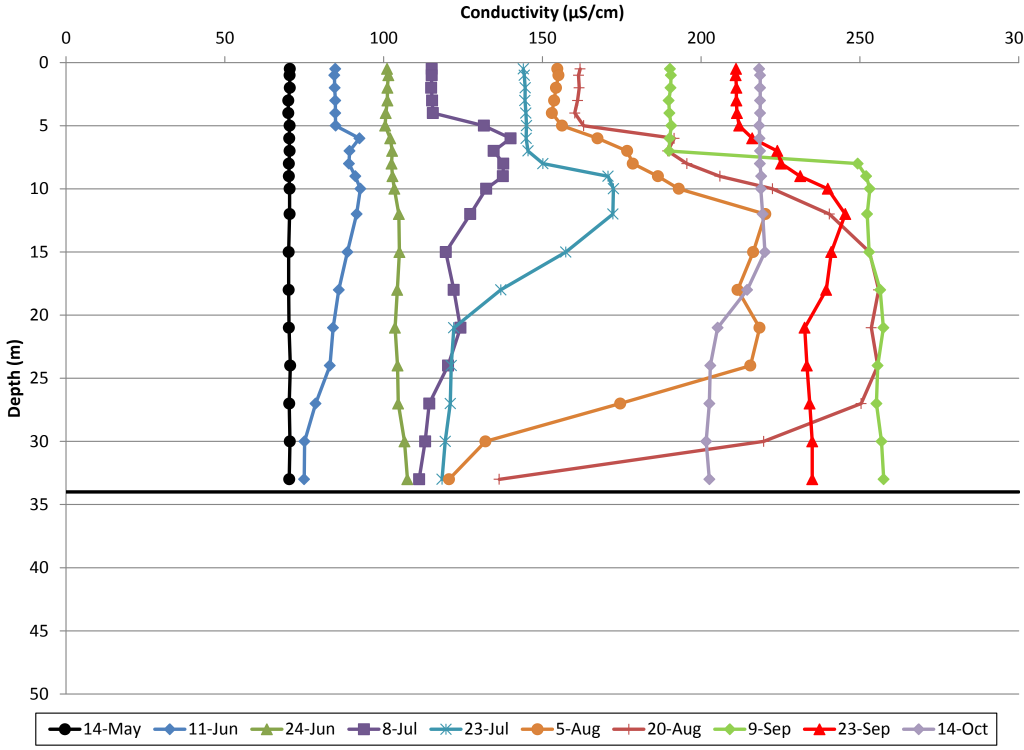

Figure 15. Conductivity Profiles for Station LL1, May-October 2014

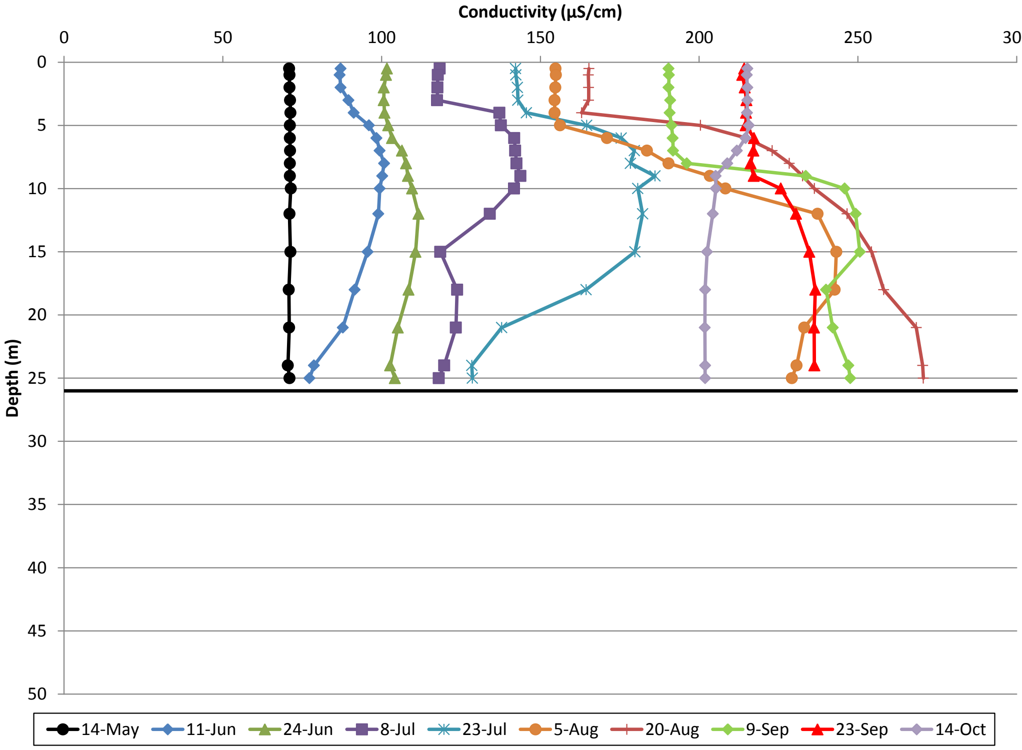

Figure 16. Conductivity Profiles at Station LL2, May-October 2014

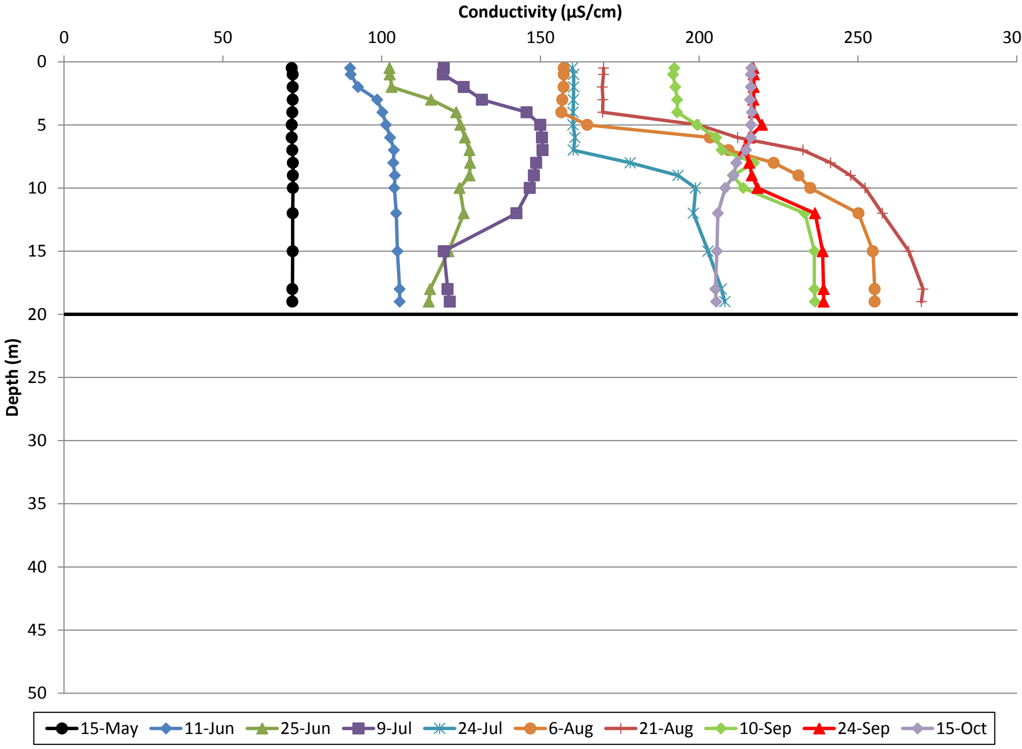

Figure 17. Conductivity Profiles at Station LL3, May-October 2014

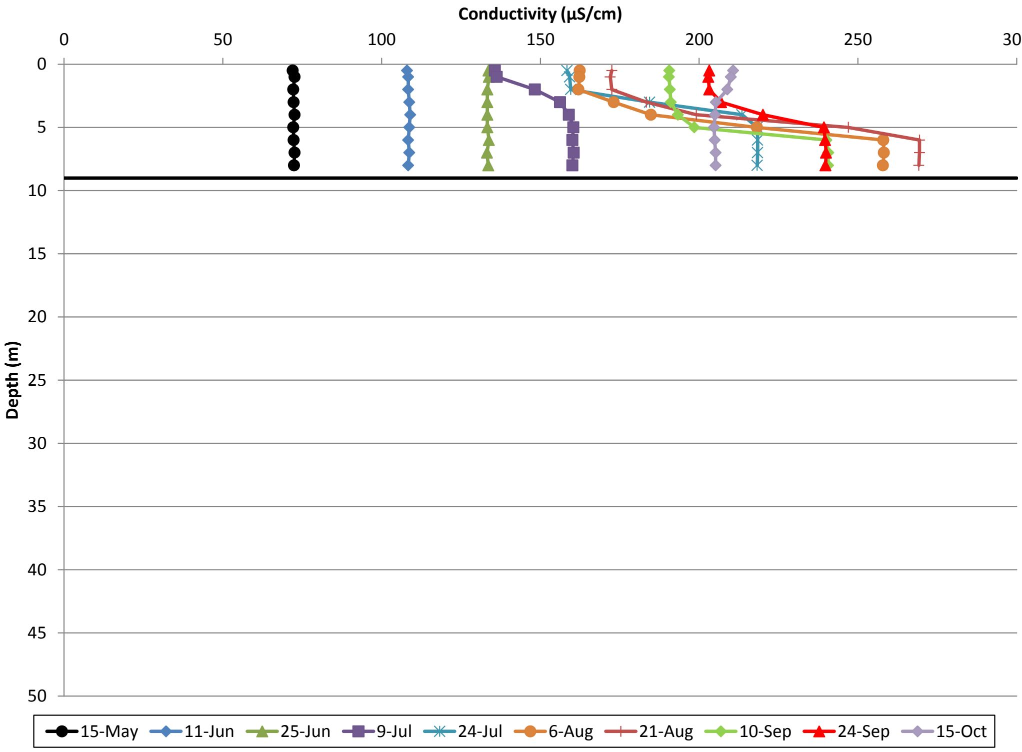

Figure 18. Conductivity Profiles at Station LL4, May-October 2014

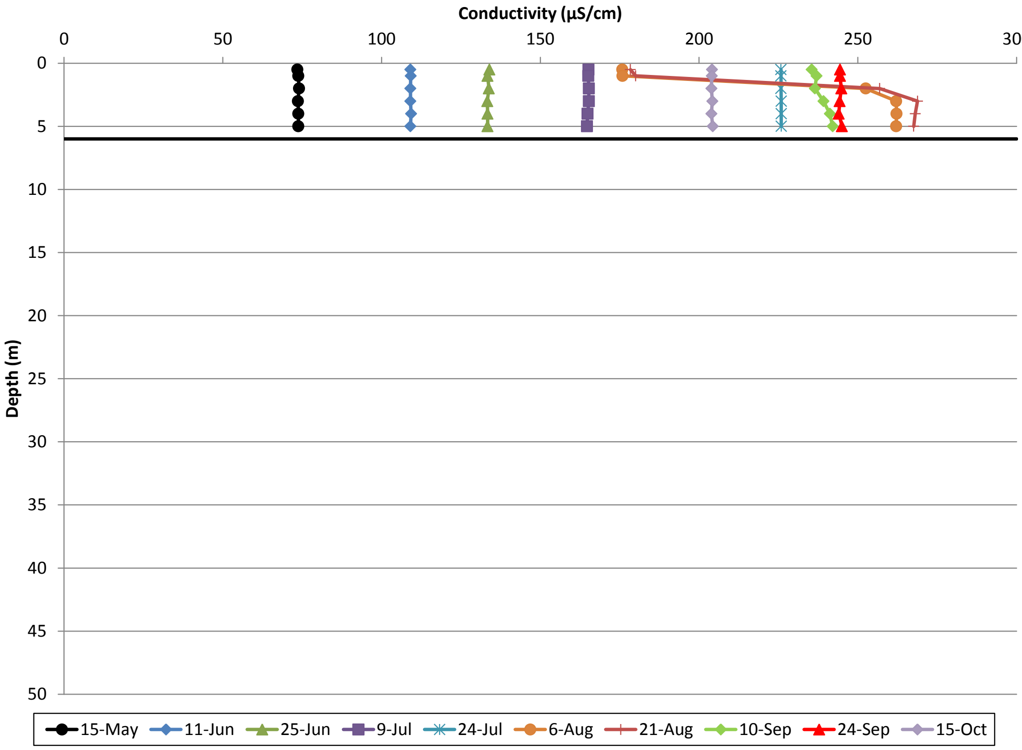

Figure 19. Conductivity Profiles at Station LL5, May-October 2014

3.2.3 DISSOLVED OXYGEN

Maximum epilimnetic DO concentrations ranged from 12.0 to 14.1 mg/L at the six stations, with higher values occurring in the lacustrine zone (Figures 20 to 25). Maximum DO concentrations ranged from 10.7 to 14.5 mg/L in 2010, 11.9 to 12.4 mg/L in 2011, 11.4 to 12.5 mg/L in 2012, and 11.6 to 13.4 mg/L in 2013. Concentrations were especially high between 4 and 6 m in August at station LL0, likely due to photosynthetic activity (Figure 20). High concentrations at LL0 occurred in July in 2013.

During the 2014 sampling, minimum DO concentrations occurred near the bottom at the two deepest stations LL0 and LL1 (Figures 20 and 21). Concentrations in the hypolimnion below 25 m declined more or less with time at these two sites. This deeper volume in the hypolimnion was probably not exchanged appreciably with the interflow, as evidenced by conductivity profiles (Figures 14 and 15), allowing DO to gradually deplete.

Minimum DO concentrations in 2010 – 2013 also occurred at the two deepest stations (LL0 and LL1), but minimum concentrations in 2011 were significantly higher (3.2, 6.9 mg/L) at those sites than those observed in 2014 (0.0, 0.0 mg/L), in 2013 (0.0, 0.9 mg/L), in 2012 (1.6, 0.5 mg/L), or in 2010 (0.13, 2.3 mg/L). Minimum DO concentrations in 2013 and 2014 were the lowest observed of the five years. Average water column DO in 2014 ranged from 8.3 to 10.3 mg/L, with the lowest values at the two deepest stations.

The effect of interflow, as indicated by conductivity, on DO depletion was most pronounced during August and September at stations LL0, LL1, and LL2 in the lacustrine zone, and to a limited extent at LL3 in the transition zone. There was less DO depletion from the interflow zone in August in 2013. Although the DO profile patterns were similar, the effect of interflow on DO in 2013 was not as pronounced as in 2014 at the deeper stations. DO depletion in the metalimnion to levels less than 6 mg/L occurred during August and September in 2014, but only during one September event in 2013. This pattern persisted until October at LL0, as in 2013, but concentrations in the hypolimnion were much higher than in August and September.

The pattern of the plunging interflow affecting DO is further shown in Figure 26 by combining profile data from the low-flow, high inflow conductivity summer period for the lacustrine zone. The marked decline in DO in the metalimnion below about 6 m corresponds with high conductivity water that plunged into the interflow, usually between 6 to 25 m, likely carrying organic matter from the productive transition and riverine zones providing DO demand...

Volume weighting the DO concentrations is a method that provides an average DO concentration throughout the water column. Volume-weighted DO concentrations for each station and sampling date were calculated using DO concentrations from 9 m and deeper and CE-QUAL-W2 model segment volumes, provided by Avista and Golder Associates, below 8.5 (Table 6). This was completed to be consistent with the methods Ecology used to produce Table 7 of the DO TMDL. More specifically, the calculation was completed by the following technique.

> *At each station, for each sampling day, measured DO concentrations from 9 m and deeper were multiplied by their associated volume of water, summed, and then divided by*

the total volume of water at each station from 9 m and deeper. The volumes of water were obtained from the CE-QUAL-W2 model segment volumes identified in the DO TMDL.

The lacustrine zone average DO includes concentrations from LL0, LL1, and LL2 but not the very small portion of the hypolimnion at station LL3.

Table 6. Volume-Weighted hypolimnetic DO Concentrations in Lake Spokane, during May-October 2014, using DO Concentrations Determined from 9 meters and Deeper

Station	Volume-Weighted DO (mg/L), Below 8.5 meters									
	May 13-14	June 11-12	June 25-26	July 9-10	July 24-25	August 5-6	August 20-21	September 9-10	September 24-25	October 14-15
LL0	11.7	9.99	9.26	8.69	7.04	5.19	4.92	3.97	6.87	7.81
LL1	12.0	9.54	9.76	8.42	6.60	6.40	6.40	6.86	7.31	8.41
LL2	11.9	9.55	9.98	8.30	6.49	7.43	7.47	7.27	8.43	8.97
LL3	11.7	9.8	9.61	8.03	7.98	8.74	8.17	9.51	9.71	9.68
LL4	No hypolimnion									
LL5	No hypolimnion									
Lacustrine Zone only Average (LL0, LL1, LL2)	11.9	9.7	9.7	8.5	6.7	6.3	6.3	6.0	7.5	8.4

Using the same technique, the volume-weighted DO concentrations for the hypolimnion from 15 m and deeper were also calculated using the model segment volumes (Table 7). The lowest volume-weighted hypolimnetic DO observed below 15 m in 2014 was during the September 9-10 sampling event at station LL0 (3.29 mg/L; Table 7), which was about 0.6 mg/L lower than in 2013 and approximately 1.5 mg/L lower than in 2012 at LL0. The minimum average hypolimnetic DO in the lacustrine zone (6.0 mg/L) was observed during late July and early August and was slightly higher than in 2013 (5.8 mg/L). The earlier occurrence of the average minimum below 15 m in 2014 than 2013 is evident in the profiles (Figures 20 and 21).

While DO conditions have improved in Lake Spokane since 1977, when 85% of point-source effluent phosphorus was removed from the river, data collected in 2014 indicate DO levels still do not meet the surface water quality standard in the hypolimnion during portions of the summer critical season. This is the reason Ecology is implementing the DO TMDL.

Table 7. Volume-Weighted Hypolimnetic DO Concentrations in Lake Spokane, during May-October 2014, using DO Concentrations Determined from 15 meters and Deeper

Station	Volume-weighted DO (mg/L), Below 15 meters									
	May 13-14	June 11-12	June 25-26	July 9-10	July 24-25	August 5-6	August 20-21	September 9-10	September 24-25	October 14-15
LL0	11.6	9.81	9.32	8.28	6.59	4.80	4.50	3.29	7.08	7.48
LL1	11.9	9.40	9.69	8.12	5.76	5.99	6.33	7.35	7.98	8.14
LL2	12.0	9.37	9.70	7.94	5.66	7.17	8.00	8.27	8.83	8.97
LL3	11.7	9.65	9.08	7.00	8.10	8.62	8.54	9.77	9.55	9.57
LL4	--	--	--	--	--	--	--	--	--	--
LL5	--	--	--	--	--	--	--	--	--	--
Lacustrine Zone only Average (LL0, LL1, LL2)	11.8	9.5	9.6	8.1	6.0	6.0	6.3	6.3	8.0	8.2
Whole Hypolimnetic Average (LL0, LL1, LL2, LL3)	11.8	9.6	9.4	7.8	6.5	6.6	6.8	7.2	8.4	8.5

Average lacustrine, volume-weighted DOs were similar from 9 m and deeper and from 15 m and deeper, usually differing by less than 0.5 mg/L (Tables 6 and 7). In July and August, average DOs were slightly higher using concentrations from 9 m and deeper; averages were much greater below 9 m than 15 m in 2013. Average DOs were also higher in September 2014 than in 2013, because metalimnetic, interflow DOs were higher in late September, 2014 than in 2013.

The rationale for including hypolimnetic volume at depths between 8.5 and 15 m for the TMDL was to include DOs in the metalimnion that are lower at times than in the hypolimnion, due to the interflow effect.

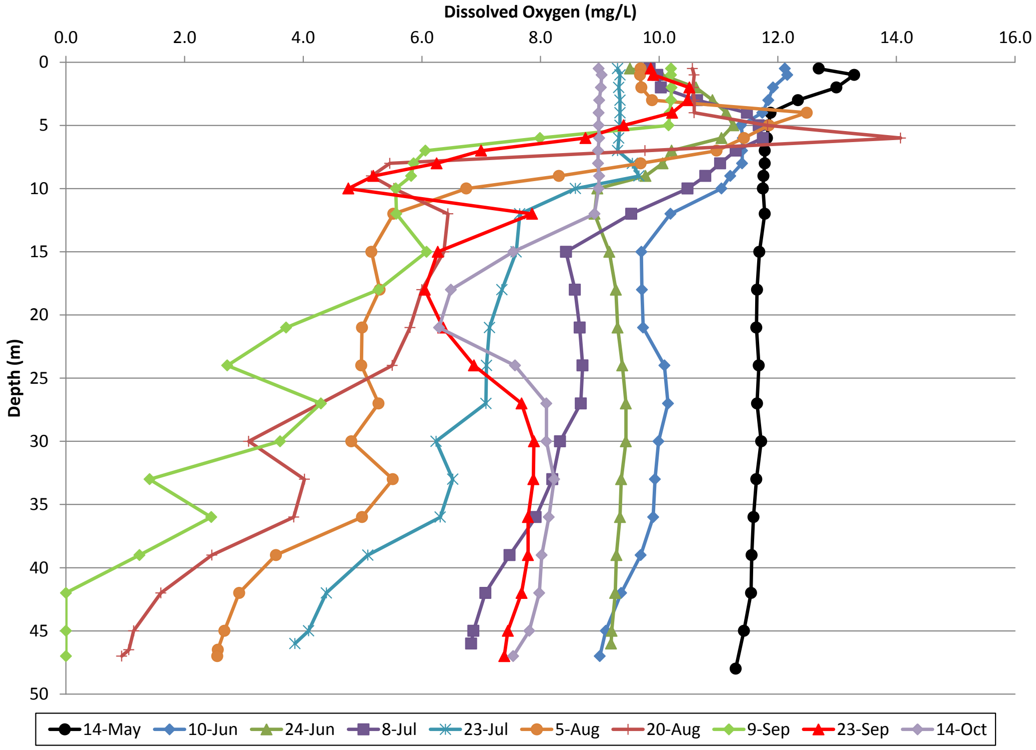

Figure 20. DO Profiles for Station LL0, May-October 2014

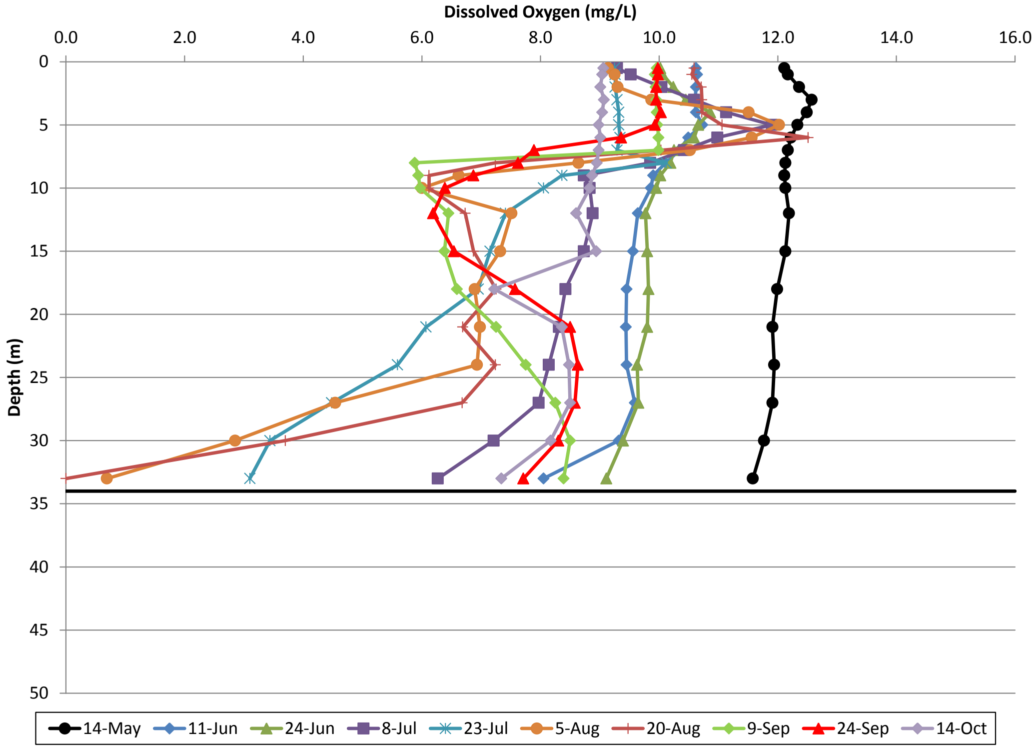

Figure 21. DO Profiles for Station LL1, May-October 2014

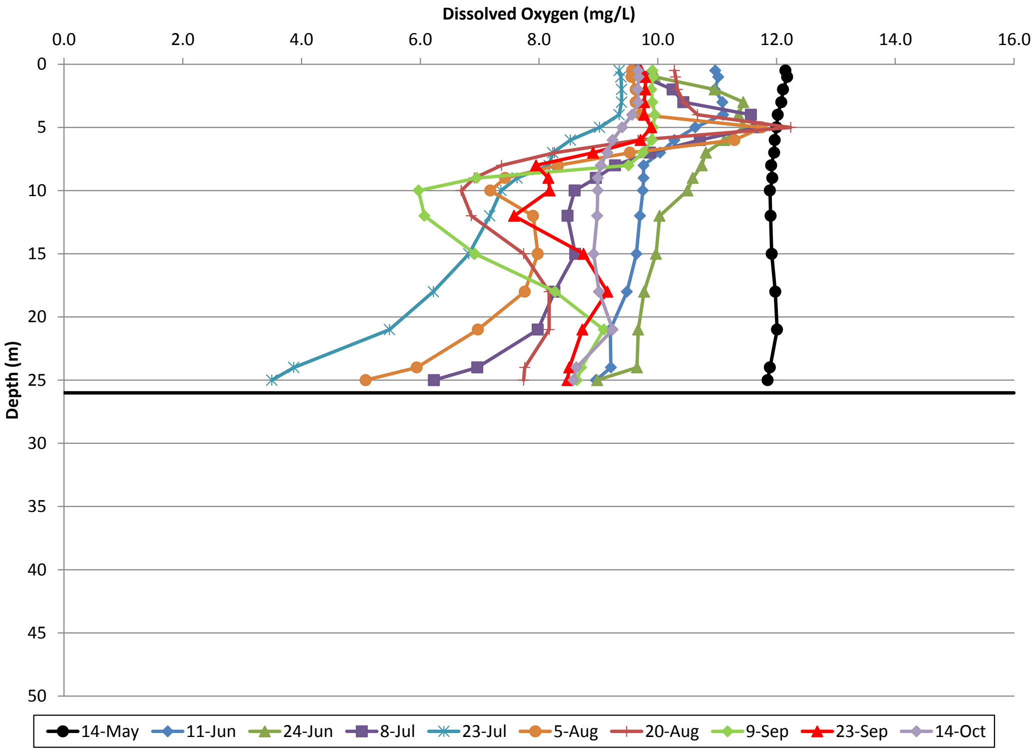

Figure 22. DO Profiles at Station LL2, May-October 2014

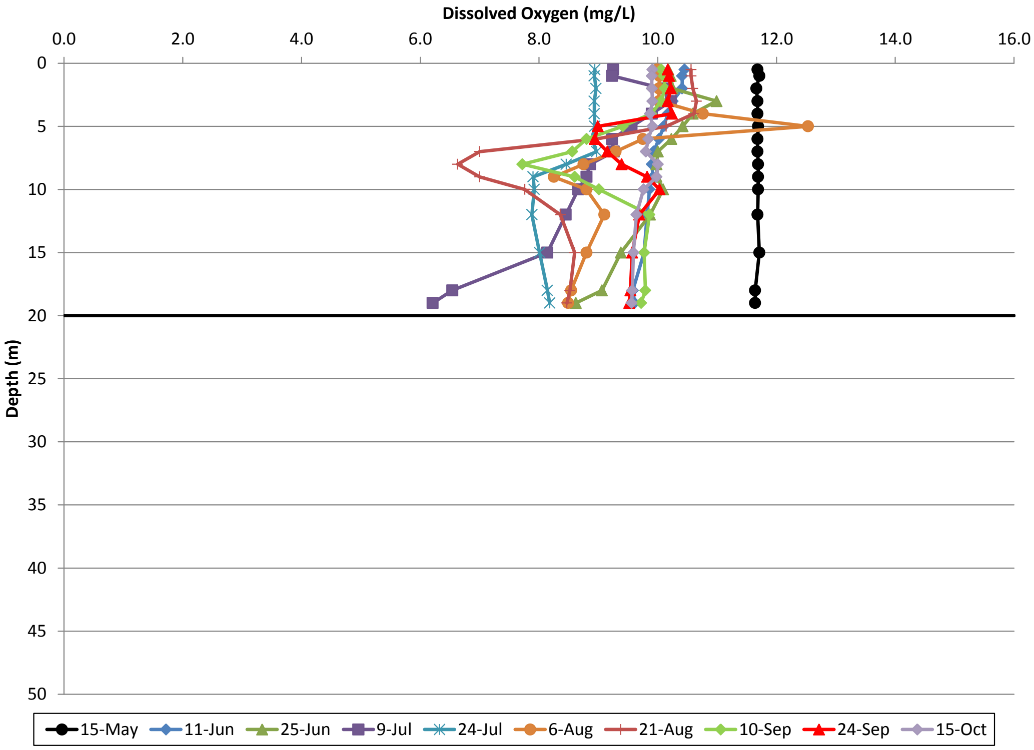

Figure 23. DO Profiles at Station LL3, May-October 2014

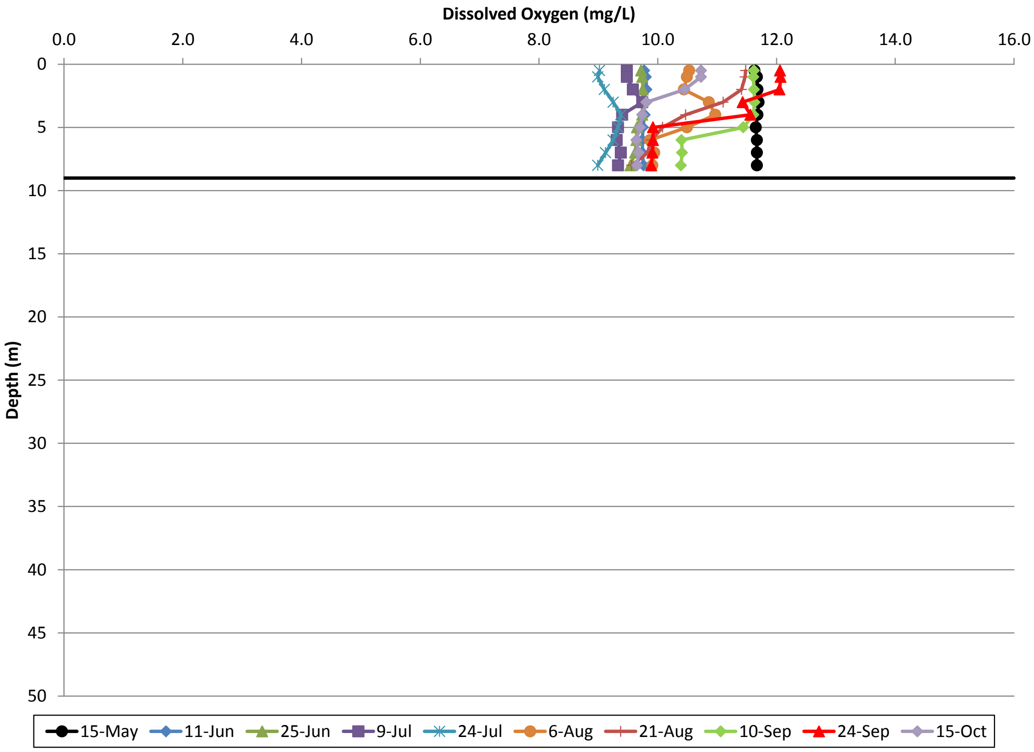

Figure 24. DO Profiles at Station LL4, May-October 2014

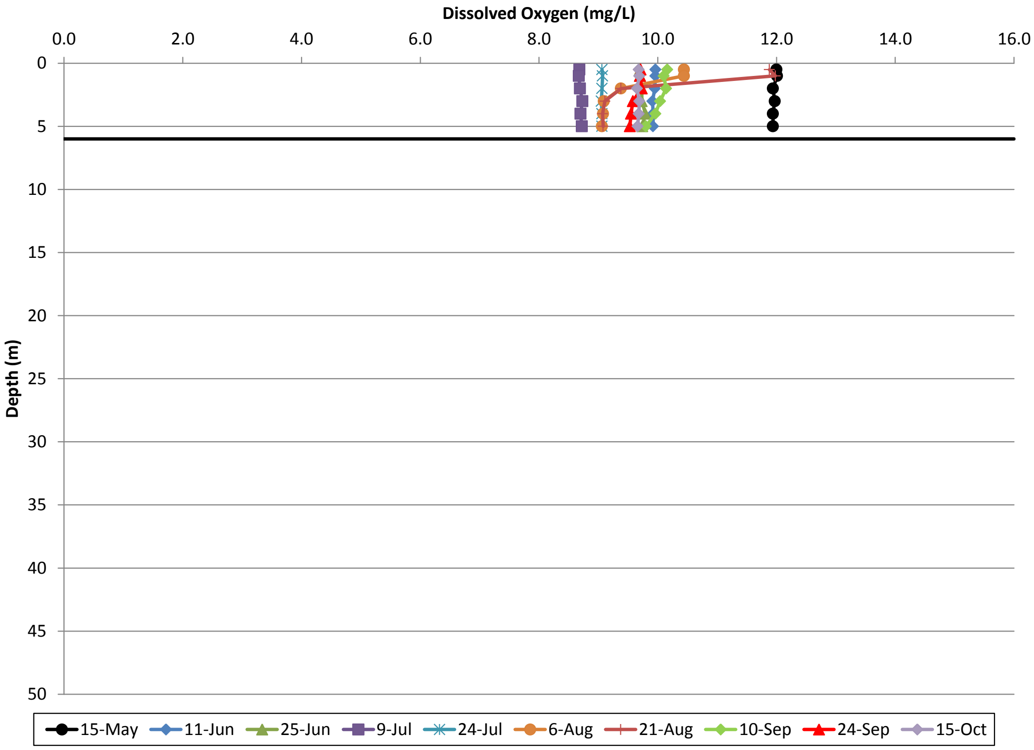

Figure 25. DO Profiles at Station LL5, May-October 2014

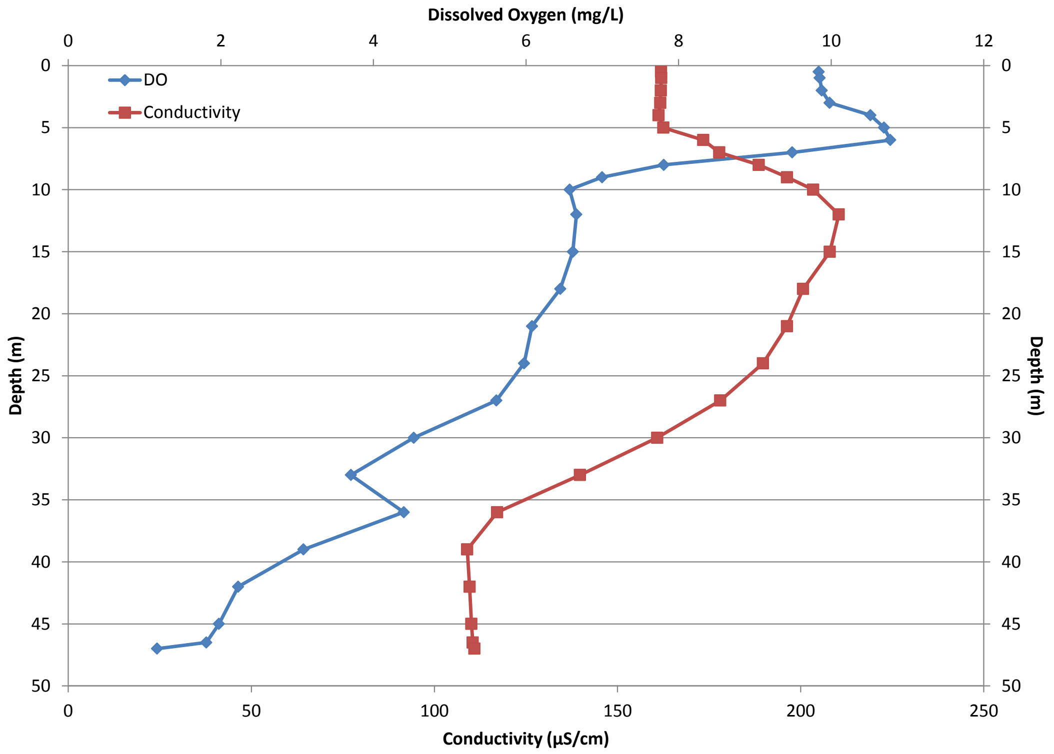

Figure 26. Average DO and Conductivity Profiles for Stations LL0, LL1, and LL2 from July 23rd through September 9th, 2014.

3.2.4 PH

The water column profiles for pH showed a range of 6.9 to 9.2 at the six stations during 2014 (Figures 27 through 32). Water column averages were narrower, ranging less than one pH unit, 7.6 to 8.2. The highest pH values occurred during August and September due to photosynthetic activity of phytoplankton. Intense phytoplankton photosynthesis can raise pH to levels above 10, which did not occur. The pH levels (9.0 to 9.2) occurred above the water quality criteria of 8.5 in the top 4 to 6 m at all stations, even at station LL5 in the riverine zone during low flow and longer water retention time. Residence times were also longer in 2013, especially in late summer, allowing more time for photosynthetic activity, with pH reaching 9.1 (above the 8.5 water quality criteria) similar to 2014. Conditions observed in 2012 indicate a few data points at LL5, in August, which were just slightly above the water quality criteria, with 8.58 being the highest. Chl concentration at LL5 peaked on August 21 at 18.2 µg/L corresponding to the peak in pH. This was also the case in 2013 when chl concentration at LL5 peaked on September 10 at 9.6 µg/L, also corresponding to the peak in pH.

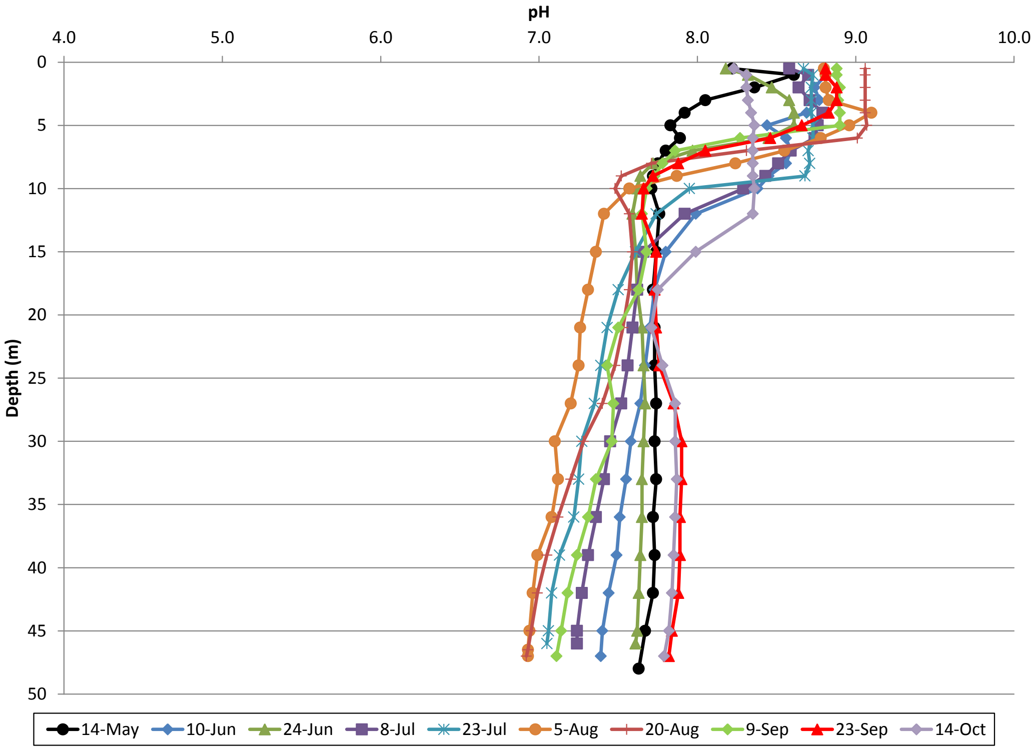

Figure 27. pH Profiles for Station LL0, May-October 2014

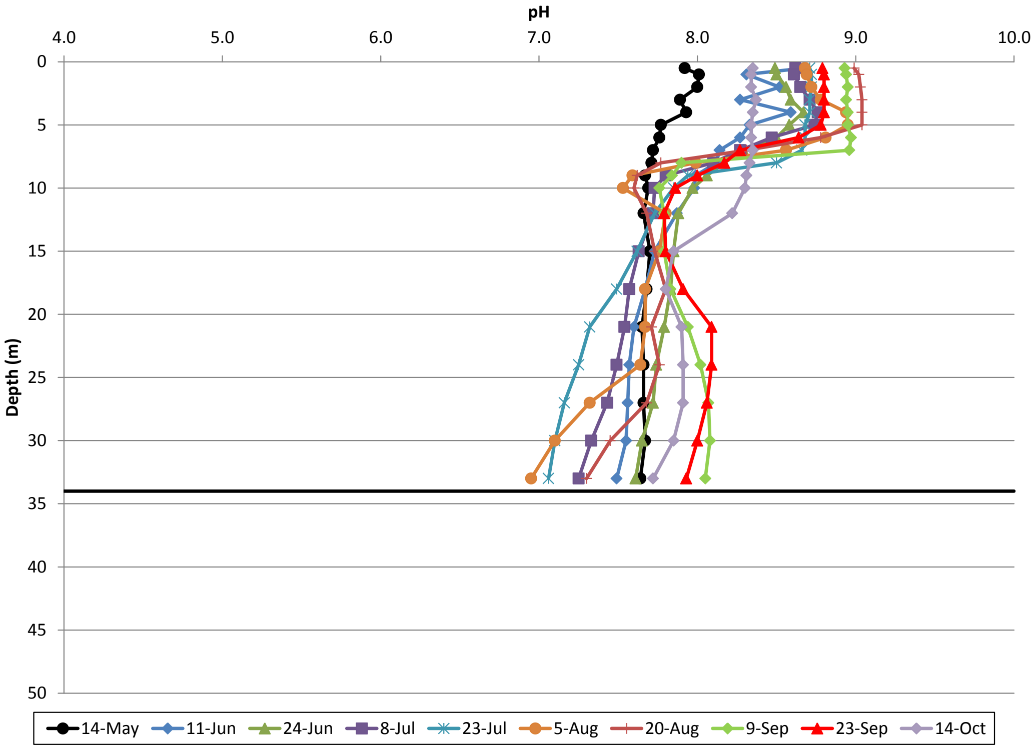

Figure 28. pH Profiles for Station LL1, May-October 2014

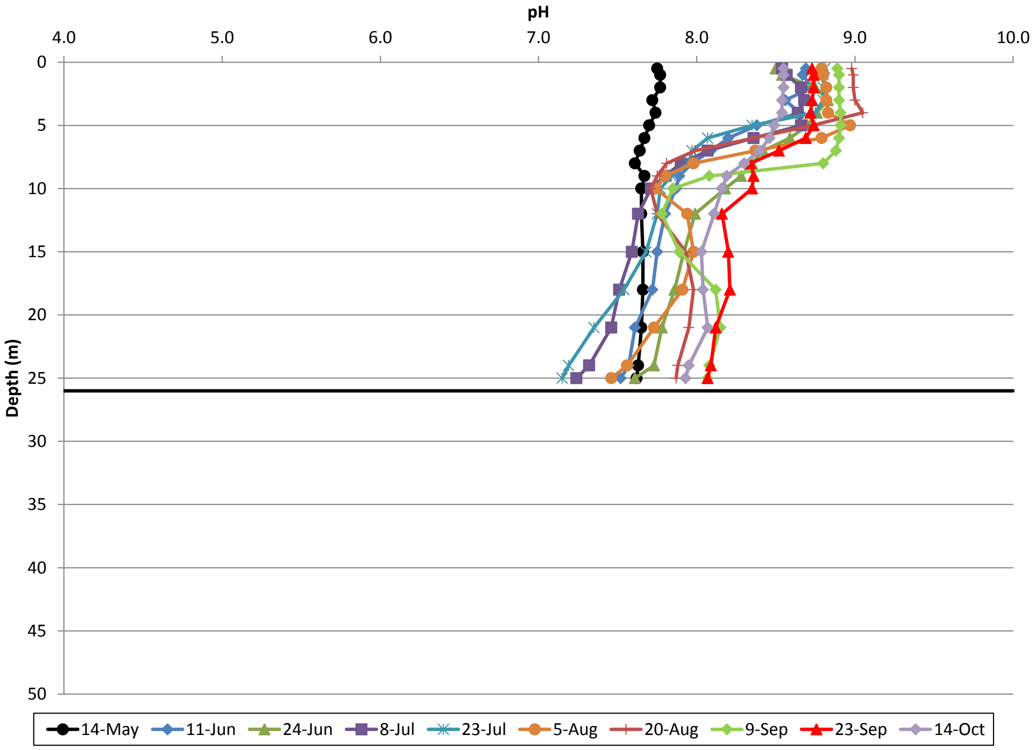

Figure 29. pH Profiles at Station LL2, May-October 2014

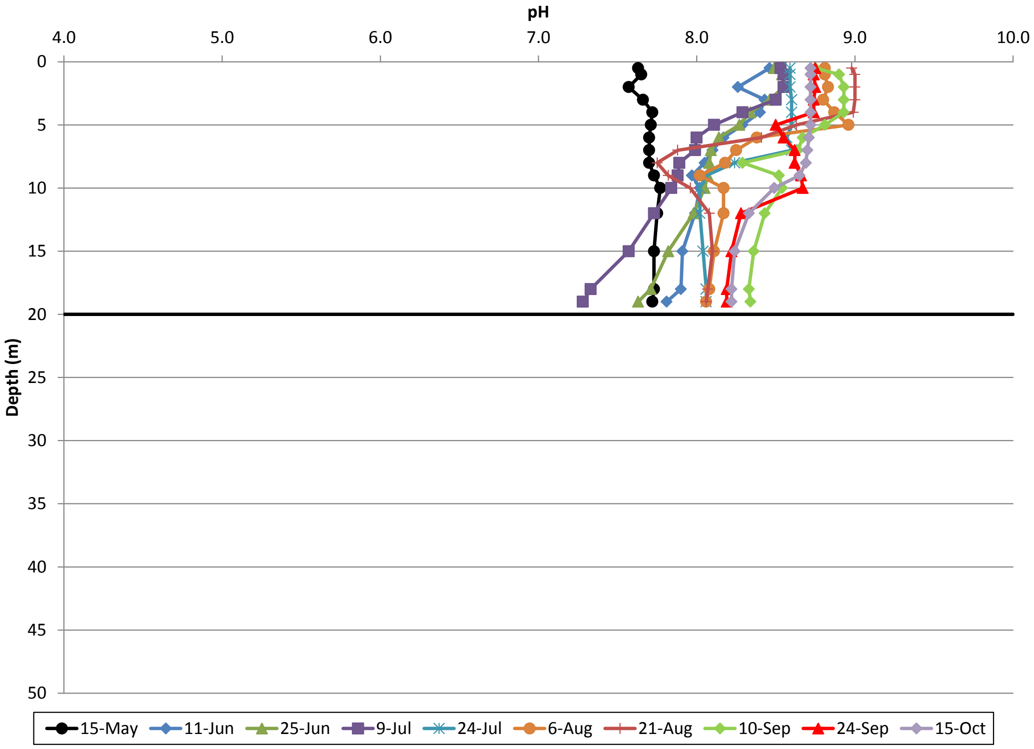

Figure 30. pH Profiles at Station LL3, May-October 2014

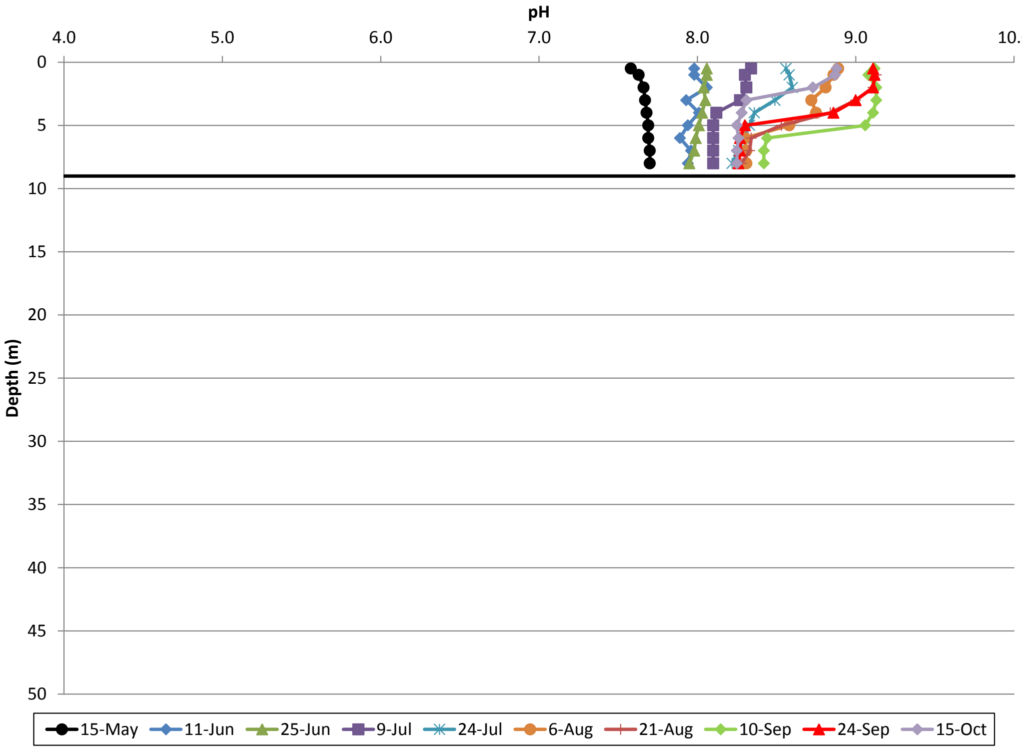

Figure 31. pH Profiles at Station LL4, May-October 2014

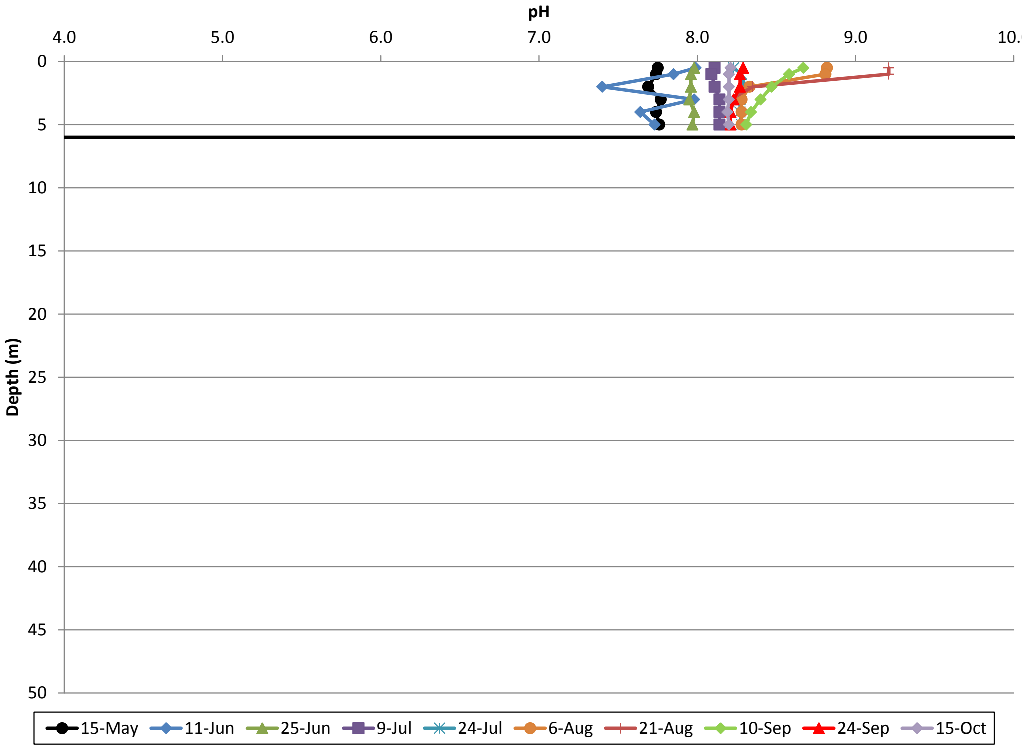

Figure 32. pH Profiles at Station LL5, May-October 2014

3.2.5 NUTRIENTS

Phosphorus

Total phosphorus concentrations ranged from about 4.0 to 70 µg/L during 2014. Soluble reactive phosphorus concentrations ranged from about 1.0 (non-detect [ND]) to 61 µg/L. Total phosphorus and SRP were usually highest at stations LL0, LL1, and LL2 in the hypolimnion (15 m and deeper) with higher levels usually starting in July (Figures 33 through 38), except for the highest concentration (70 µg/L), which occurred at the bottom at LL0 in June. At these three stations, TP was consistently higher at the bottom with peaks much greater than in 2013, when highest levels occurred at 5 m at various times throughout the summer, which was also not the case in 2012. While the highest TPs occurred at the bottom, there was no consistent pattern with DO; in fact, TP declined when bottom DOs were lowest in August – September, even with anoxia at LL0 (Figures 33-35).

A similar pattern occurred with SRP in 2014, but has varied from year to year. In 2013, peak bottom SRP occurred at LL0 in early July and again at the end of August while the peak was in June in 2014. Minimum DOs of ≤ 2 mg/L occurred more often in 2013; on three occasions at LL0, two at LL1 and never at LL2. Minimum bottom DOs ≤ 2 mg/L occurred on only two occasions in 2014 at LL0 and LL1 in August – September. Yet peak SRP occurred earlier in July prior to minimum DO at all three sites.

At station LL3, TP and SRP concentrations were higher at the bottom of the water column (Figures 39 and 40). This is similar to 2013 and contrasts with 2012 where TP peaked at 5 m in October.

Total phosphorus at LL4 began to increase at 0.5 and 4 m in July and reached a peak in September (Figure 41). Peak TP occurred at 4 m in both early August and late September in 2013, and bottom concentrations were usually lower both years. The increased TP at 0.5 and 4 m in August and September to near 40 µg/L corresponded to a large increase in chl to 20 µg/L. Peak TP and chl also occurred there in September 2013. Soluble reactive phosphorus concentrations at LL4 were very stable, almost always below 5 µg/L during both years (Figure 42).

Total phosphorus concentrations at station LL5 were relatively stable throughout the period with the exception of a small spike to about 25 µg/L in August (Figure 43). The pattern was similar in 2013 in August at 0.5 m, but the peak was 65 µg/L. Water column TP concentrations were usually around 15 µg/L or less both in 2013 and 2014.. Soluble reactive phosphorus concentrations at LL5 were usually about 5 µg/L or less both years (Figure 44).

Epilimnetic TP concentrations in the lacustrine zone (LL0, LL1, LL2) varied some in 2014, but were usually less than or equal to about 10 µg/L (Figure 45). Seasonal patterns and concentration ranges have been rather consistent over the five year period averaging a little less than 10 µg/L during June-September. Transition and riverine zone (LL3, LL4, and LL5) TP was often greater than 10 µg/L and occasionally above 20 µg/L. Soluble reactive phosphorus concentrations were usually less than 5 µg/L in the epilimnion at all sites, which may be the result of algae scavenging that available form of phosphorus.

Volume-weighted water column TP concentrations at the six stations were fairly similar for most of the year (Table 8; Figure 46). TP concentrations were slightly lower at LL1 and LL0 than at other sites during the beginning of the period but tended to be higher in July. TP at stations LL4 and LL5 were usually higher than at down-reservoir stations during August and September (Figure 46; Table 8). However, volume-weighted TP concentrations for all stations were below 35 µg/L and for most of the period below 25 µg/L. The generally higher water column TPs at LL4 and LL5 during August and September in 2014, was similar to 2013, which is in contrast to the pattern in 2012.

Table 8. Volume-Weighted Water Column TP Concentrations for Monitoring Stations in 2014 (values indicated with an asterisk do not include bottom TP concentrations in the volume weighted calculation due to suspect data quality)

2014 Sampling Event	Volume Weighted Water Column TP (µg/L)					
	LL0	LL1	LL2	LL3	LL4	LL5
May 14-15	11	16*	14*	22	17	15
June 10-11	13	9*	10*	9*	8	9
June 24-25	10	8*	20	10	8	8
July 8-9	8	7	9	11	6	7
July 23-24	13	9	10	13	16	9
August 5-6	18	14	14	13	14	14
August 20-21	7	7	10	12	20	23
September 9-10	22	18	10	24	35	15
September 23-24	7	6	12	15	21	10
October 14-15	9	13	14	12	14	8.5
Mean	12	11	12	14	16	12
Summer Mean (Jun-Sep)	12	10	12	14	16	12

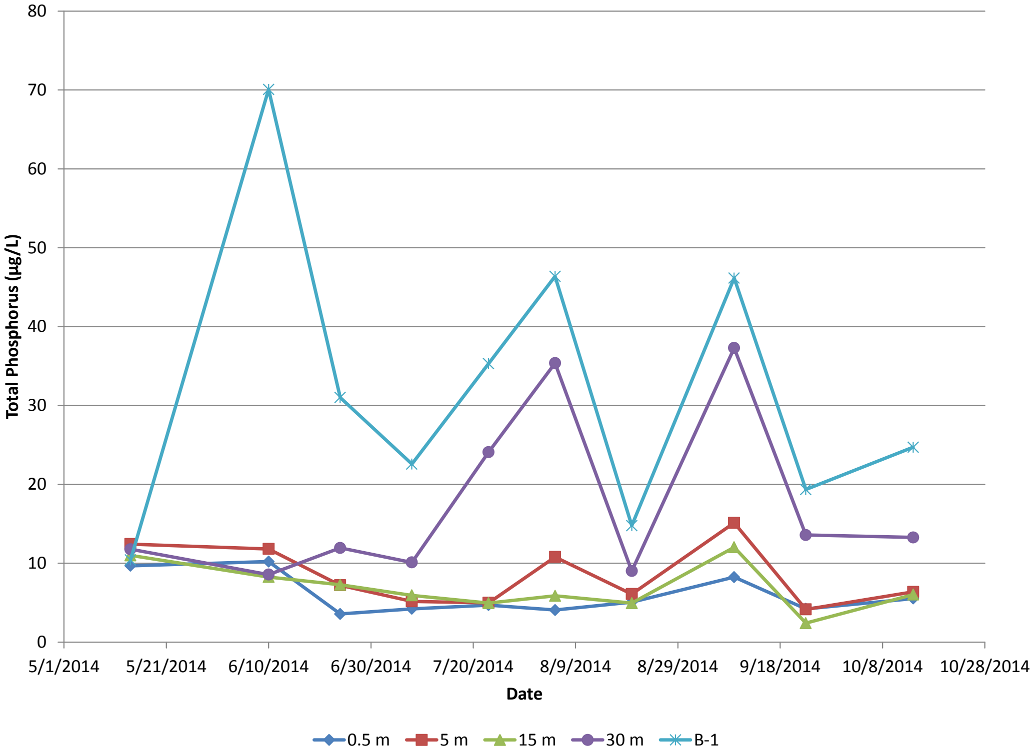

Figure 33. TP Concentrations (µg/L) at Station LL0, May-October 2014

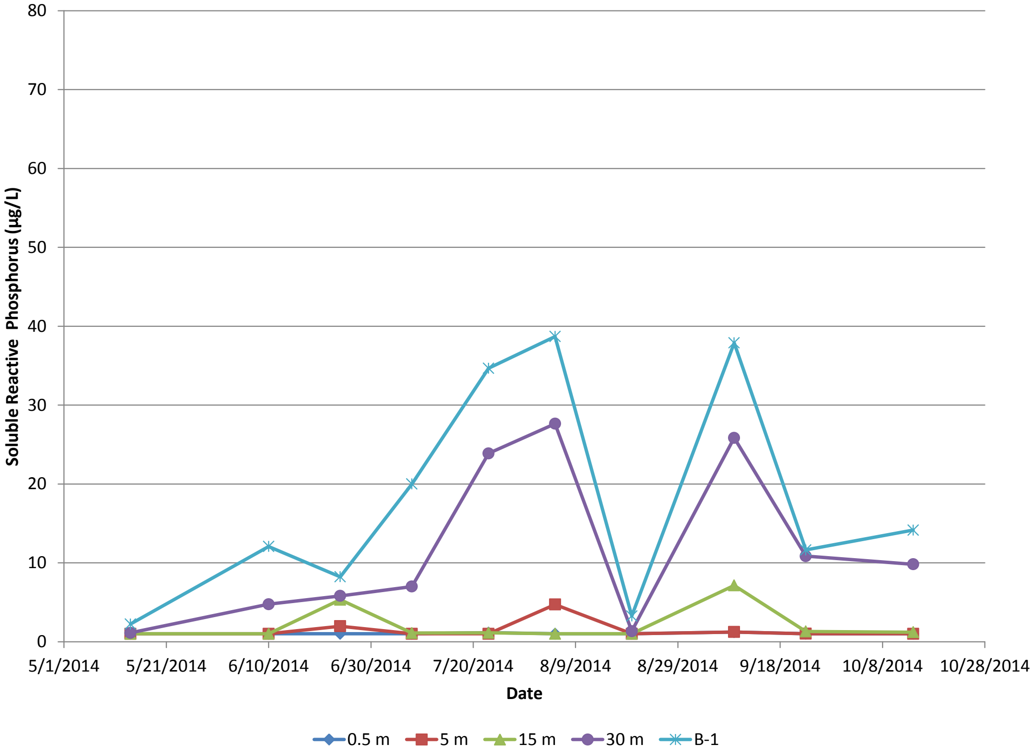

Figure 34. SRP Concentrations (µg/L) at Station LL0, May-October 2014

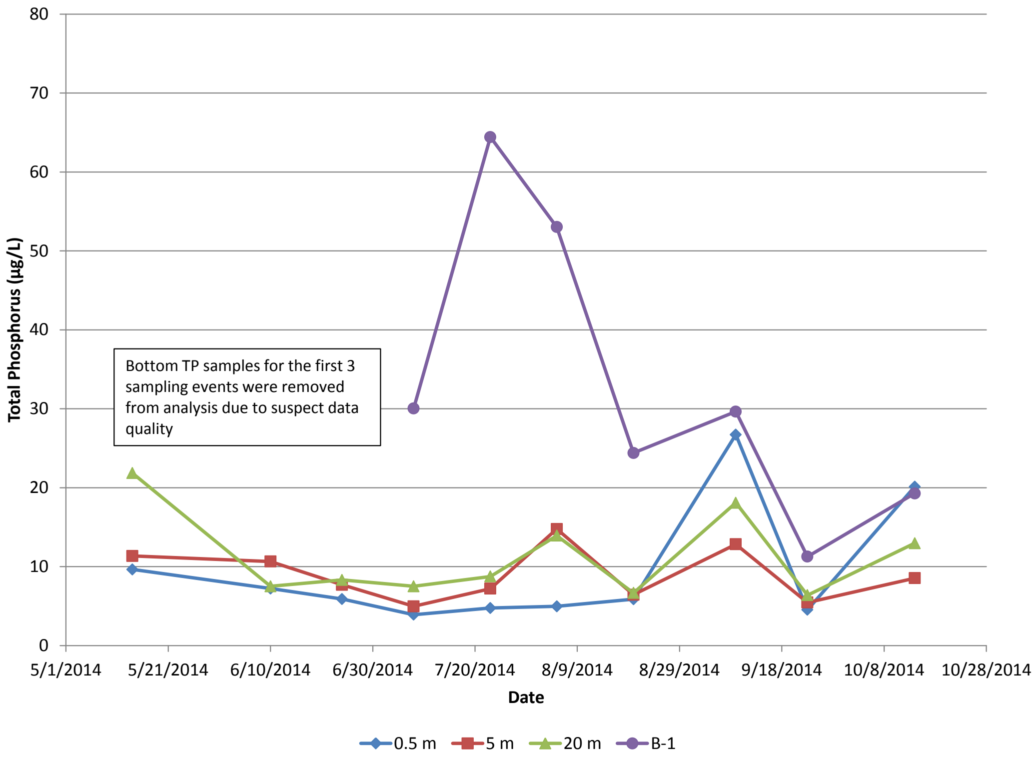

Figure 35. TP Concentrations (µg/L) at Station LL1, May-October 2014

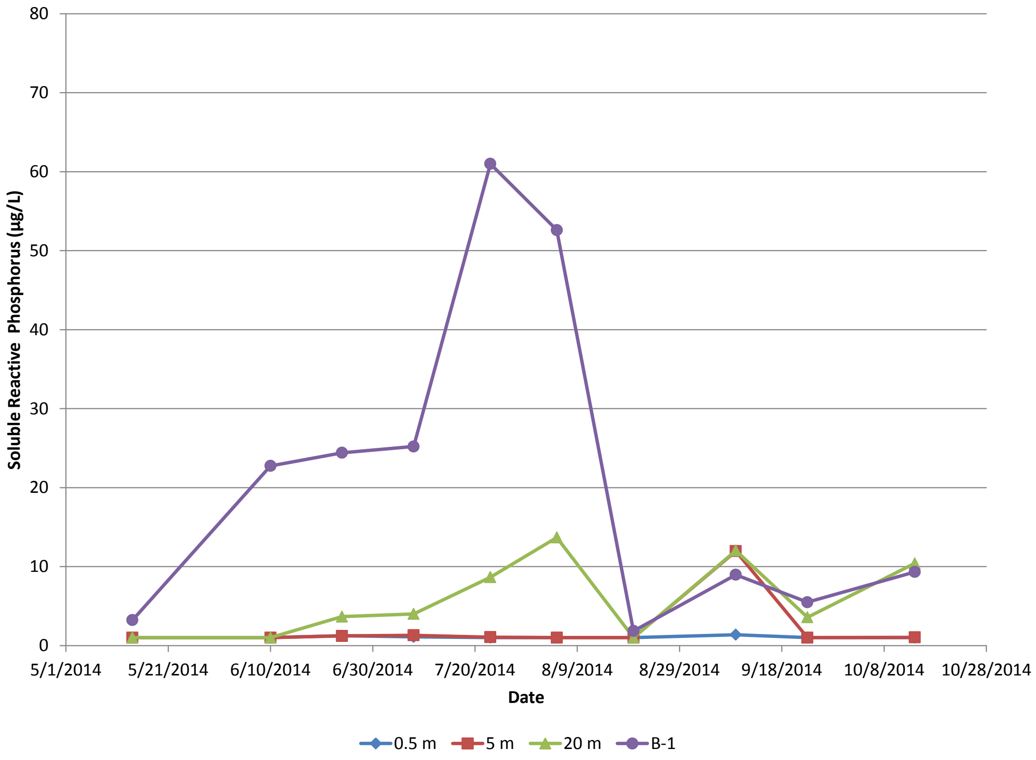

Figure 36. SRP Concentrations (µg/L) at Station LL1, May-October 2014

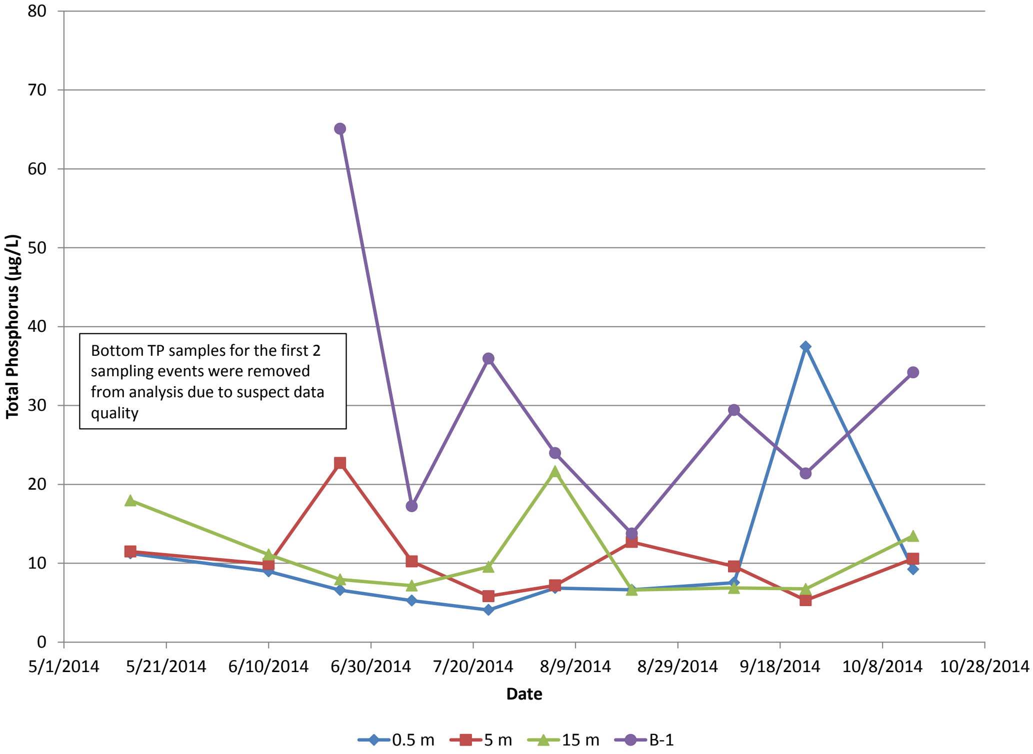

Figure 37. TP Concentrations (µg/L) at Station LL2, May-October 2014

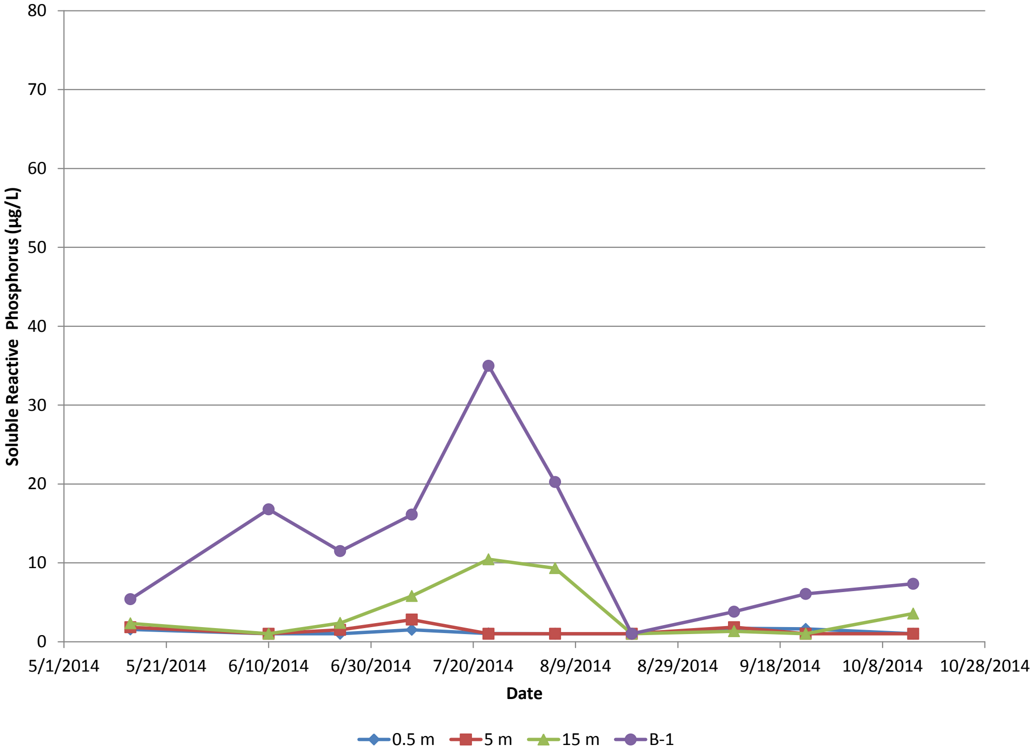

Figure 38. SRP Concentrations (µg/L) at Station LL2, May-October 2014

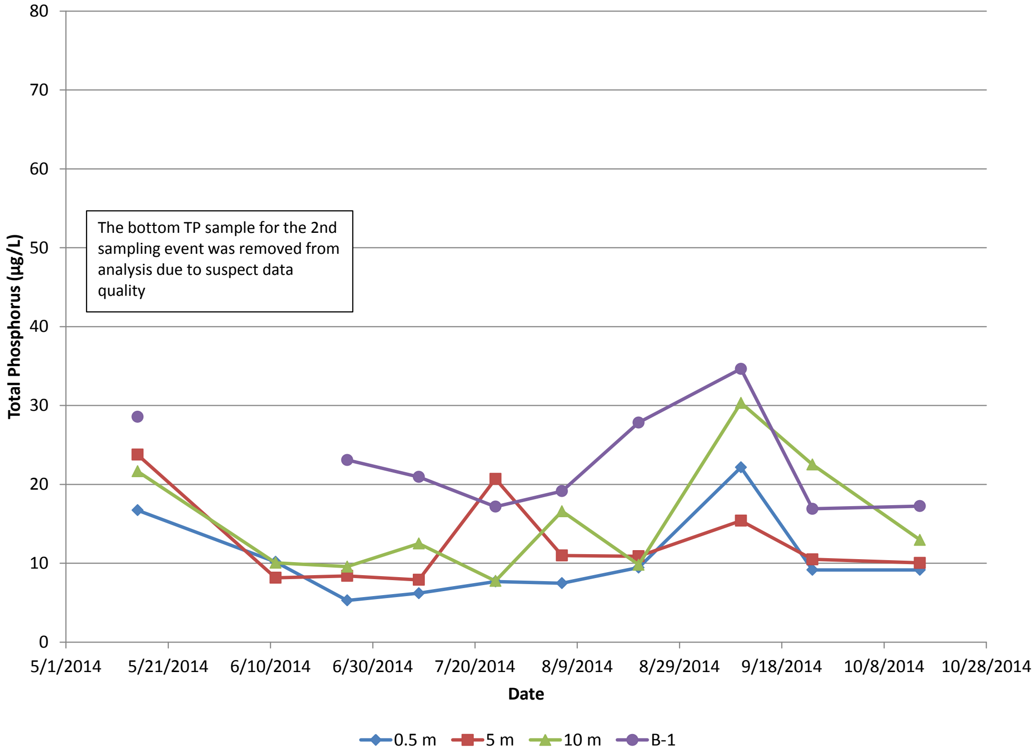

Figure 39. TP Concentrations (µg/L) at Station LL3, May-October 2014

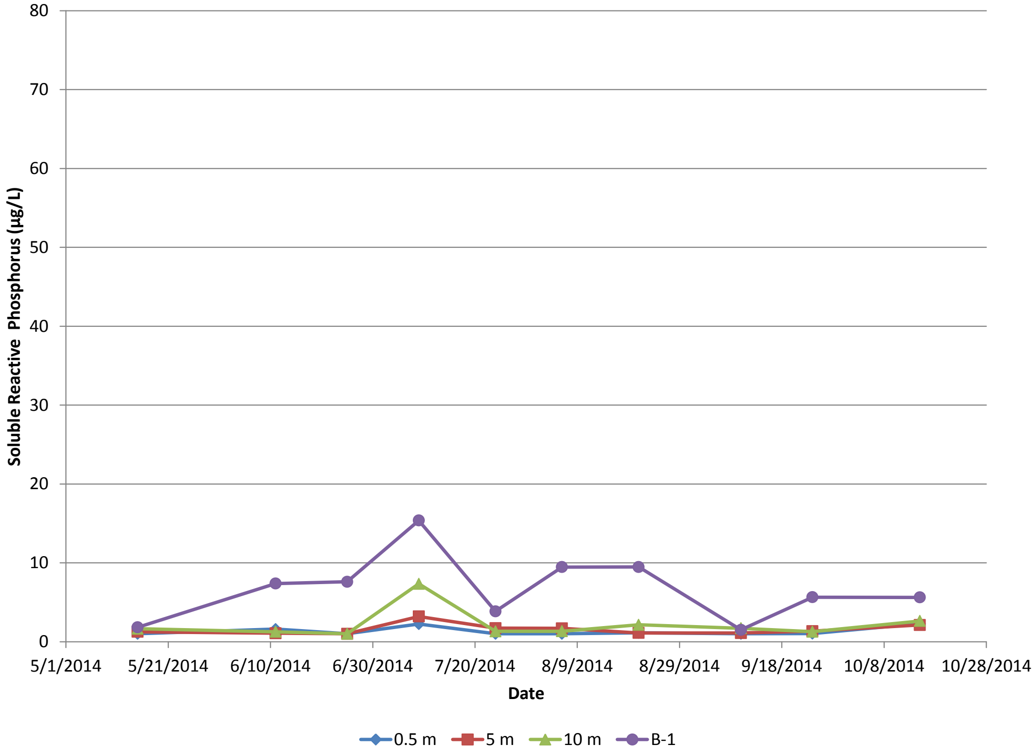

Figure 40. SRP Concentrations (µg/L) at Station LL3, May-October 2014

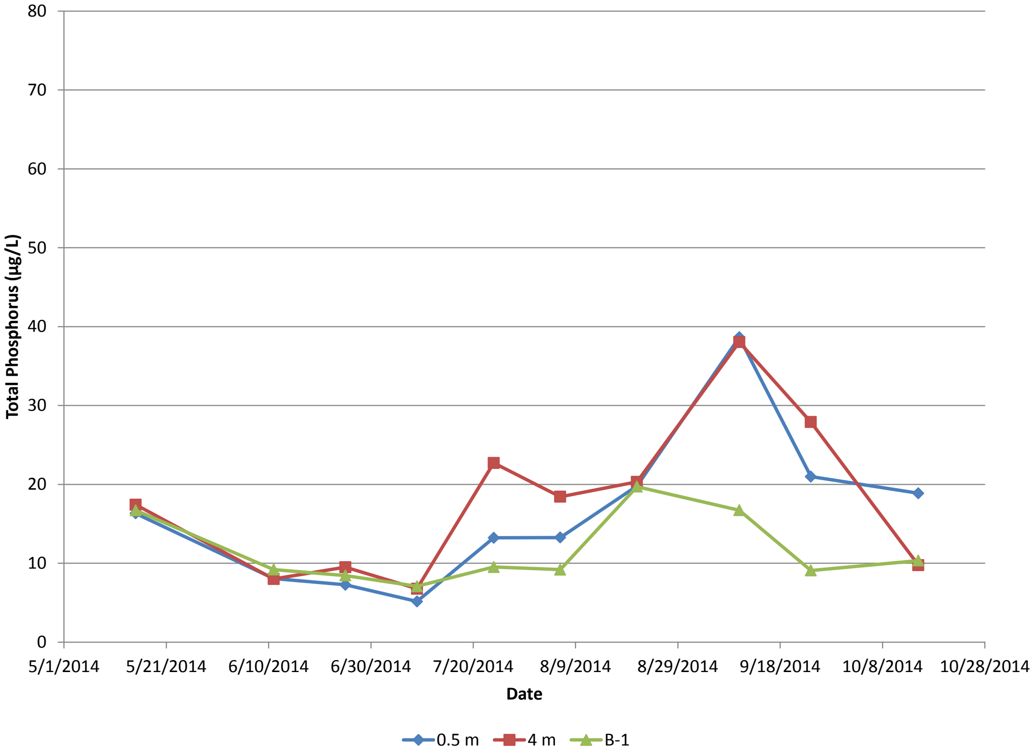

Figure 41. TP Concentrations (µg/L) at Station LL4, May-October 2014

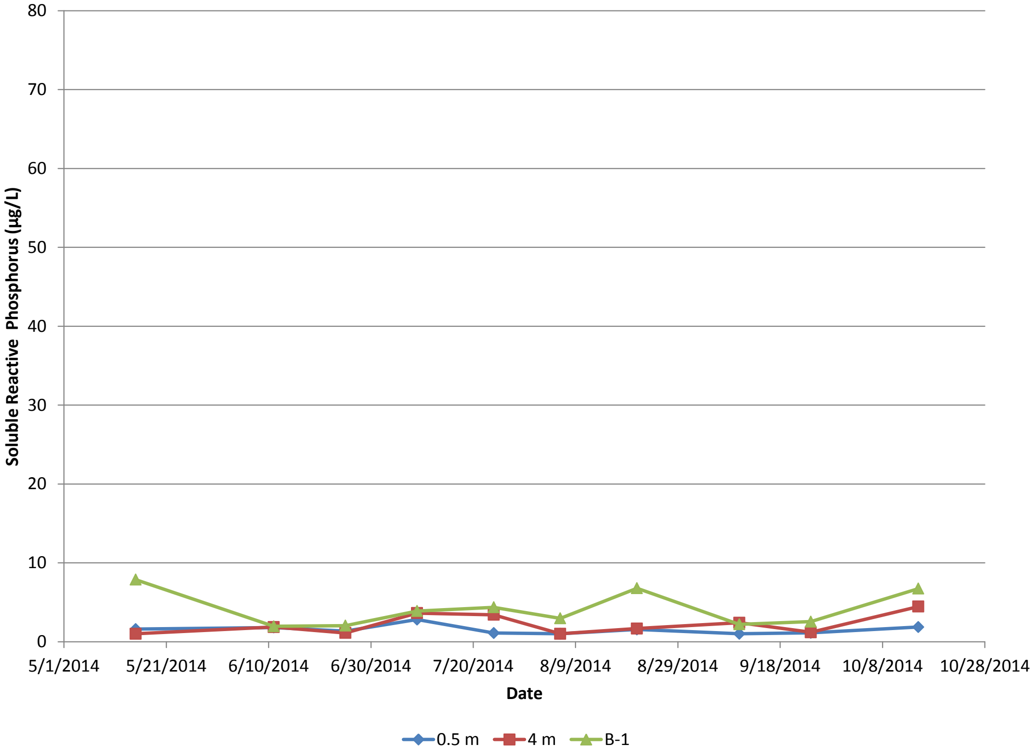

Figure 42. SRP Concentrations (µg/L) at Station LL4, May-October 2014

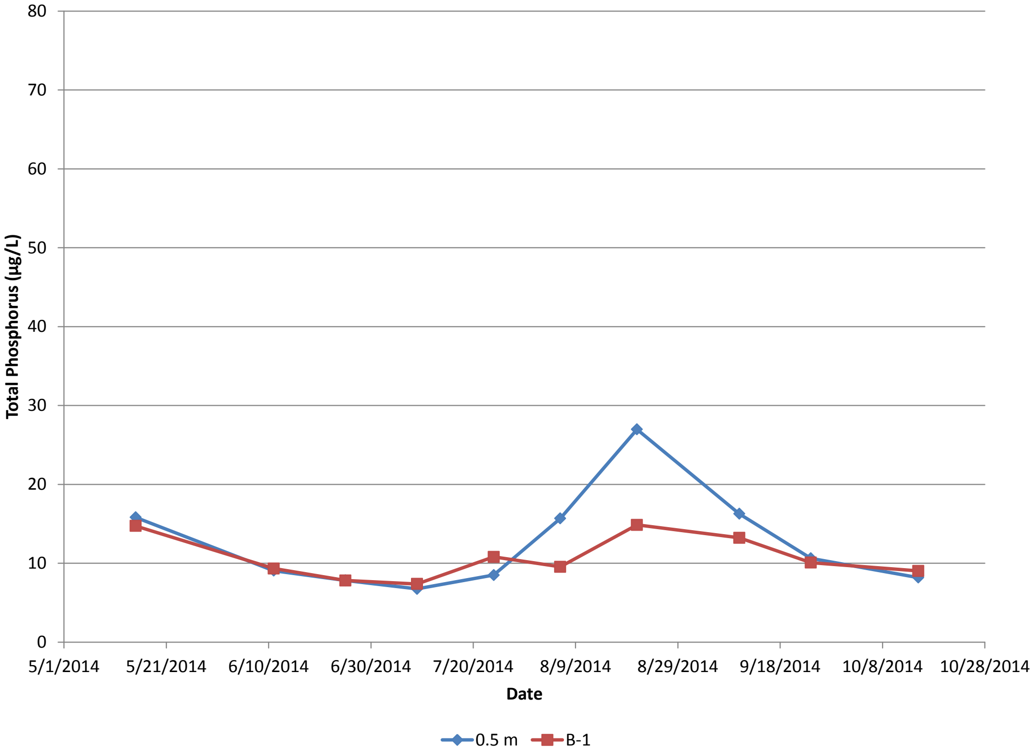

Figure 43. TP Concentrations (µg/L) at Station LL5, May-October 2014

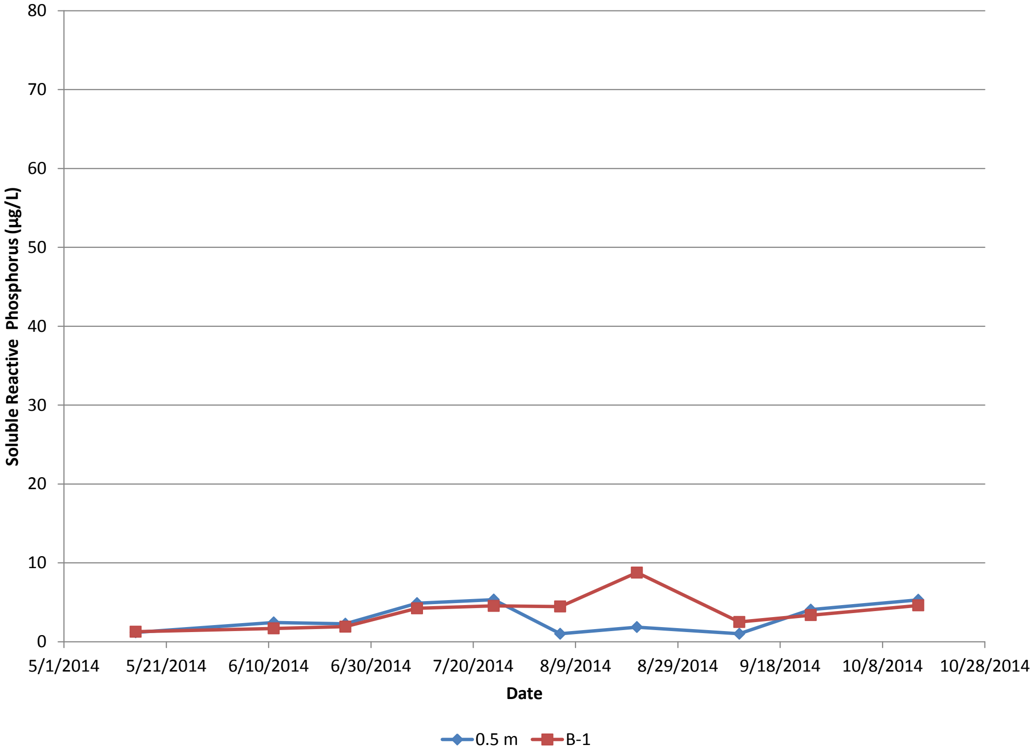

Figure 44. SRP Concentrations (µg/L) at Station LL5, May-October 2014

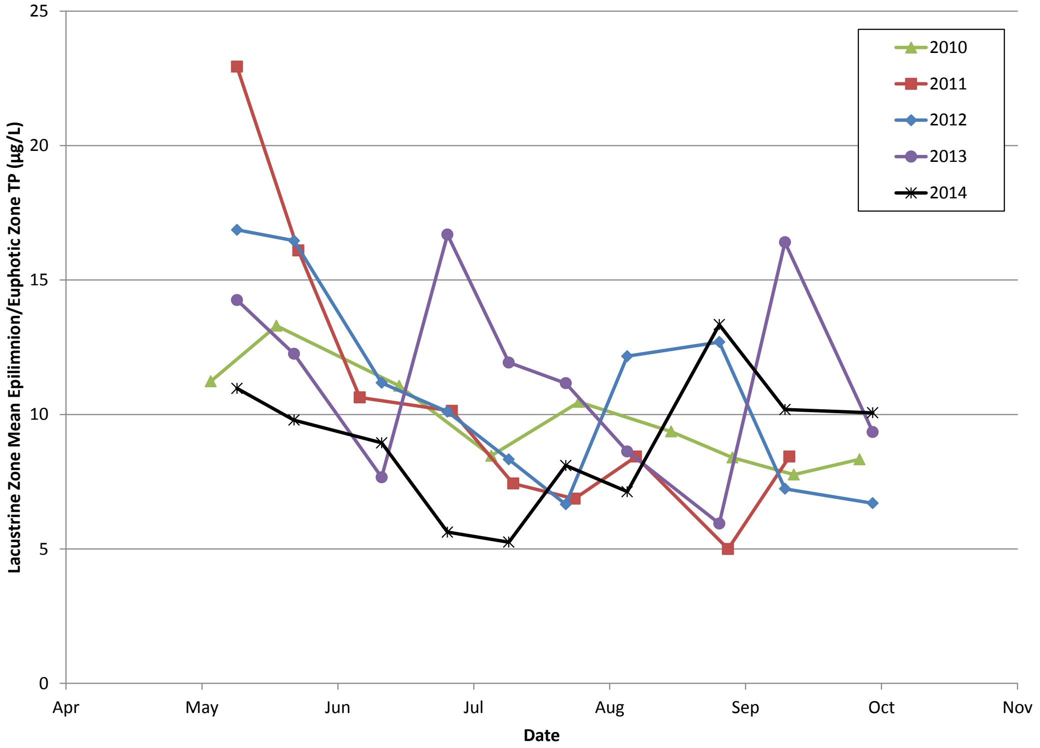

Figure 45. Mean Epilimnion TP Concentrations in the Lacustrine Zone in Lake Spokane, 2010-2014

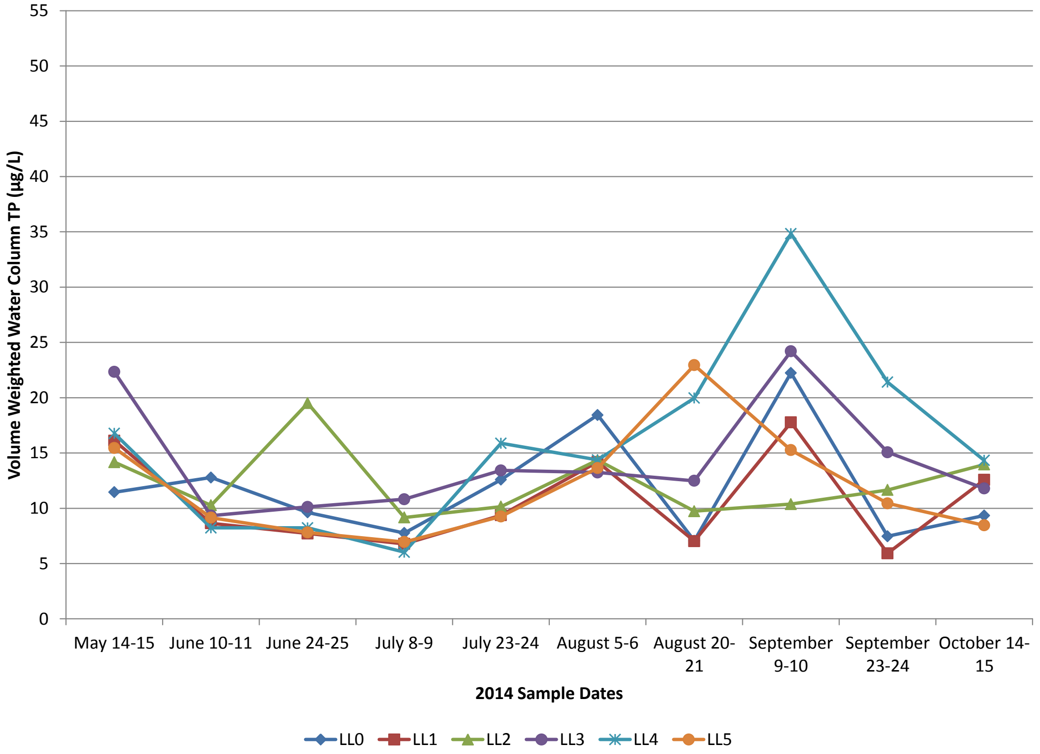

Figure 46. Volume-Weighted Water Column TP Concentrations, 2014

Nitrogen

Total nitrogen (TN) concentrations at all six stations ranged from about 250 to 2000 µg/L over the monitoring period. Nitrate+nitrite N (NO_3+NO_2-N) concentrations ranged from about 200 to 1600 µg/L over the monitoring period. Thus, most of the TN is nitrate+nitrite. Average lacustrine epilimnetic TN and nitrate+nitrite concentrations during June-September were 606 and 480 µg/L, respectively.

The lowest levels of nitrogen occurred in May at all sites. Nitrogen increased, for the most part, throughout the reservoir during the monitoring period (Figures 47 through 58). Starting in July, concentrations in the metalimnion and upper hypolimnion increased more than in the epilimnion at most sites. Higher concentrations were generally observed in the hypolimnion and bottom water at all stations, except at station LL0 where nitrogen concentrations at the bottom were much lower than concentrations observed at 15 and 30 m. Bottom concentrations at LL0 increased in October when the water column began to mix. This pattern and concentrations were similar to that in 2013.

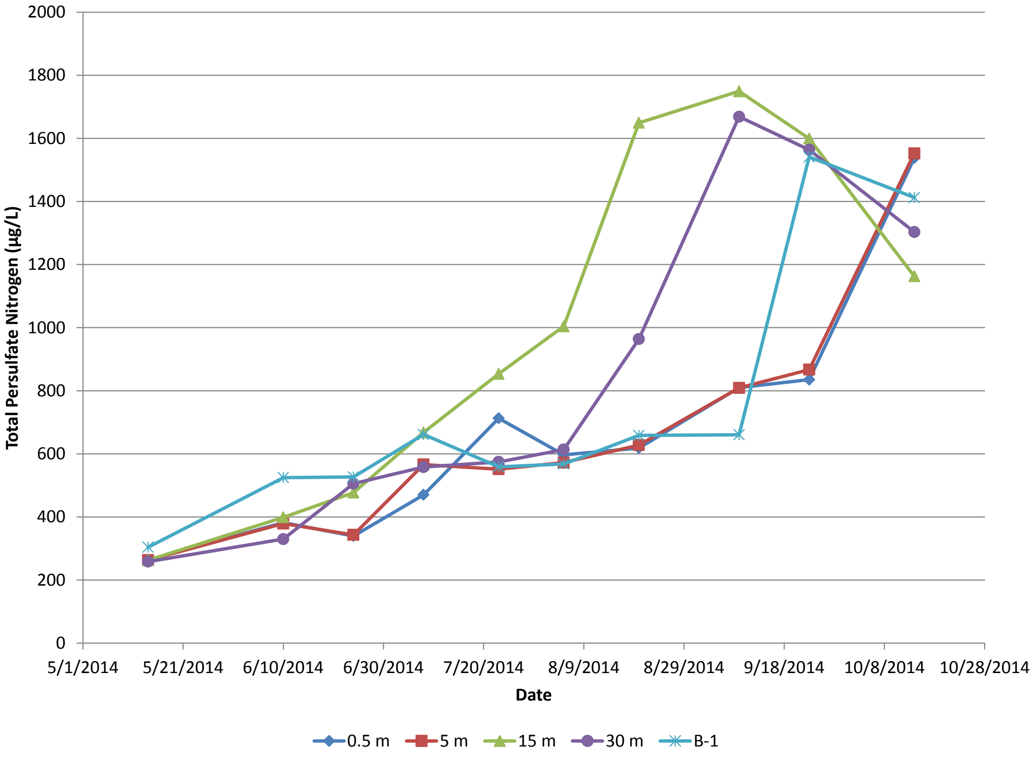

Figure 47. TN Concentrations (µg/L) at Station LL0, May-October 2014

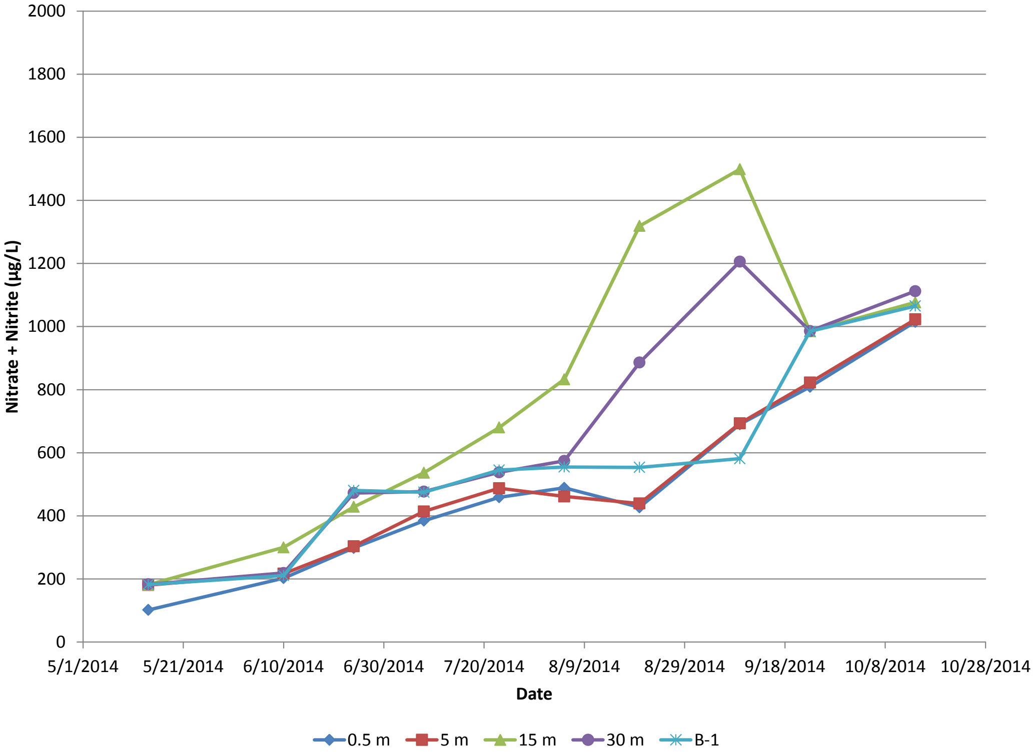

Figure 48. NO_3+NO_2 Concentrations (µg/L) at Station LL0, May-October 2014

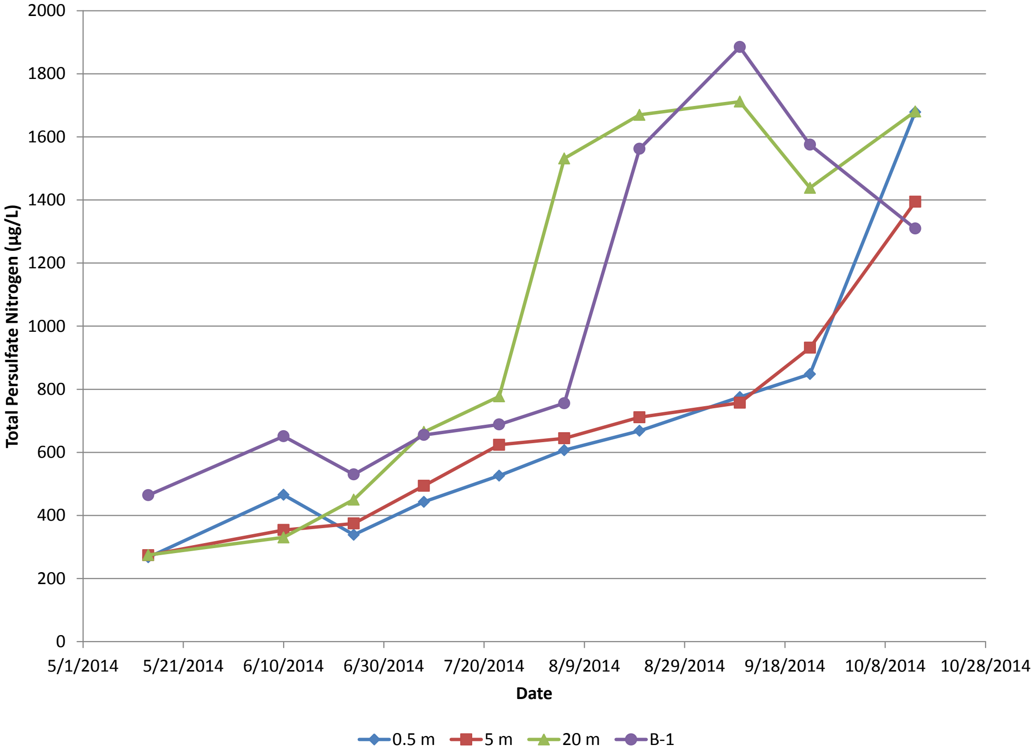

Figure 49. TN Concentrations (µg/L) at Station LL1, May-October 2014

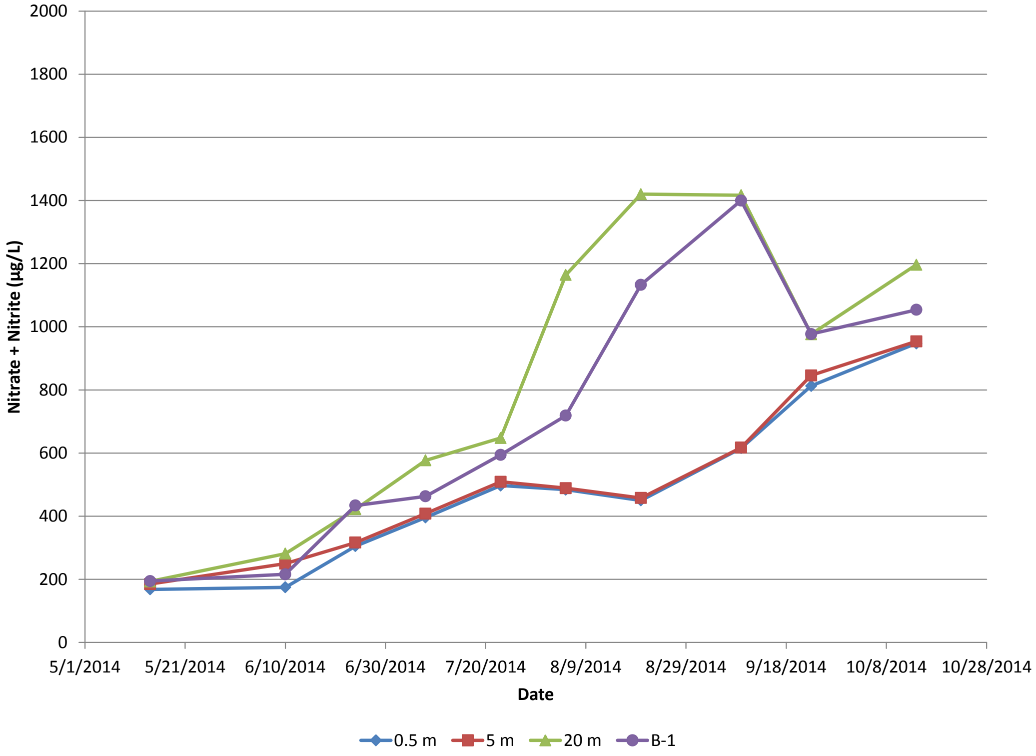

Figure 50. NO_3+NO_2 Concentrations (µg/L) at Station LL1, May-October 2014

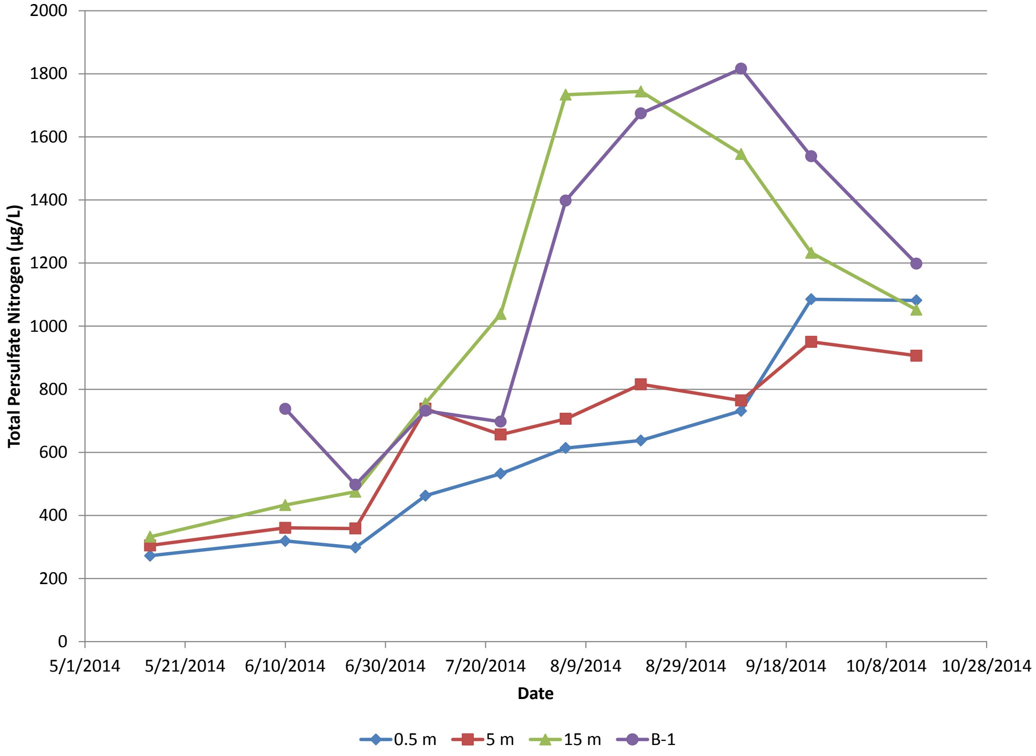

Figure 51. TN Concentrations (µg/L) at Station LL2, May-October 2014

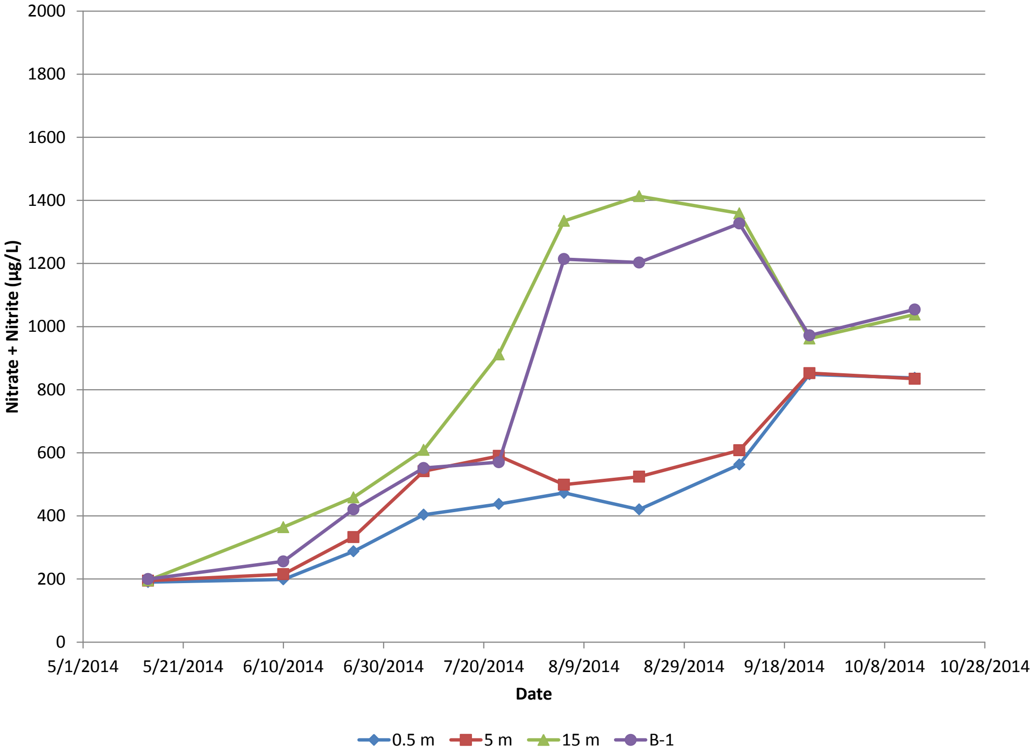

Figure 52. NO_3+NO_2 Concentrations (µg/L) at Station LL2, May-October 2014

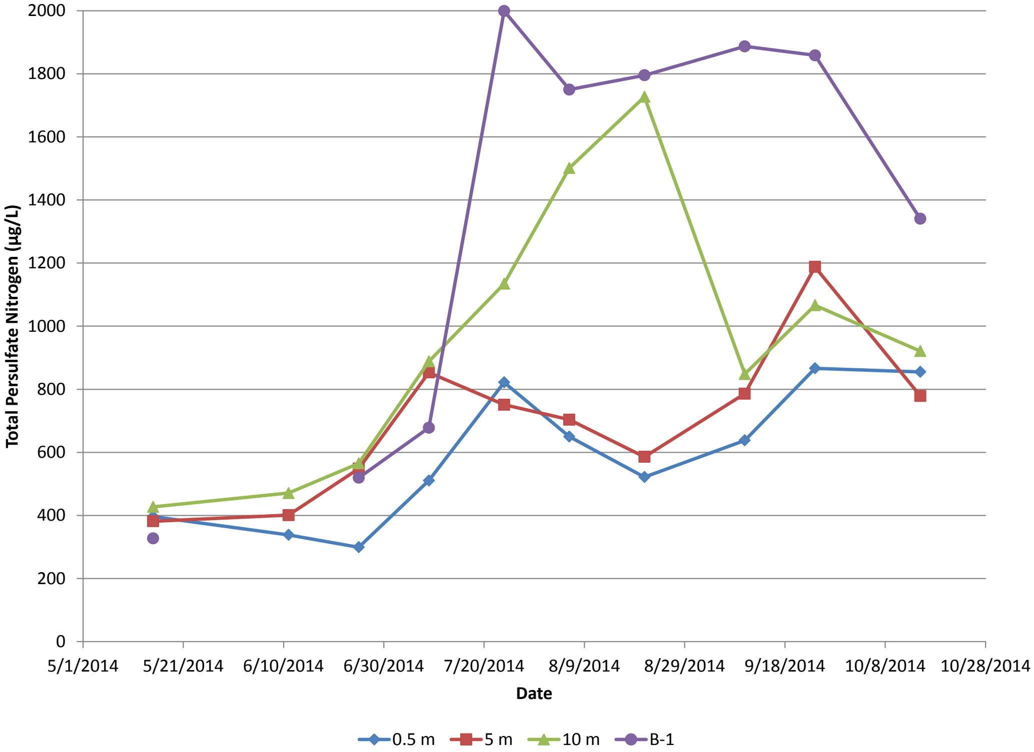

Figure 53. TN Concentrations (µg/L) at Station LL3, May-October 2014

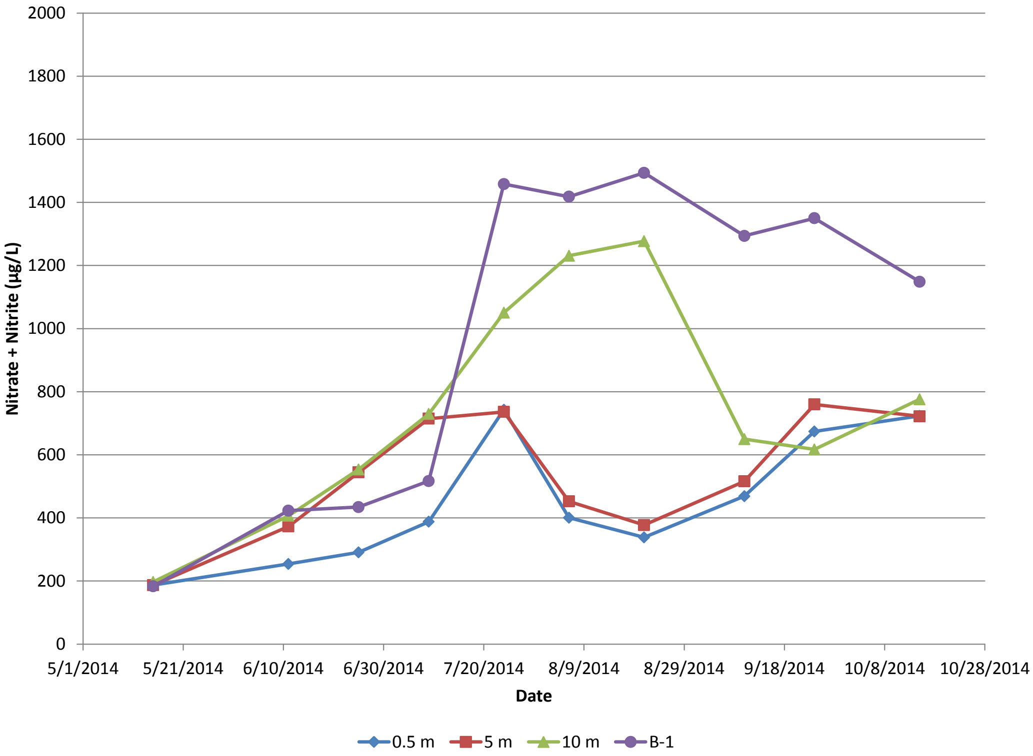

Figure 54. NO3+NO2 Concentrations (µg/L) at Station LL3, May-October 2014

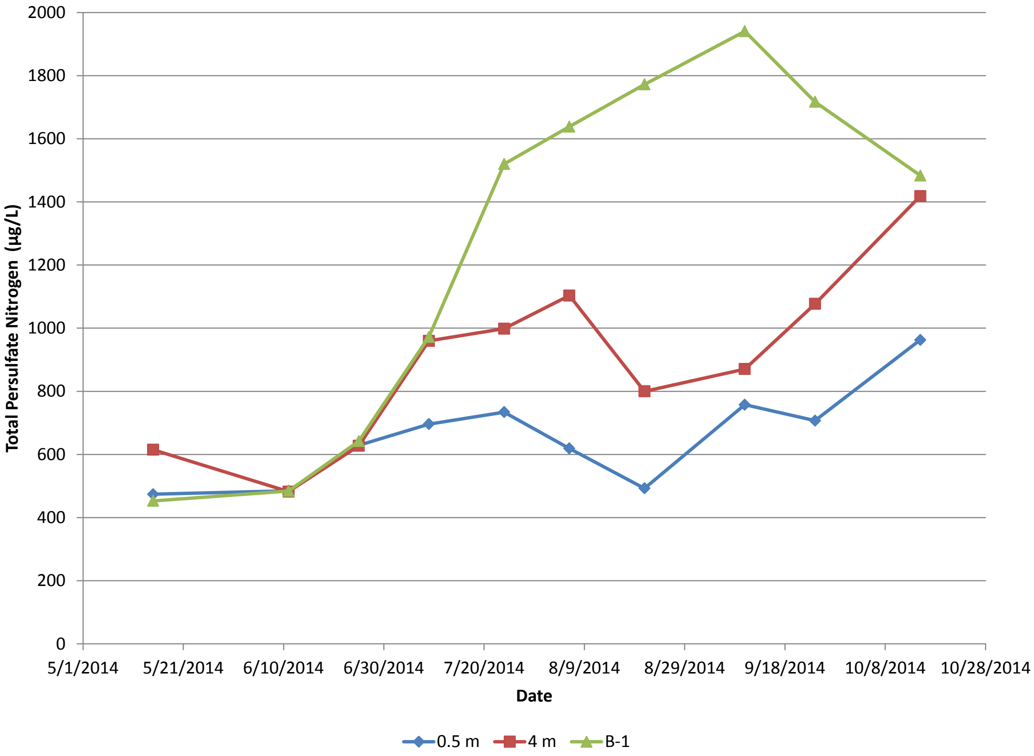

Figure 55. TN Concentrations (µg/L) at Station LL4, May-October 2014

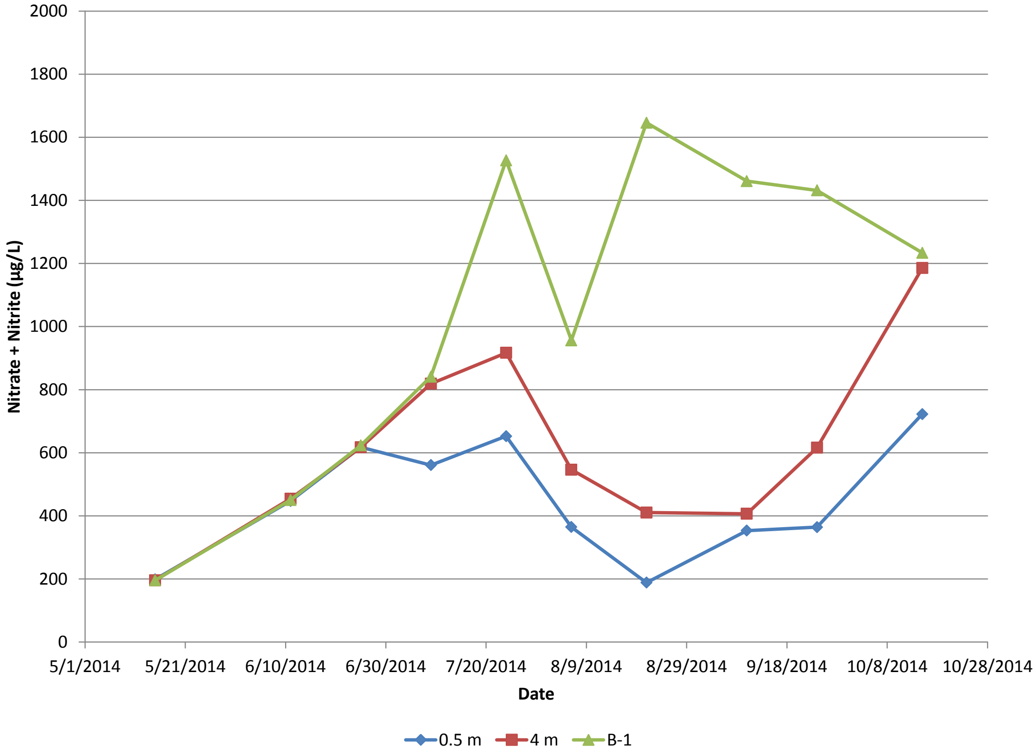

Figure 56. NO_3+NO_2 Concentrations (µg/L) at Station LL4, May-October 2014

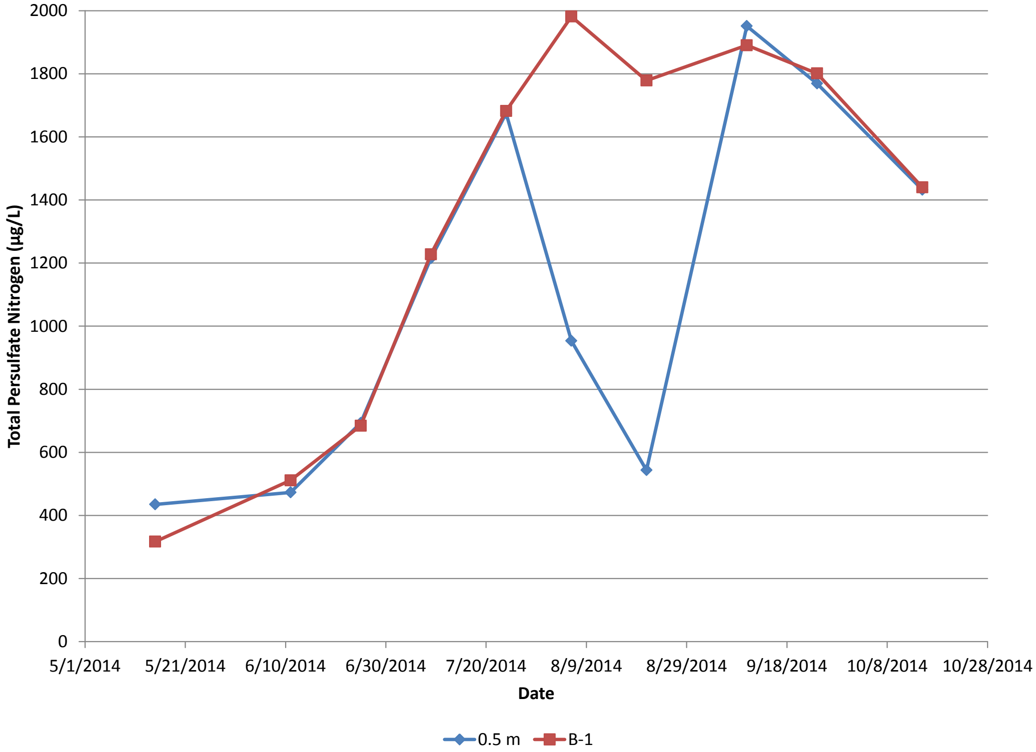

Figure 57. TN Concentrations (µg/L) at Station LL5, May-October 2014

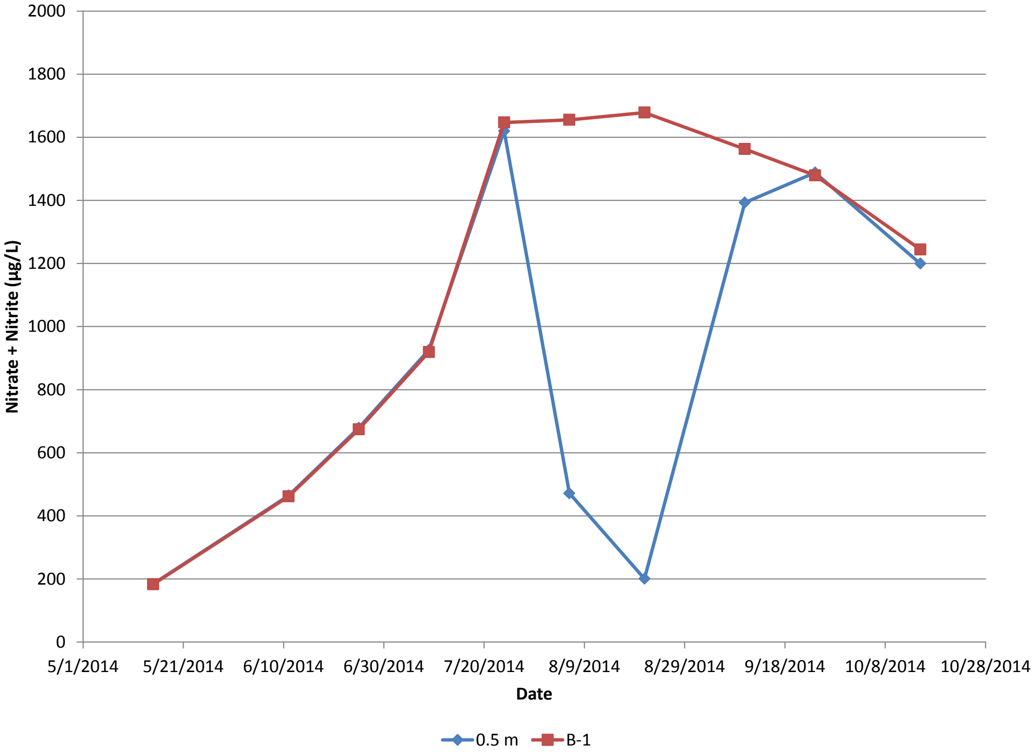

Figure 58. NO_3+NO_2 Concentrations (µg/L) at Station LL5, May-October 2014

3.2.6 PHYTOPLANKTON

Chlorophyll concentrations at the six stations ranged from 0.5 to 25.4 µg/L in 2014. Maximums at most sites were higher than in 2012 or 2013. Chlorophyll was often highest at the 5 m depth, which was the case in 2012 and 2013. (Figures 59 through 64). However, chl differed more seasonally than with depth at the three up-reservoir sites, where sizable blooms occurred in August and September, especially at LL4 during both 2013 and 2014. The maximum chl concentration observed (25.4 µg/L) in 2014 was at 10 m at LL3 during early September. This high concentration was most likely due to transport of algae within the interflow zone from LL4 after the increase in inflow following Labor Day.

Chlorophyll was higher in May-June at the two deepest stations (LL0 and LL1) than at the shallower stations where there were lower levels in the spring and higher in summer (Figures 59 through 64). The higher summer levels corresponded with TP concentrations reaching 38.6 µg/L at LL4 in September (Figure 41). Chlorophyll at the shallower stations peaked in August-September, with concentrations observed at LL4 of around 20 µg/L. Chlorophyll reached a peak as high in 2013 as in 2014, but did not persist as long. The pattern at LL5 was similar to those in 2012 and 2013, but the maximum occurred earlier and was greater in 2014. These chl peaks correspond to the dates in which the water column at LL5 was stratified and residence time was high allowing time for algal biomass to accumulate. Also, surface water temperatures at LL5 in late summer 2014 were much higher than the previous years, which would facilitate water column stability.

The sharp increase in chl at LL4 and LL5 in late August corresponded to the water column at both sites having a very green color and low transparency, which persisted at LL4 through September but not at LL5. Increased inflows in early September were observed to mix the water column at LL5 and transport algae downstream. Although an algal bloom occurred at LL4 and in between LL4 and LL5, a large scum did not develop. In fact, there were no scums observed during 2014. This contrasts with previous years (2010 and 2012), in which a thick scum of accumulated algae (primarily cyanobacteria) occurred up-reservoir of LL4, just down-reservoir from the Nine Mile Falls boat launch, as well as at LL5. That is surprising since transition/riverine zone average water residence time was greater in 2014 (5.9 days) than in 2010 and 2012 (4.5 and 3.6 days).

Composition of the phytoplankton showed that diatoms (*Chrysophyta*) were dominant at all stations during the spring, based on both cell counts and biovolume (Figures 65-76). Cyanobacteria increased numerically (cells/ml) at all sites in August, but were represented by significant biovolume at LL4 and LL5 only. In 2013, cyanobacteria were not strongly represented at any site. The 2014 pattern is similar to 2012 when diatoms dominated during the spring at all sites, but cyanobacteria dominated cell counts at all sites in late summer. Diatoms and green algae represented the greatest biovolume at all sites in 2014, although substantial cyanobacteria biovolume existed at LL4 and especially at LL5 in August. Apparently the green color of the water and high chl at LL4 was due mostly to diatoms, but also with some cyanobacteria (Figure 74).

The percent of biovolume represented by cyanobacteria was much greater in 2012 and 2014 than in 2013, averaging 17 times more in 2014 than 2013 (Table 9). It appears the high late summer water temperature with low inflow and longer water residence time, a more stratified water column and high TP concentrations (LL4) in 2014 were favorable for bloom development of cyanobacteria. A TP of 35 µg/L (volume-weighted) was reached at LL4 in September. Average TP in the inflow at Nine Mile Bridge was much lower than at LL4 (14.0 µg/L; see Section 3.2.9 and Table 14). Also, TP at LL4 was greater than at LL5 in September.

The difference in phytoplankton composition among the years may be related to the markedly different water residence times, which were much greater for both the whole lake (37 and 31 days) and the transition/riverine zones (6.9 and 5.9 days) in 2013 and 2014 than in 2012 (19 and 3.6 days). Phytoplankton density and biovolume were greater at LL5 in 2013 and 2014 than 2012, consistent with the longer residence times. Cyanobacteria were also more abundant at LL4 and LL5 in 2013 and 2014. Cyanobacteria would be expected to dominate the algal community with longer residence times, because cyanobacteria are slower growing and cannot tolerate short residence times. In general, residence times <10 days begin to limit biomass accumulation (Welch and Jacoby 2004). Diatoms and green algae also had high densities and biovolumes at both LL4 and LL5 in 2014. While residence time may partly explain the differences among years at these two sites, its effect at the other sites is not apparent; residence time is not a limitation in the lacustrine zone. Thus, there are likely other factors that account for the marked difference in composition among years in that zone. Nutrients probably do not explain the difference; average TP concentrations were not appreciably different among the years in any of the three zones.

The pattern of phytoplankton distribution, showing maximum chl, cell density, and biovolume at LL4, may indicate an in-reservoir source of phosphorus and algal-generated organic matter that provides DO demand to the lacustrine zone’s metalimnia and hypolimnia. This source of organic matter from phytoplankton was much greater in the 1970s and 1980s, before and after wastewater phosphorus reduction. Average whole-lake summer chl, before and immediately after phosphorus reduction was 20 and 11 µg/L and average biovolume was 7.1 and 2.7 mm^3/L, respectively. That is compared to whole-lake summer averages for 2013 and 2014 of 3.7 and 4.4 µg/L chl and 2.0 and 1.9 mm^3/L, respectively.

Phytoplankton were largely confined to the epilimnion in July and August when three depths (0.5, 5, and 15 m) were sampled in the lacustrine zone. Both density and biovolume of the same taxa composition at 15 m were a relatively small fraction of those at 0.5 and 5m (see Appendix III). In July, 0.5 and 5 m samples in the lacustrine zone were composed of the same cyanobacteria species, *Anacystis*. However, cyanobacteria (any species) was only present in one 15 m sample, LL0, in July. This was different from August when samples at all depths contained multiple species of cyanobacteria, although the dominant species was still *Anacystis*.

The dominant taxa in terms of maximum biovolume were the diatoms *Asterionella formosa* and *Fragilaria crotonensis* at most times throughout the reservoir (see Appendix III). Another diatom, *Melosira* (or *Aulososeira*) was dominant in the upper reservoir on a couple occasions in September and October. On the basis of density (cells/ml), the cyanobacterium *Anacystis* dominated in July and August at all sites, while *Coelospherium* was most abundant at some sites and times in September. *Anacystis* was again dominant in October in the lacustrine zone. Cyanobacteria were greater in cell density than diatoms, while diatoms dominated the biovolume, because their cells are much larger.

Table 9. Average phytoplankton biovolume and percent cyanobacteria at the six stations during 2012-204.

Station	Mean Summer Phytoplankton (mm^3/L)			Mean Summer % Cyanos by Volume			Max Summer % Cyanos by Volume		
	2012	2013	2014	2012	2013	2014	2012	2013	2014
LL0	0.57	1.77	1.06	0.68	0.28	8.73	1.79	1.27	24.1
LL1	0.69	1.13	1.07	1.56	0.67	7.62	7.76	2.48	20.8
LL2	0.77	1.20	1.19	0.68	0.56	6.75	1.79	1.51	18.6
LL3	0.82	2.16	1.87	1.01	0.57	7.75	4.18	2.47	37.4
LL4	0.93	3.07	3.73	2.80	1.24	8.72	11.9	8.62	39.5
LL5	0.67	2.62	2.33	0.31	0.64	16.7	0.72	1.61	81.3

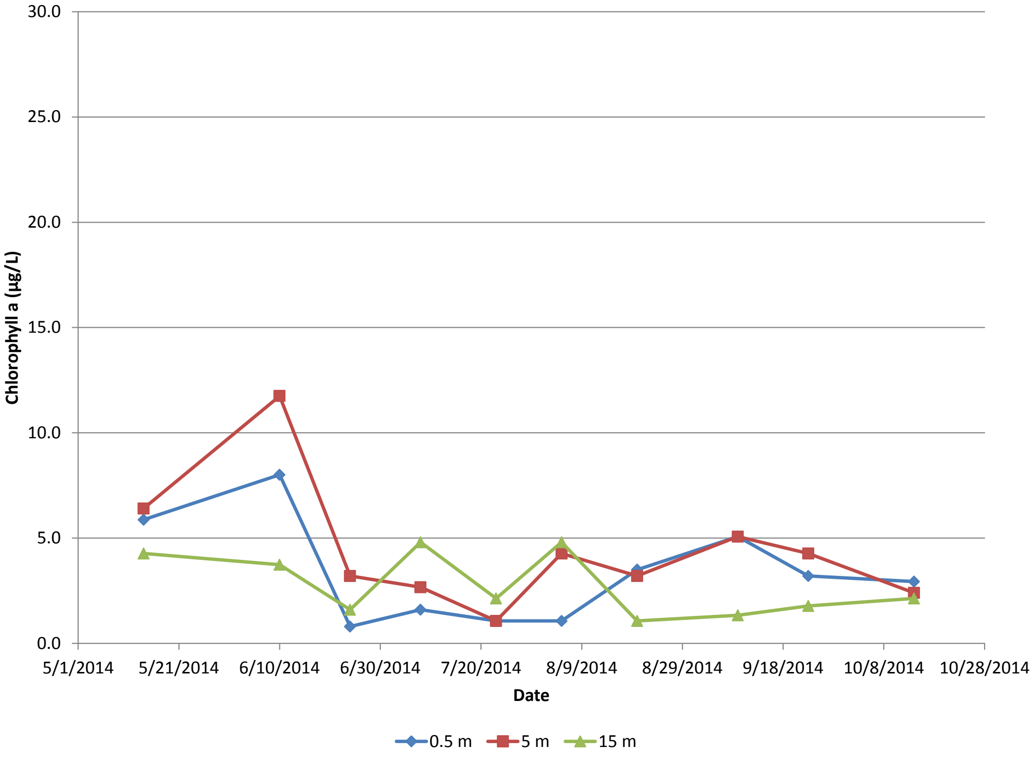

Figure 59. Chl Concentrations (µg/L) at Station LL0, May-October 2014

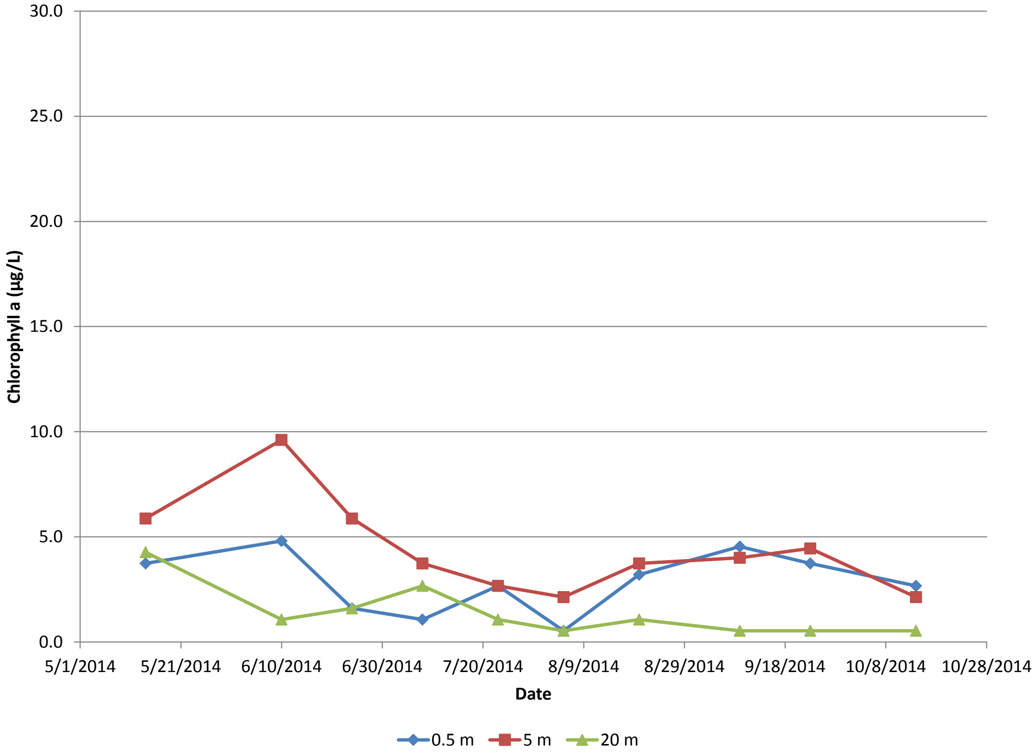

Figure 60. Chl Concentrations (µg/L) at Station LL1, May-October 2014

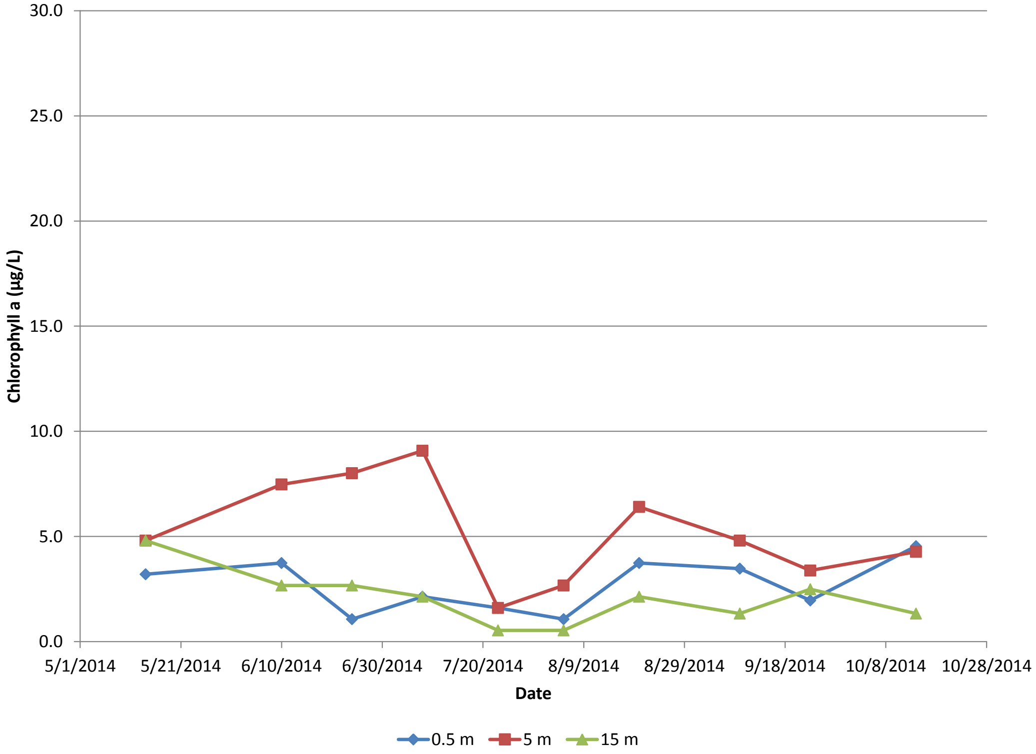

Figure 61. Chl Concentrations (µg/L) at Station LL2, May-October 2014

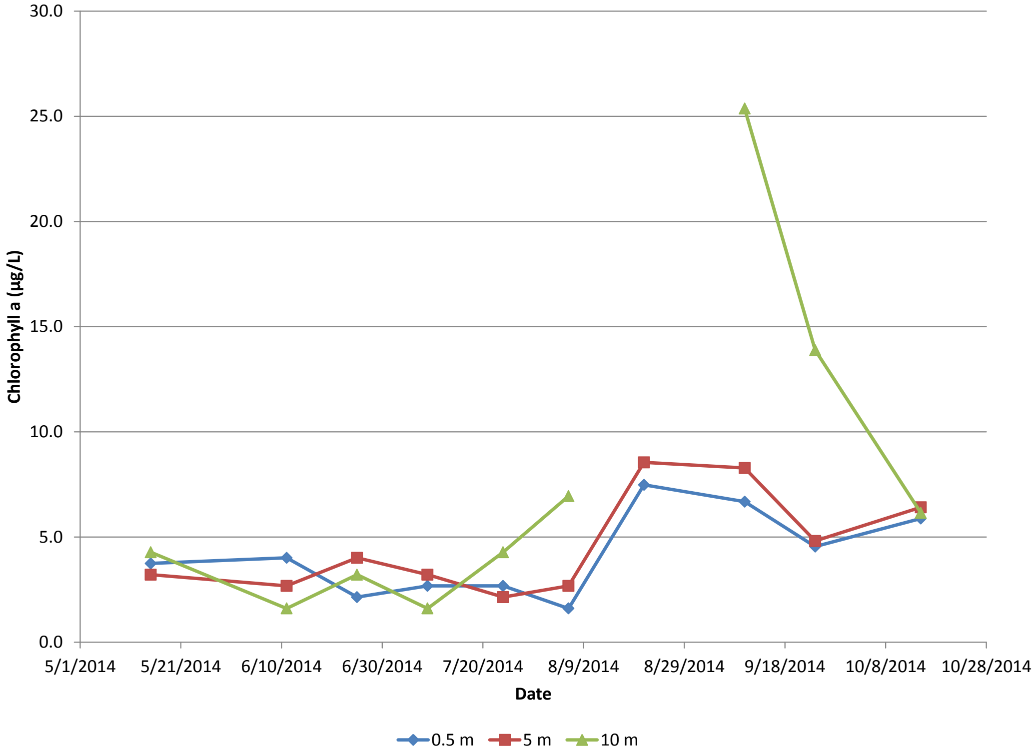

Figure 62. Chl Concentrations (µg/L) at Station LL3, May-October 2014

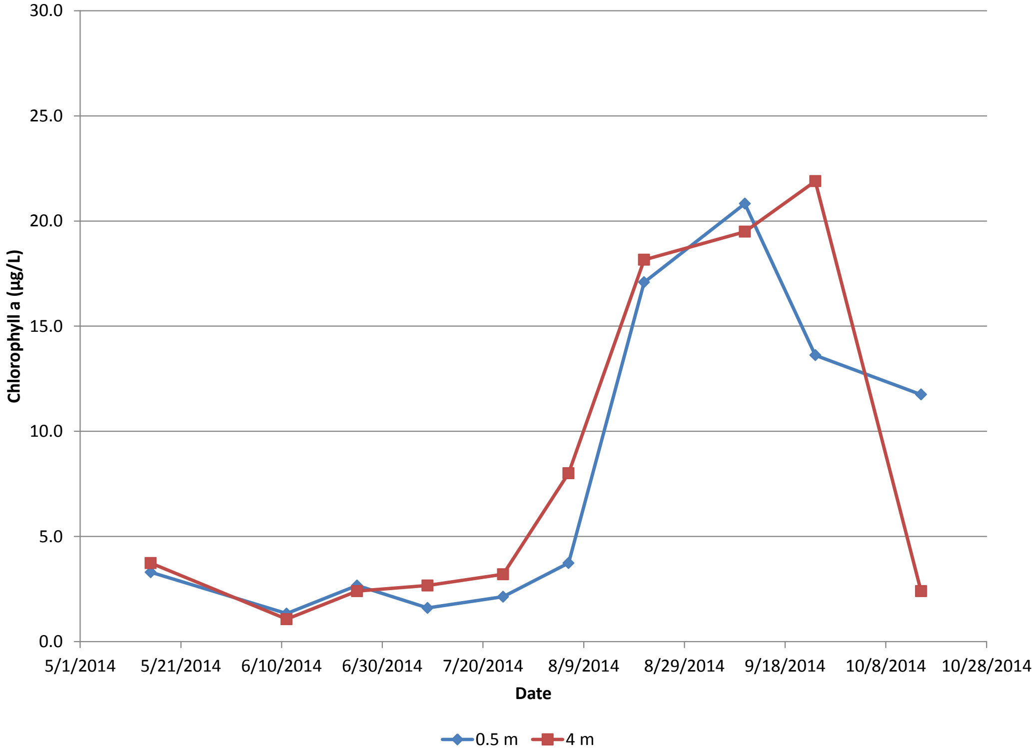

Figure 63. Chl Concentrations (µg/L) at Station LL4, May-October 2014

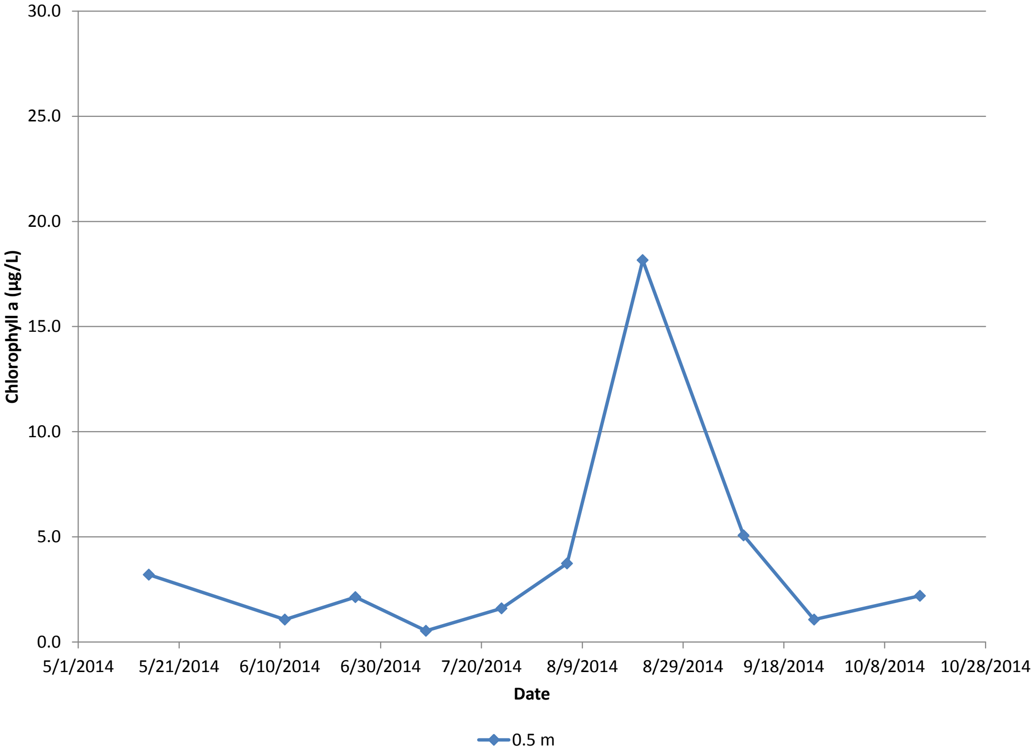

Figure 64. Chl Concentrations (µg/L) at Station LL5, May-October 2014

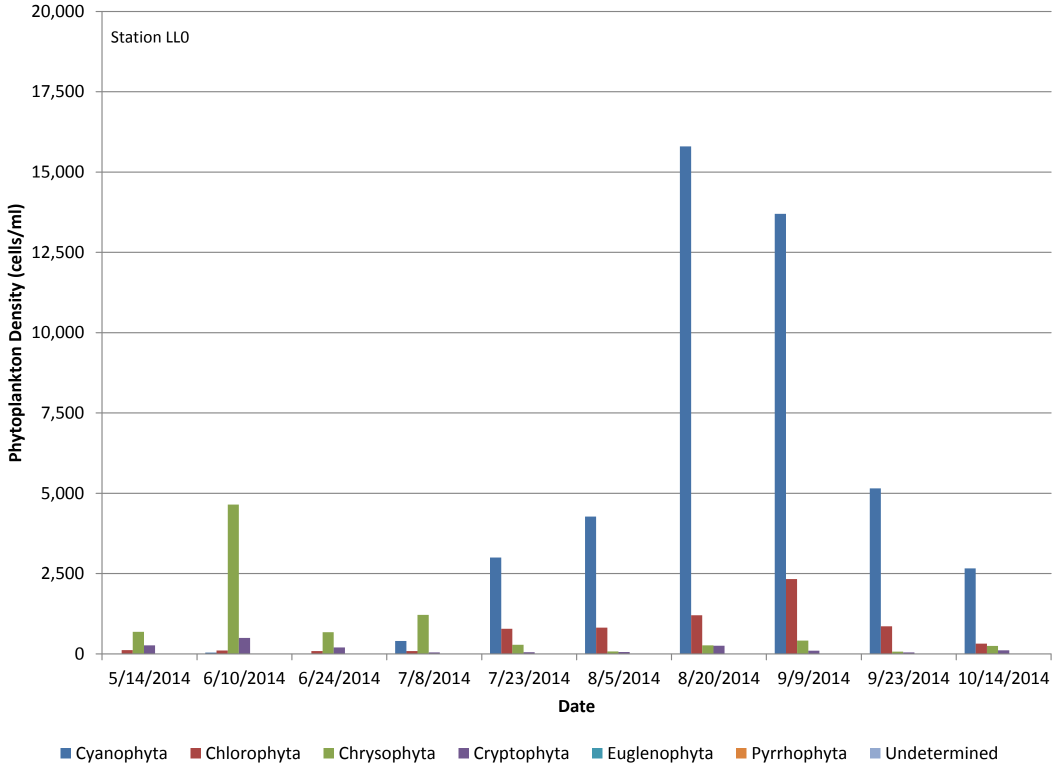

Figure 65. Phytoplankton Density (cells/ml) at Station LL0, May-October 2014

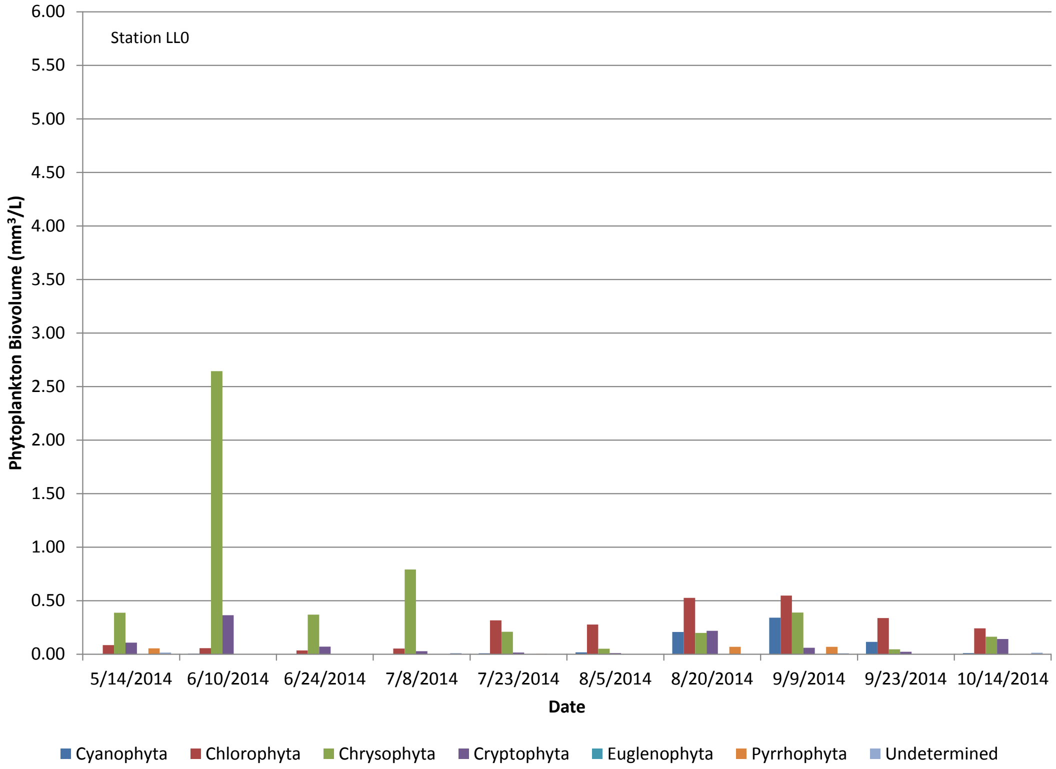

Figure 66. Phytoplankton Volume (mm^3/L) at Station LL0, May-October 2014

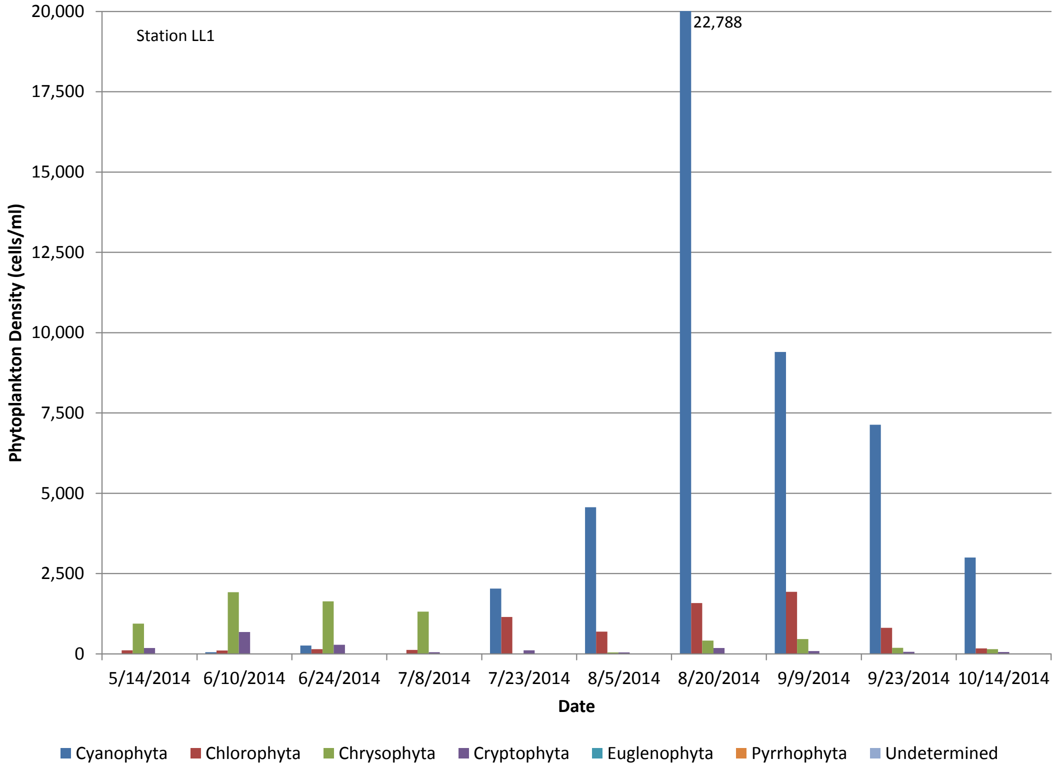

Figure 67. Phytoplankton Density (cells/ml) at Station LL1, May-October 2014

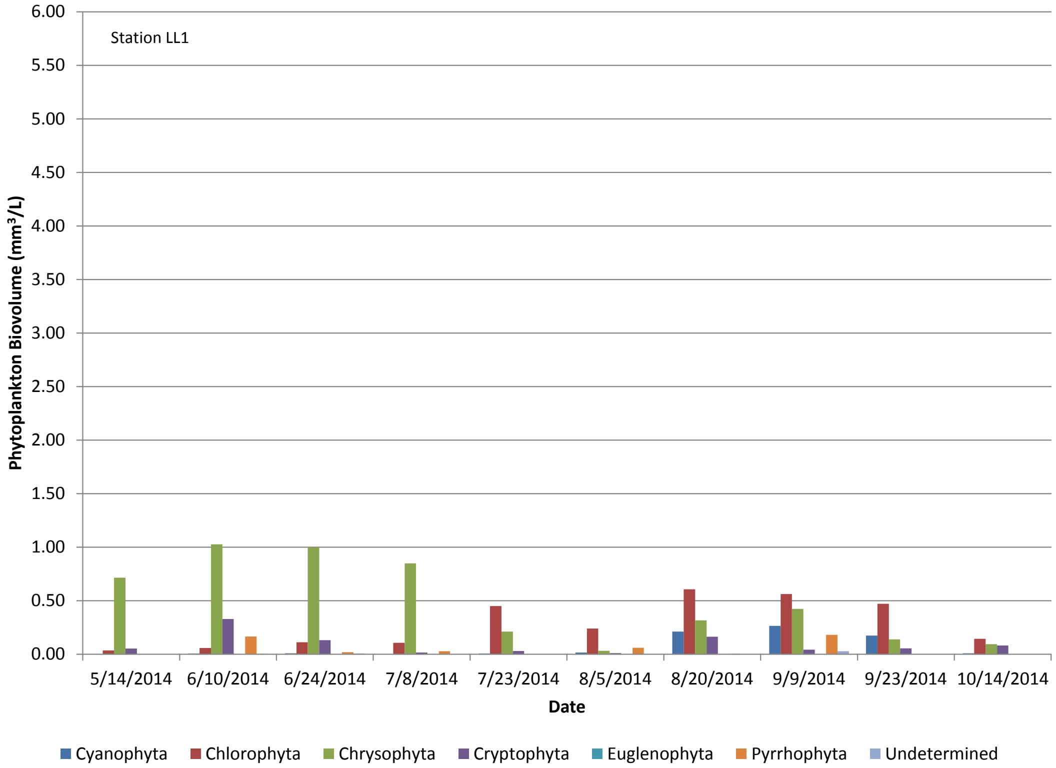

Figure 68. Phytoplankton Volume (mm^3/L) at Station LL1, May-October 2014

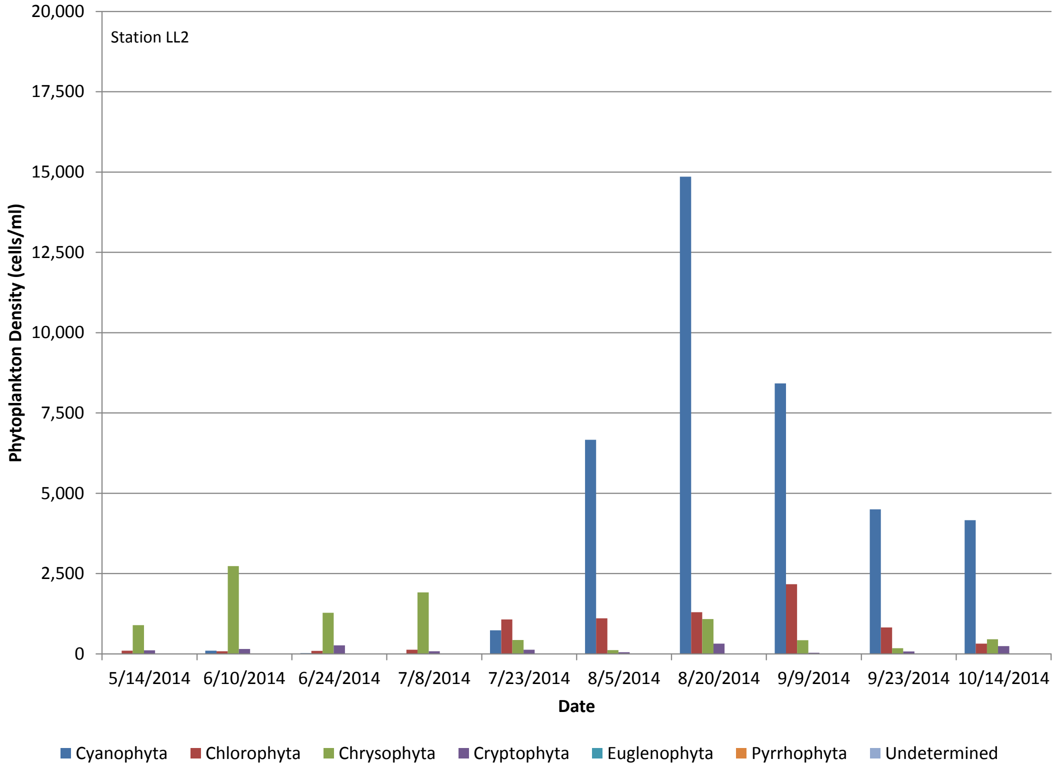

Figure 69. Phytoplankton Density (cells/ml) at Station LL2, May-October 2014

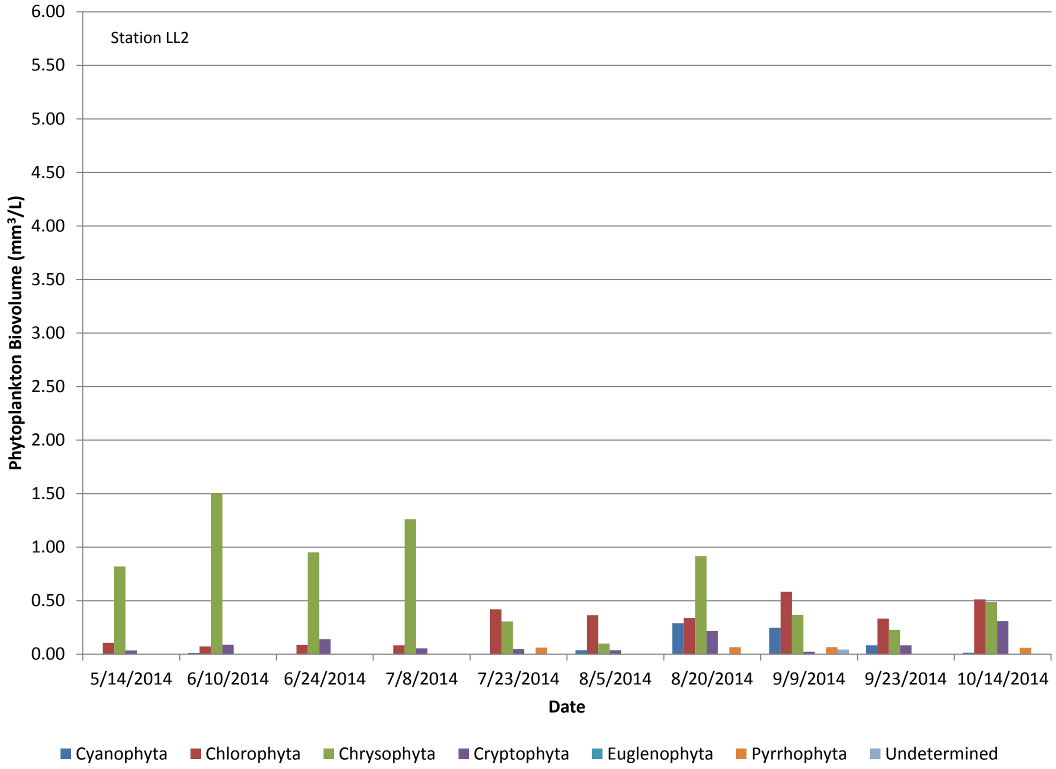

Figure 70. Phytoplankton Volume (mm^3/L) at Station LL2, May-October 2014

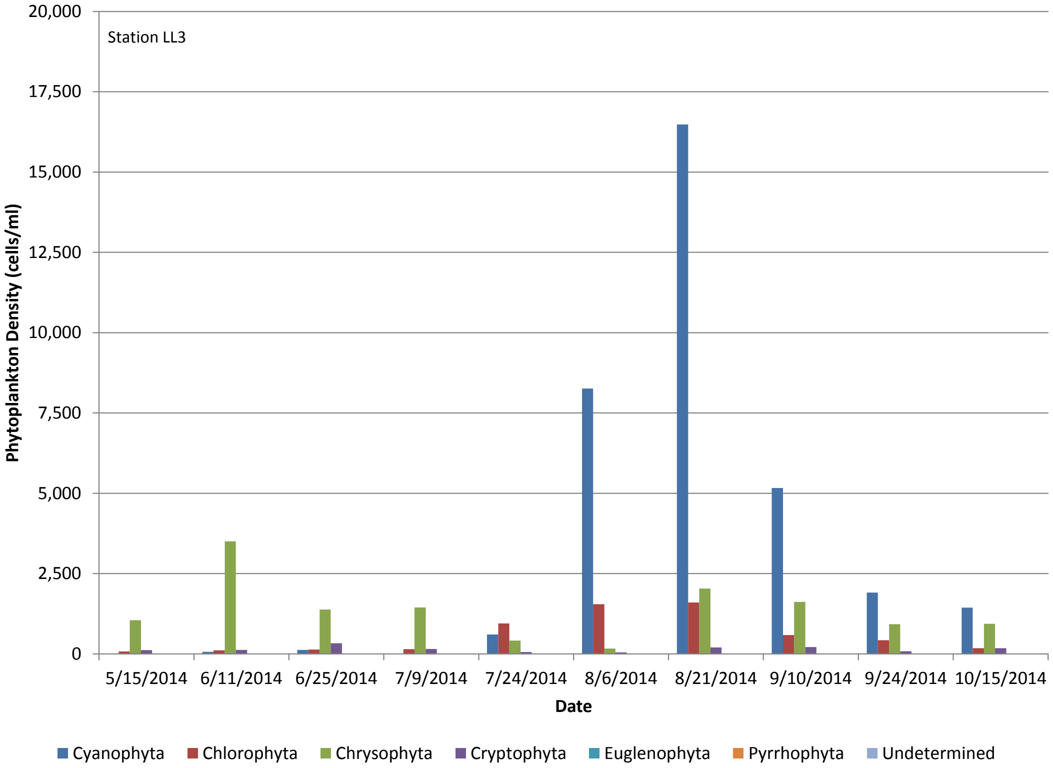

Figure 71. Phytoplankton Density (cells/ml) at Station LL3, May-October 2014

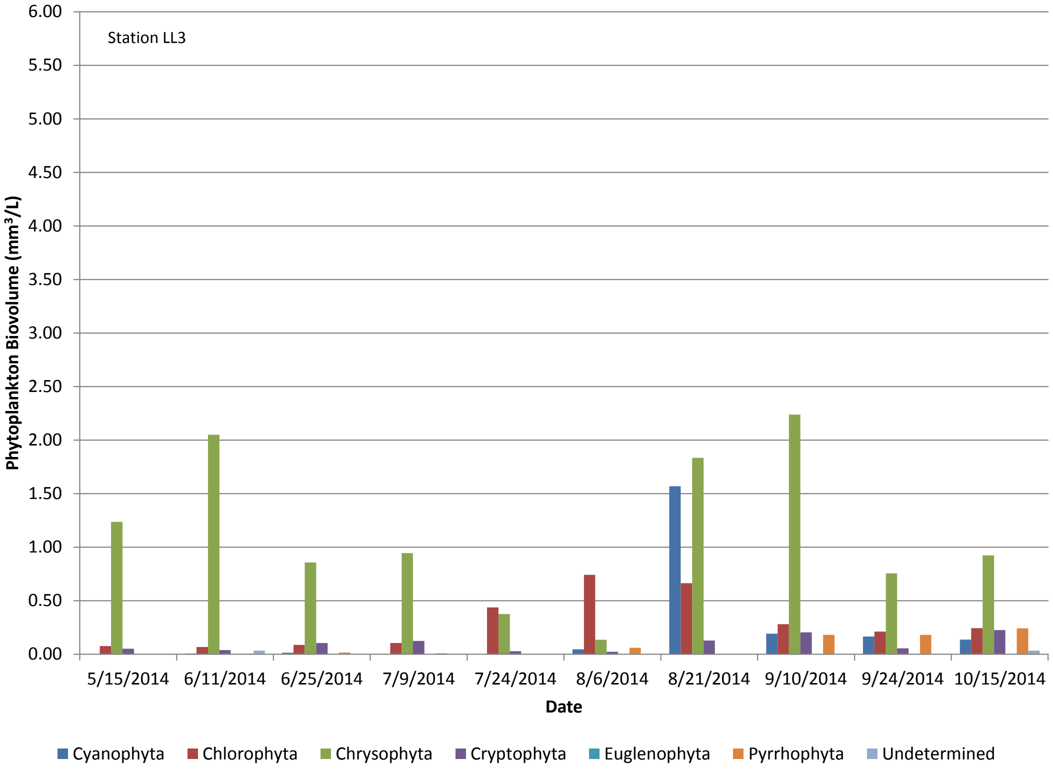

Figure 72. Phytoplankton Volume (mm^3/L) at Station LL3, May-October 2014

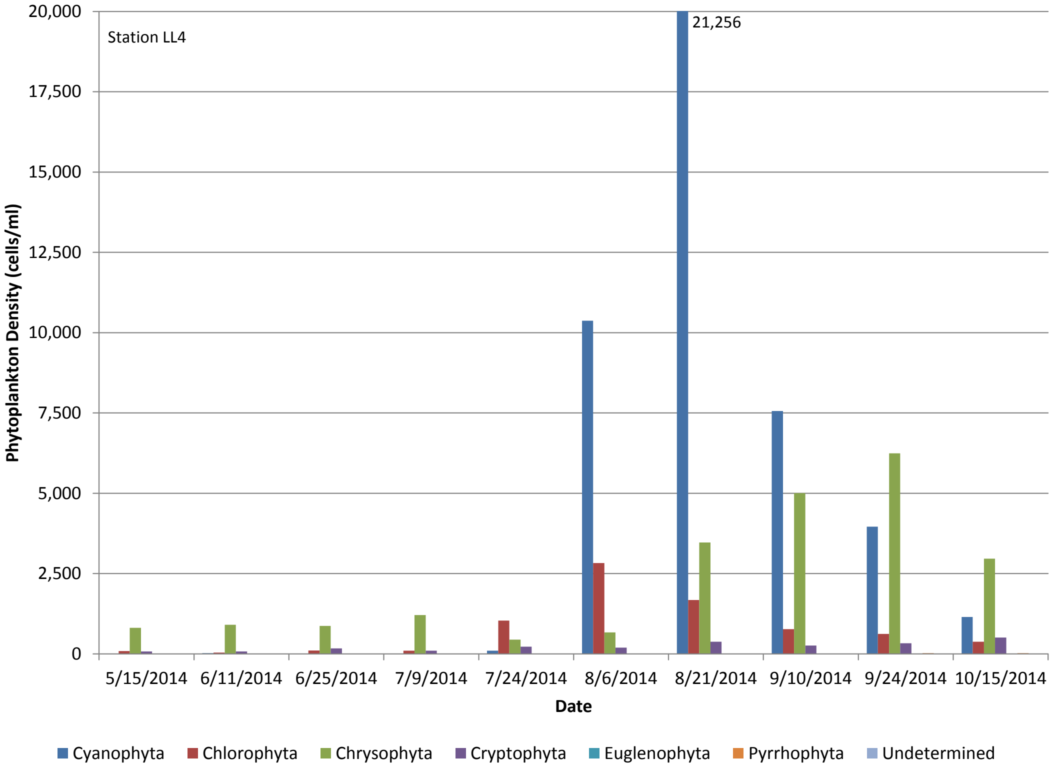

Figure 73. Phytoplankton Density (cells/ml) at Station LL4, May-October 2014

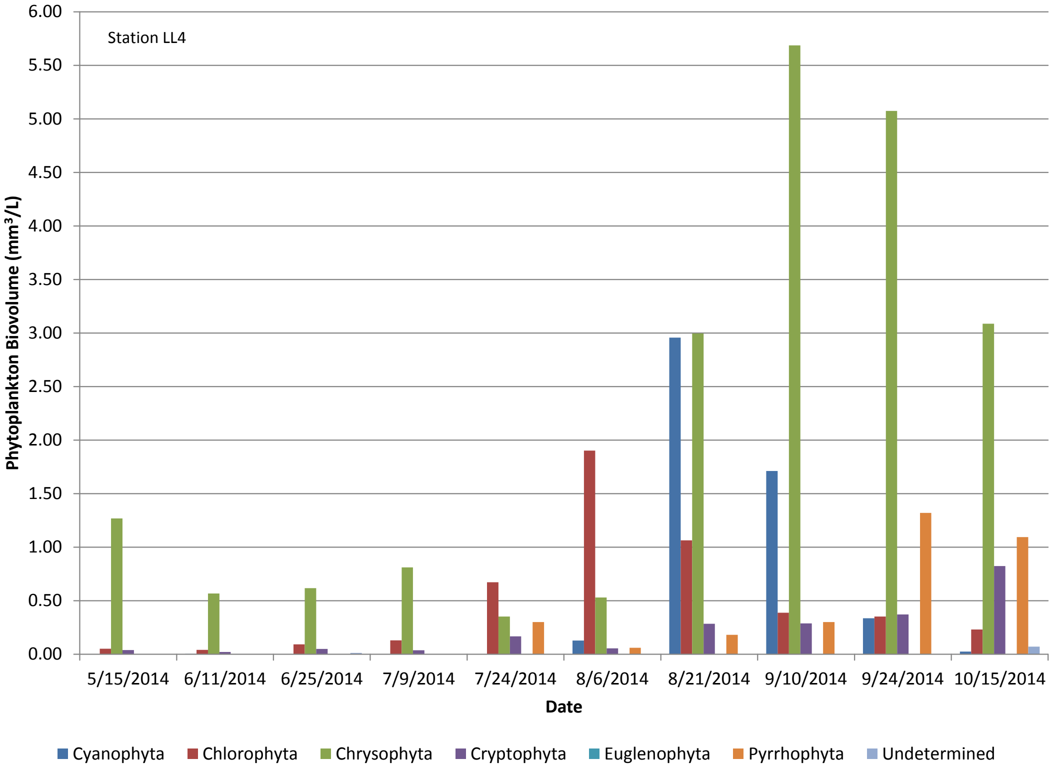

Figure 74. Phytoplankton Volume (mm^3/L) at Station LL4, May-October 2014

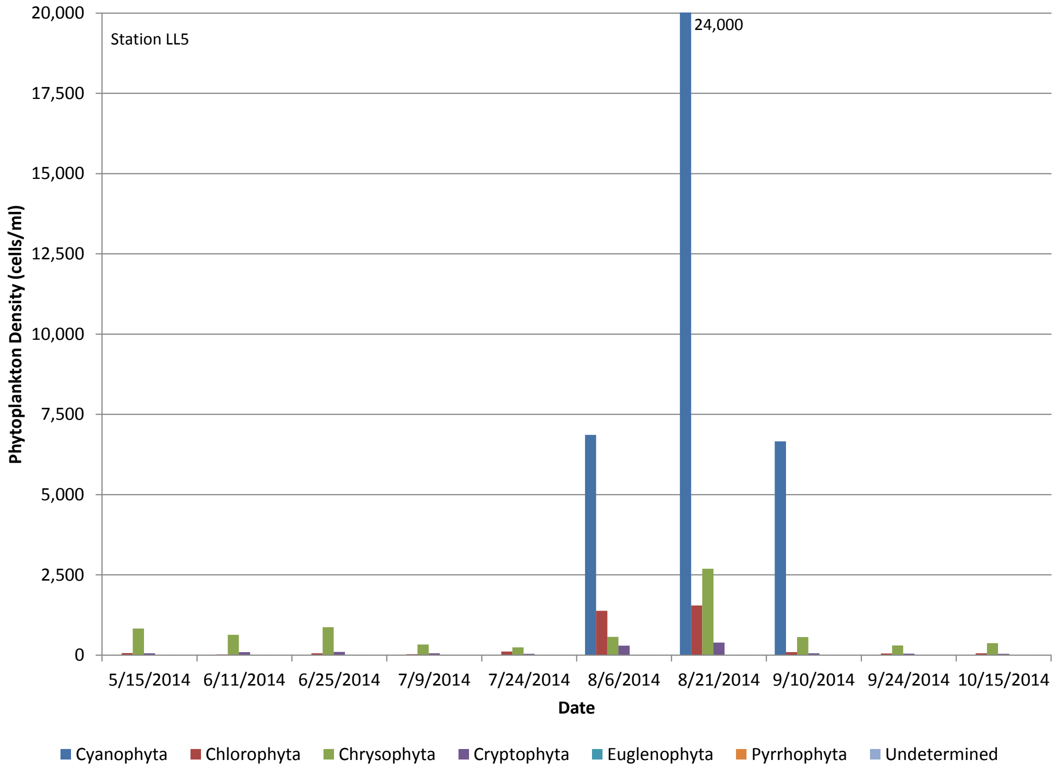

Figure 75. Phytoplankton Density (cells/ml) at Station LL5, May-October 2014

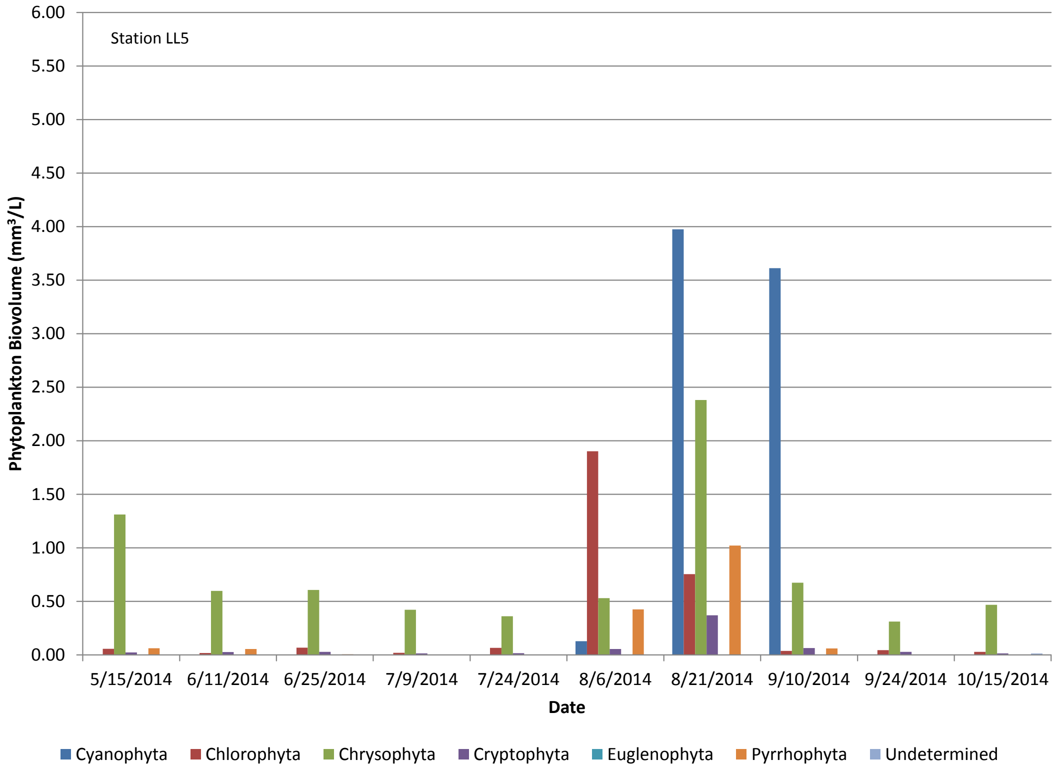

Figure 76. Phytoplankton Volume (mm^3/L) at Station LL5, May-October 2014

3.2.7 TRANSPARENCY (SECCHI DISK DEPTH)

Transparency ranged from 1.6 to 7.7 m throughout the reservoir during 2014 (Figures 77 through 82). The maximums occurred at different times, depending on the station, but were coincident with low chl concentrations. The minimums for most stations were in May when inflow was high and light attenuation was affected by non-algal particulate matter, although similar minimums occurred at LL4 and LL5 during a phytoplankton bloom in late August and early September. There were lower transparencies at the other stations in late August and early September as well. Transparency was determined largely by phytoplankton except during May and early June.

Transparency increased down-reservoir with greatest transparency occurring in the lacustrine zone. Much of that trend was likely due to longer water retention time and greater loss of particulate matter through settling, as well as plunging inflows that tend to isolate the lacustrine epilimnion allowing even more settling time from the upper layer.

Whole-lake, area-weighted mean transparency during July-October of 2010-2014 was 5.3 ± 0.5 m. In contrast, mean transparency during that period in 1971-1977, before phosphorus reduction, was 2.4 ± 0.44 m, and after reduction, 3.3 ± 0.39 m.

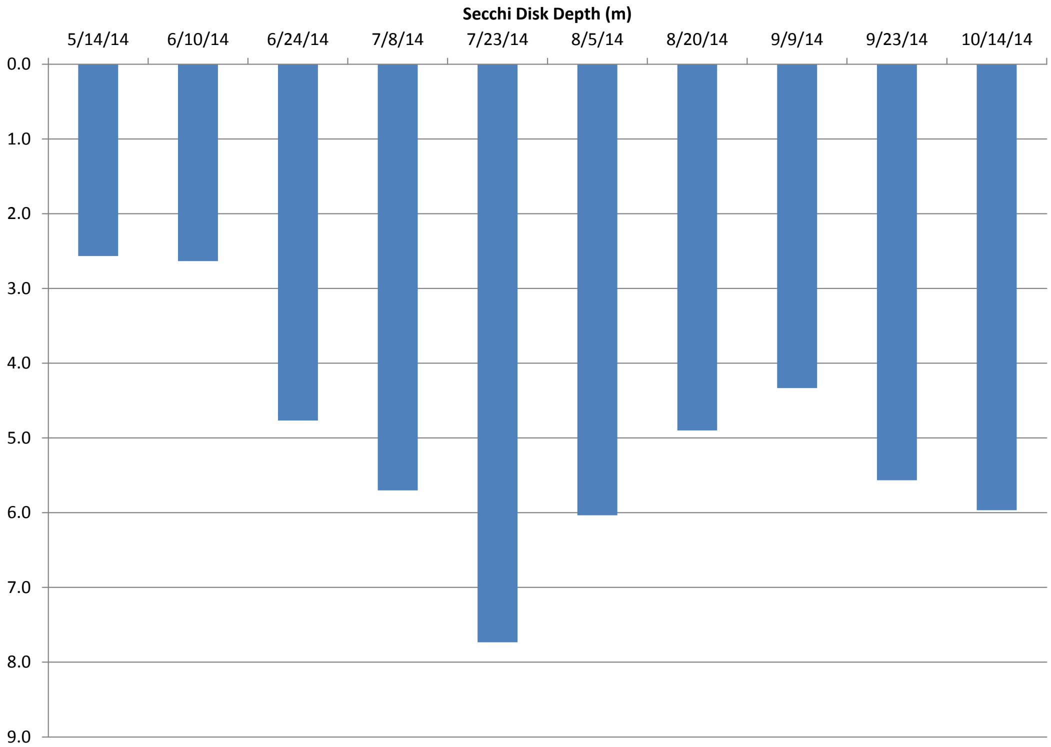

Figure 77. Secchi Disk Depths (m) for Station LL0, May-October 2014

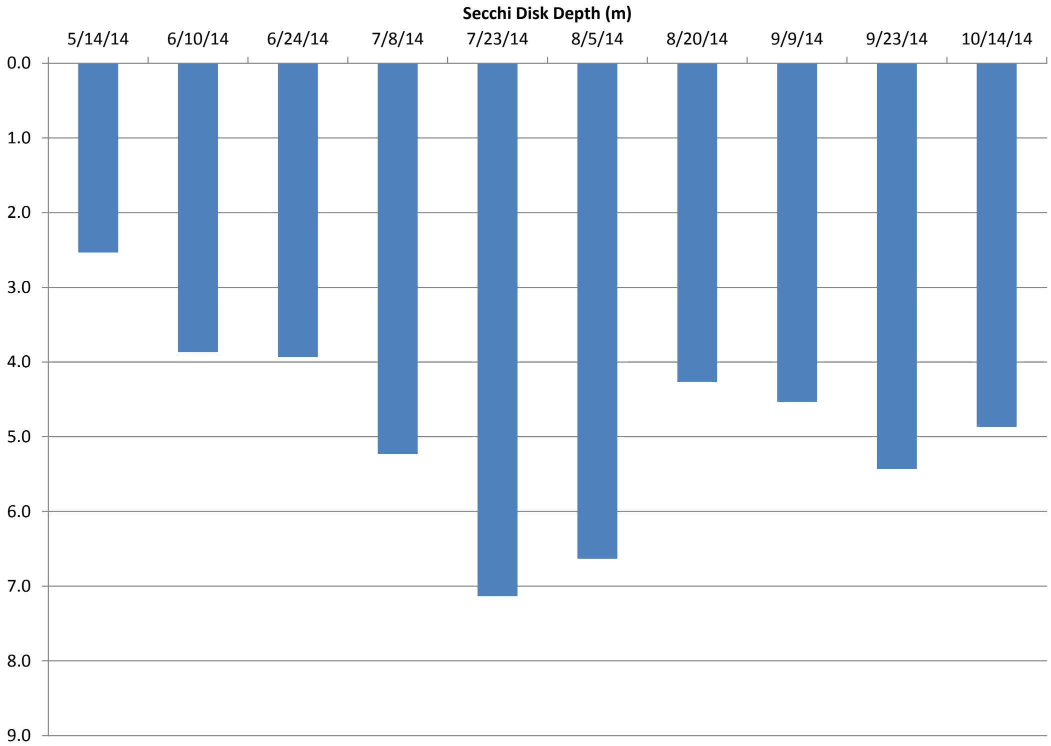

Figure 78. Secchi Disk Depths (m) at Station LL1, May-October 2014

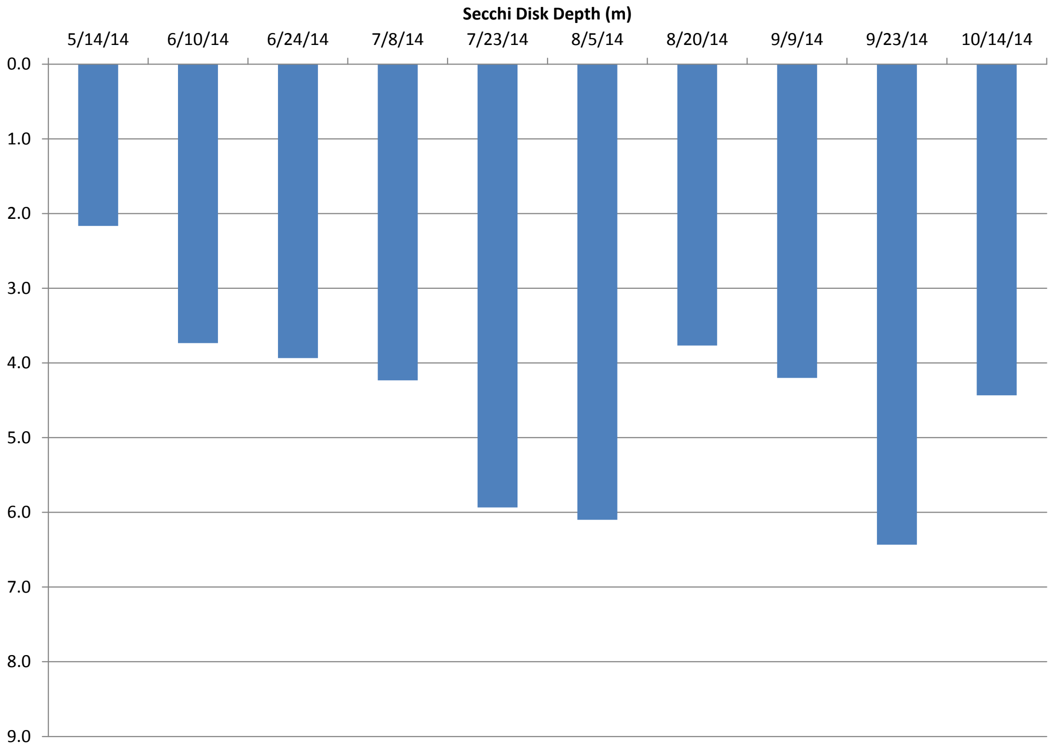

Figure 79. Secchi Disk Depths (m) at Station LL2, May-October 2014

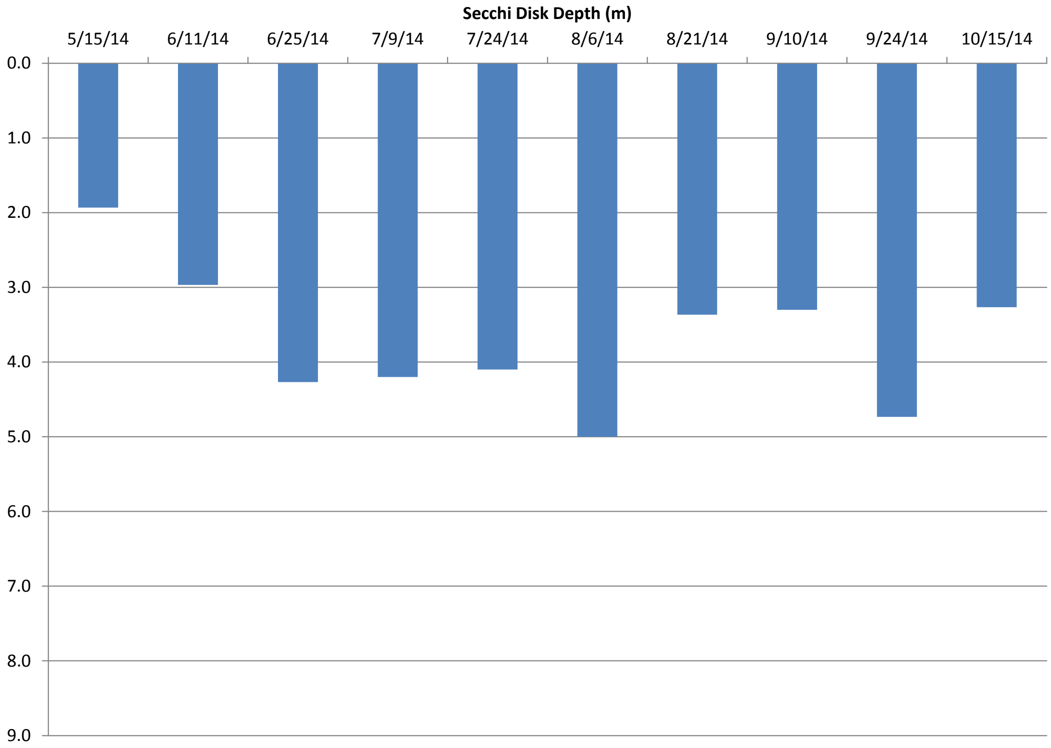

Figure 80. Secchi Disk Depths (m) at Station LL3, May-October 2014

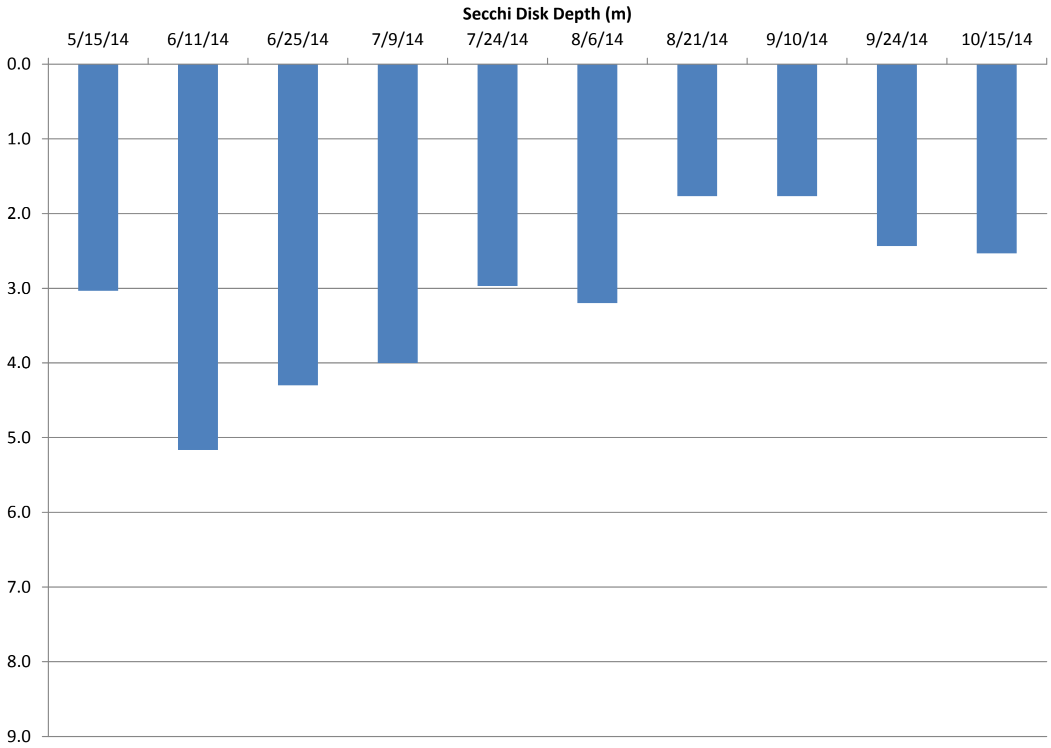

Figure 81. Secchi Disk Depths (m) at Station LL4, May-October 2014

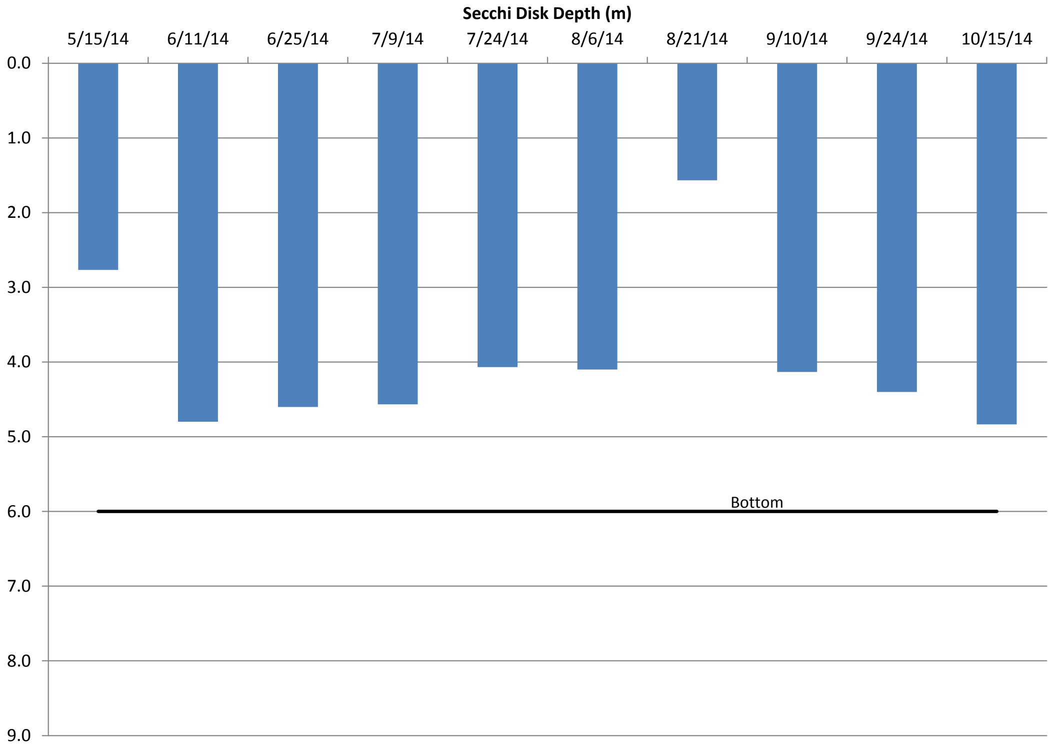

Figure 82. Secchi Disk Depths (m) at Station LL5, May-October 2014

3.2.8 ZOOPLANKTON

Rotifers, usually dominated the zooplankton density (abundance) at most stations, especially during the spring in the lacustrine zone (Figures 83 through 94). However, they are relatively small and did not dominate biomass. Rotifer densities were usually higher in spring in 2013 at the deeper sites, but greatest at LL3 – LL5 in summer during both 2013 and 2014. That may be due to rotifers being detritus and bacteria eaters; abundance of such particles may occur at high concentrations in the upper hypolimnion and lower metalimnion and account for high densities despite the dilution effect of deep net hauls. Higher densities in summer, but not in spring, in the riverine and transition zones (LL4 – LL5) may be due to shorter water residence times in the upper reservoir.

Cladocerans (*Cladocera*) are the largest zooplankton and they dominated biomass at all stations for most of the period. *Calanoid* zooplankton were relatively unimportant in contrast to natural lakes in which they usually dominate in the spring. Density and biomass of cladocerans, as well as other groups, were probably artificially reduced at the deeper lacustrine stations because animals were sampled by net hauls from approximately 1 m off the reservoir bottom. Large mobile zooplankton are much less likely to occur in the hypolimnion where food particles, especially phytoplankton, are scarce. That is especially apparent at LL3 and LL4 with very high maximum densities above 100/L and much lower densities at LL0 – LL2 with net hauls of 25-47 m. Biomass of cladocerans was also frequently over 100 µg/L at LL4 – LL5.

Multiplying concentrations by net haul depth, giving density and biomass per surface area, tends to even out the station differences (Tables 10-12). Although depth-corrected average seasonal cladoceran concentrations were higher at LL3 – LL4 in 2014 (Table 10), they were even higher in 2013 (26-56/ L) at LL4 – LL5. Thus, part of the reason for low cladoceran density and biomass at deep sites is likely a dilution effect with greater net haul depths.

There was a shift in cladoceran density and biomass among upper reservoir sites (LL3 – LL5) over the past three years. Densities were highest in 2013, averaging 26 and 56/L and over 200,000/m2 at LL4 – LL5. Maximum densities were lower in the transition and riverine zones (LL4 – LL5) in 2012 (10 and 6.2/L), and were similar to the highest means in 2014 (6.2 and 9.2/L), which were at LL3 – LL4 (Tables 11 and 12). Mean densities at LL4 – LL5, corrected for net-haul depth (no/m2), were much lower in 2012 and 2014 than in 2013. Season (June-October) average water residence times may explain some of the differences in density among the years; 2012 and 2014 with less density had shorter residence times, at 3.6 and 5.9 days, than 2013 (6.9 days) with the high densities, although the difference of only 1 day between 2013 and 2014 may not be too significant. Clearly, the lowest mean density corrected for depth of any of the three years and sites occurred at LL5 in 2014 with an average residence time of 5.9 days. Therefore, residence time does not appear to account for the lowest density at that site of 13,000/m2 (Table 10).

Compared to 2013, cladoceran density at 5 of 6 stations in 2014 was significantly less and similar to densities in 2012 (Tables 10-12). The highest summer mean cladoceran density observed in 2014 was at station LL3 with nearly 117,000/m2, corrected for net haul depth. In 2013 at station LL0 summer mean *Cladocera* density was over 254,000/m2 or nearly 5 times that in 2014. The largest difference was observed at station LL5 where cladoceran density in 2012 was slightly over 13,000/m2 and in 2013 the density was nearly 281,000/m2 (Tables 10 and 12). Cladocerans (including *Daphnia*) also had the largest biomasses during summer at all sites, with maximums reaching 150 µg/L, or more in 2014 at LL3 and LL4. These maximums were lower than in 2013 at LL4 and LL5 with biomass well over 200 µg/L. In August 2012, biomass maximums averaged only about 80 µg/L. Variability in cladoceran abundance from year-to-year has been quite large. The reason for this variability is not clear, but such is not unusual with dynamic plankton populations responding to sometimes rapidly changing environmental conditions.

Because of their large size, cladocerans are usually the most important grazers, with *Daphnia* being the largest. *Daphnia* size at LL4 has ranged from 1.0 to 2.8 mm, mostly between 1.75 to 2.1 mm. At that size they are the favorite food for visually-feeding, planktivorous fish. Moreover, *Daphnia* usually had “helmets” throughout the summer in 2014. Helmets usually indicate low predation. *Daphnia* were helmeted in 2012 and 2013 as well. The presence of helmets may not be due to fish predation in this case, because a large number of catchable size trout were stocked in the lake beginning in June of 2014 (155,000), with no such intensive stocking in 2012 or 2013. Although temperatures in top 5 m were above optimum during July-August, suitable temperatures existed below that depth for fish predation.

The trophic state, or degree of enrichment, of a lake can be judged by the amount of zooplankton consumer production relative to that of phytoplankton producers. The transfer of food energy from one trophic level (producers) to the next (zooplankton consumers) is nominally 10%. That is, 10% of carbon produced gets to the next level, or the transfer is 10% efficient. If biomass turnover rate were the same at each trophic level, then the ratio of zooplankton dry biomass to phytoplankton dry biomass would be one tenth, assuming all phytoplankton are edible and all zooplankton are eating algae. However, productivity, or turnover rate, of producer levels is usually greater than at consumer levels. Cyanobacteria are largely inedible, but their percent of the phytoplankton biomass averaged only 4.7 and 3.0 in 2012 and 2013, but increased to 37% in 2014. These fractions are relatively low in the earlier two years but surprisingly high in the past year. As a lake becomes more eutrophic, the fraction of inedible cyanobacteria increases and the zooplankton: phytoplankton ratio decreases. Percent cyanobacteria begins to increase around 30 µg/L TP or more (Downing et al. 2001). Total phosphorus concentrations were not higher in 2014 – only 12 µg/L, so the reason for the higher cyanobacteria fraction is not clear. Also, cladocerans are large and usually the major consumers, and they have averaged 69% of total zooplankton biomass over the past three years. Over 90% of cladocerans have been *Daphnia*, which can have very high growth rates and are capable of consuming all the algae produced per day under ideal conditions (Welch and Jacoby, 2004).

The zooplankton: phytoplankton biomass (dry-weight) ratio was determined by converting phytoplankton biovolume to dry weight, assuming cells are 85% water. In Lake Spokane the ratio has ranged from a three-year per site average of 0.3 to 0.59, with an overall mean of 0.44, which would indicate nearly half the phytoplankton are apparently being consumed, assuming biomass turnover rates were the same for each trophic level. As eutrophication increases and cyanobacteria become more and more dominant and abundant and energy transfer goes through decomposition, instead of grazing by zooplankton, that ratio can decrease to a very low fraction.

Thus, the zooplankton: phytoplankton ratio and % cyanobacteria in Lake Spokane indicate more of a mesotrophic than eutrophic state (Welch and Jacoby, 2004). Ratios of actual productivity in a group of experimental ponds showed zooplankton: phytoplankton ratios ranging from 0.08 to 0.41 with medium enrichment to 0.20 to 0.56 with low enrichment (Hall et al., 1970).

Table 10. 2014 Summer Mean Density of *Cladocera* at the Six Stations Corrected for Depth of Net Haul to Aerial Units

Station	Net Haul Depth (m)	No./L	No./m^3	No./m^2
LL0	47	1.21	1,210	56,892
LL1	33	2.39	2,393	78,959
LL2	25	2.87	2,869	71,735
LL3	19	6.17	6,166	117,150
LL4	8	9.19	9,187	73,497
LL5	5	2.63	2,629	13,147

Table 11. 2012 Summer Mean Density of *Cladocera* at the Six Stations Corrected for Depth of Net Haul to Aerial Units

Station	Net Haul Depth (m)	No./L	No./m^3	No./m^2
LL0	48	1.70	1,702	81,695
LL1	33	1.14	1,143	37,733
LL2	25	1.86	1,861	46,525
LL3	18	2.98	2,984	53,714
LL4	8	9.97	9,967	79,737
LL5	5	6.22	6,223	31,117

Table 12. 2013 Summer Mean Density of *Cladocera* at the Six Stations Corrected for Depth of Net Haul to Aerial Units

Station	Net Haul Depth (m)	No./L	No./m^3	No./m^2
LL0	47	5.41	5,413	254,388
LL1	33	4.14	4,136	136,483
LL2	25	4.33	4,331	108,265
LL3	18	5.09	5,085	91,533
LL4	8	25.7	25,726	205,804
LL5	5	56.2	56,154	280,768

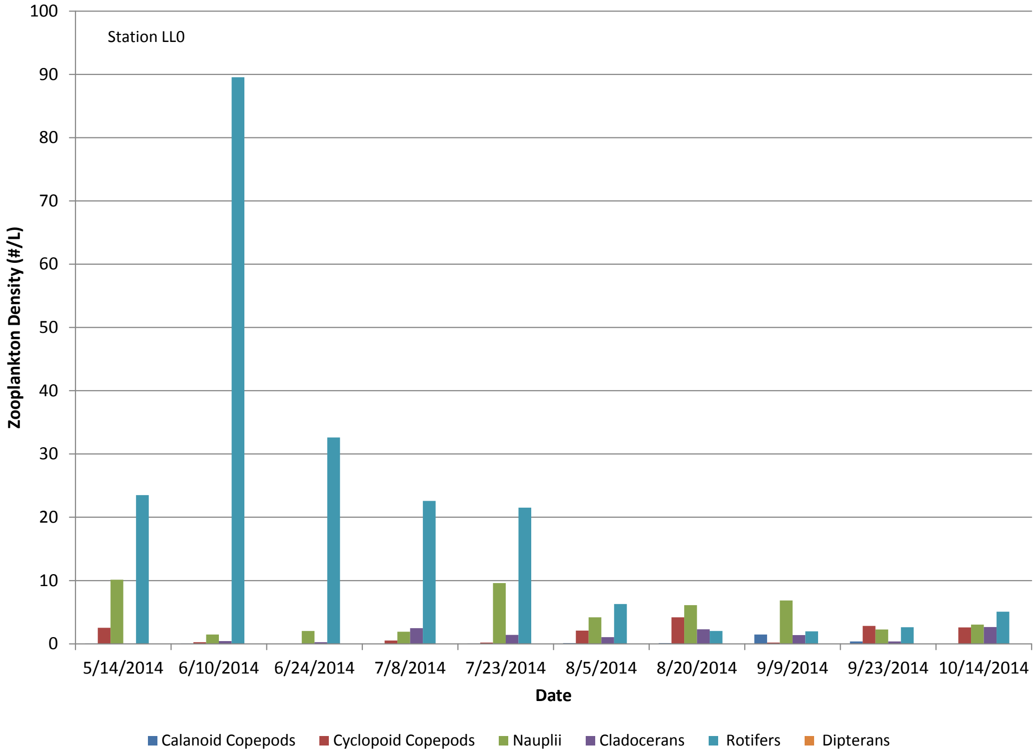

Figure 83. Zooplankton Density (#/L) at Station LL0, May-October 2014

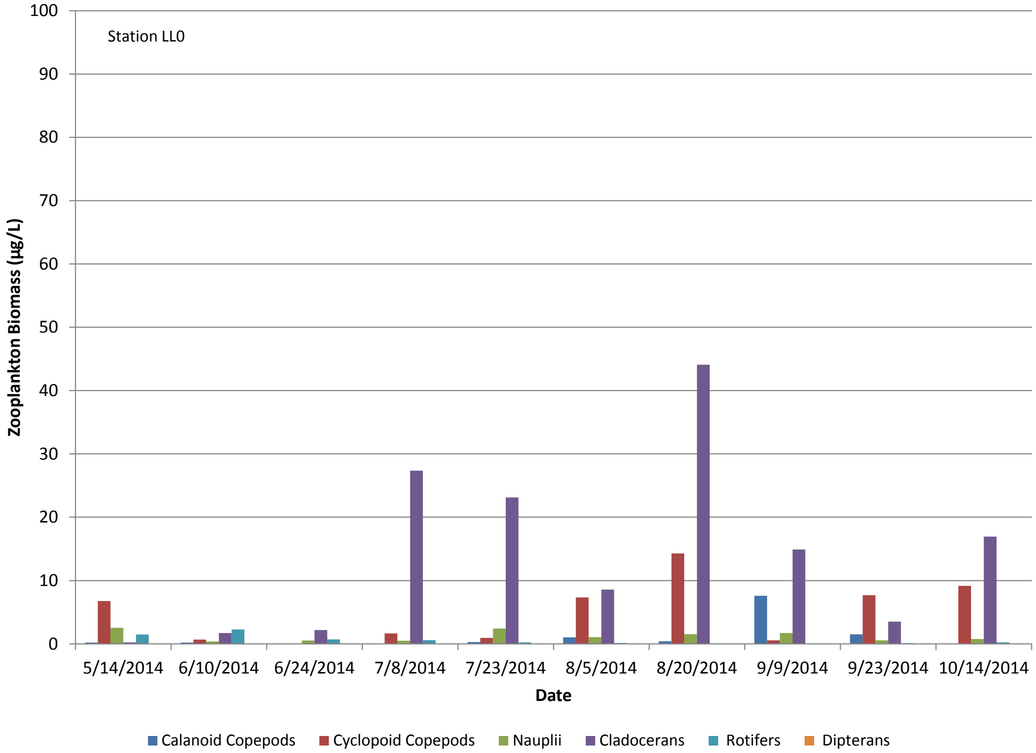

Figure 84. Zooplankton Biomass (µg/L) at Station LL0, May-October 2014

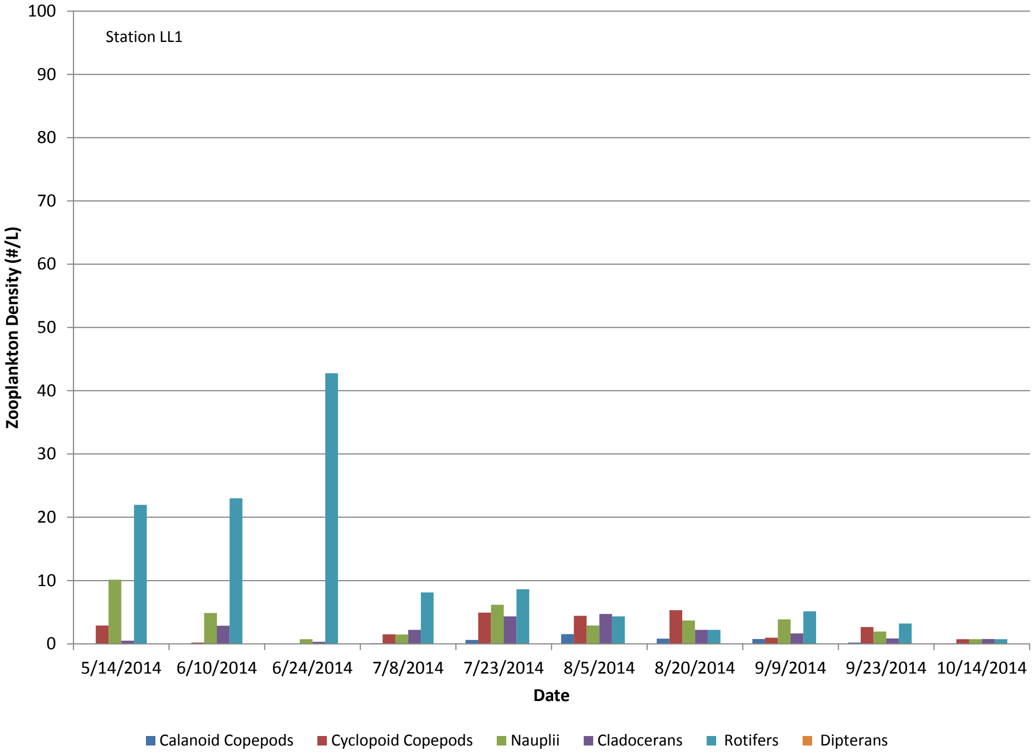

Figure 85. Zooplankton Density (#/L) at Station LL1, May-October 2014

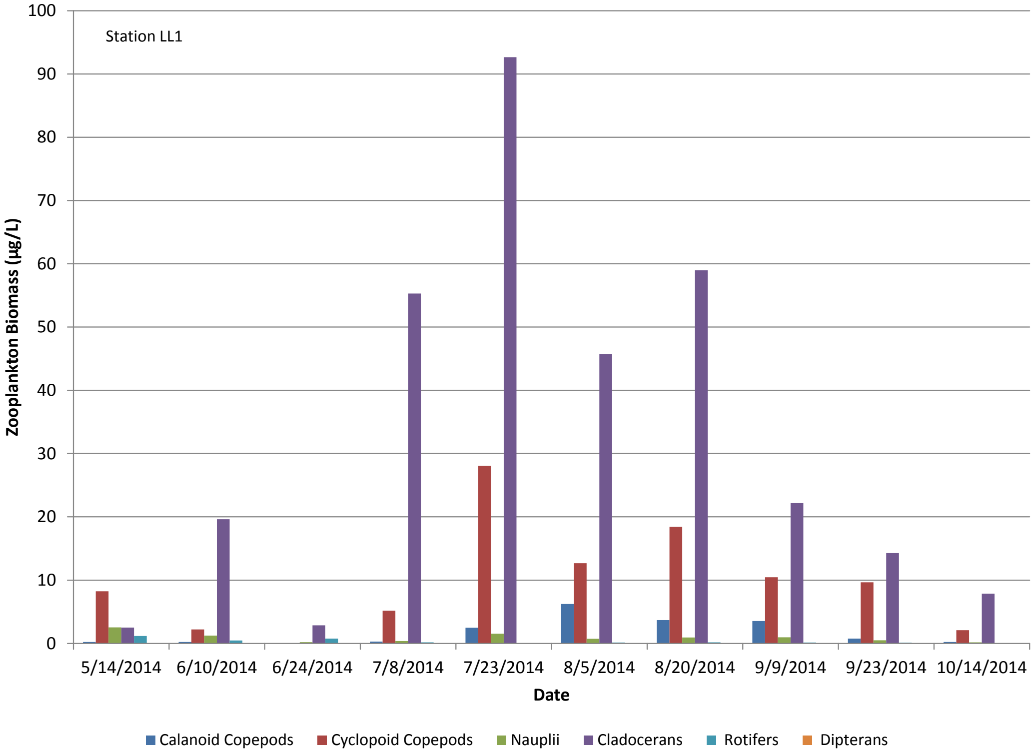

Figure 86. Zooplankton Biomass (µg/L) at Station LL1, May-October 2014

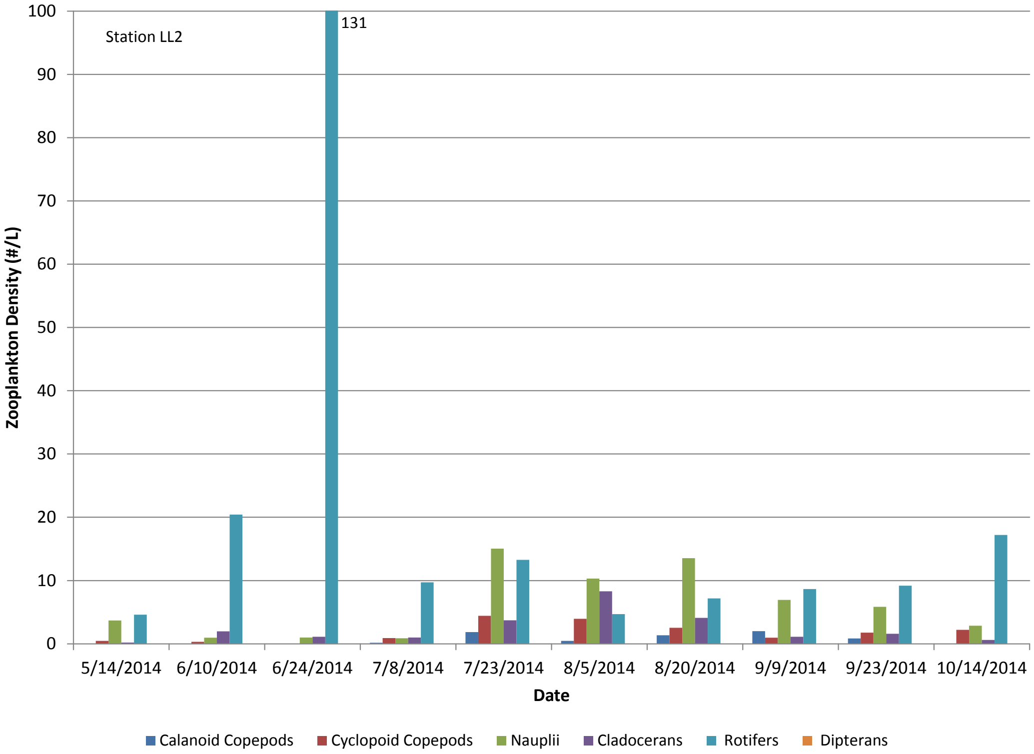

Figure 87. Zooplankton Density (#/L) at Station LL2, May-October 2014

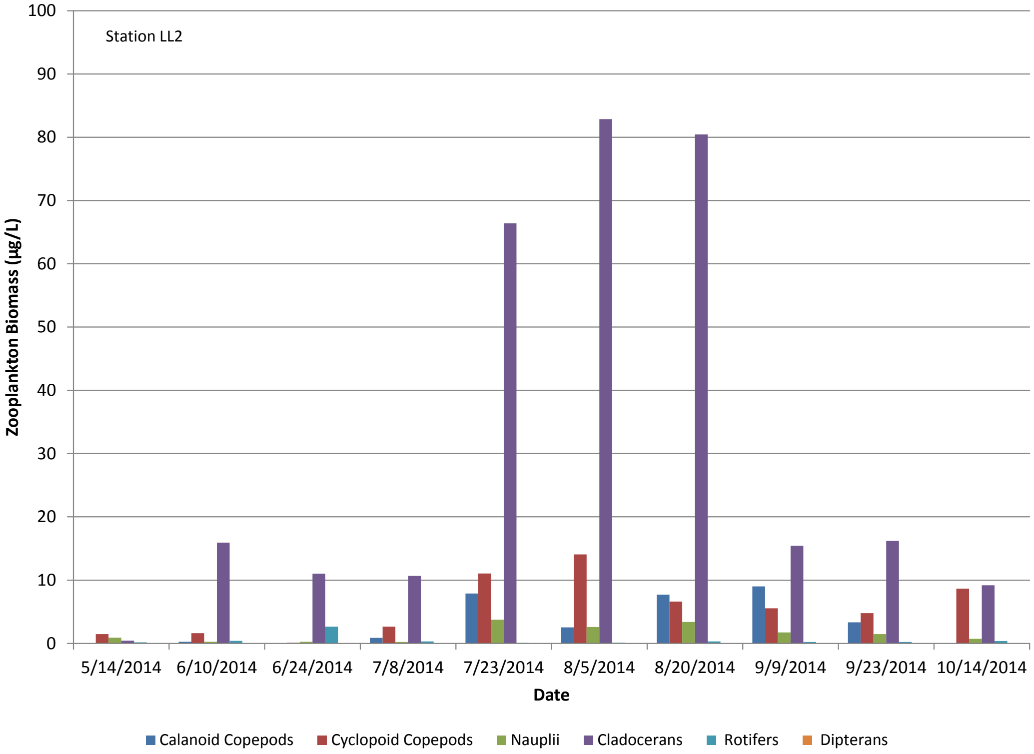

Figure 88. Zooplankton Biomass (µg/L) at Station LL2, May-October 2014

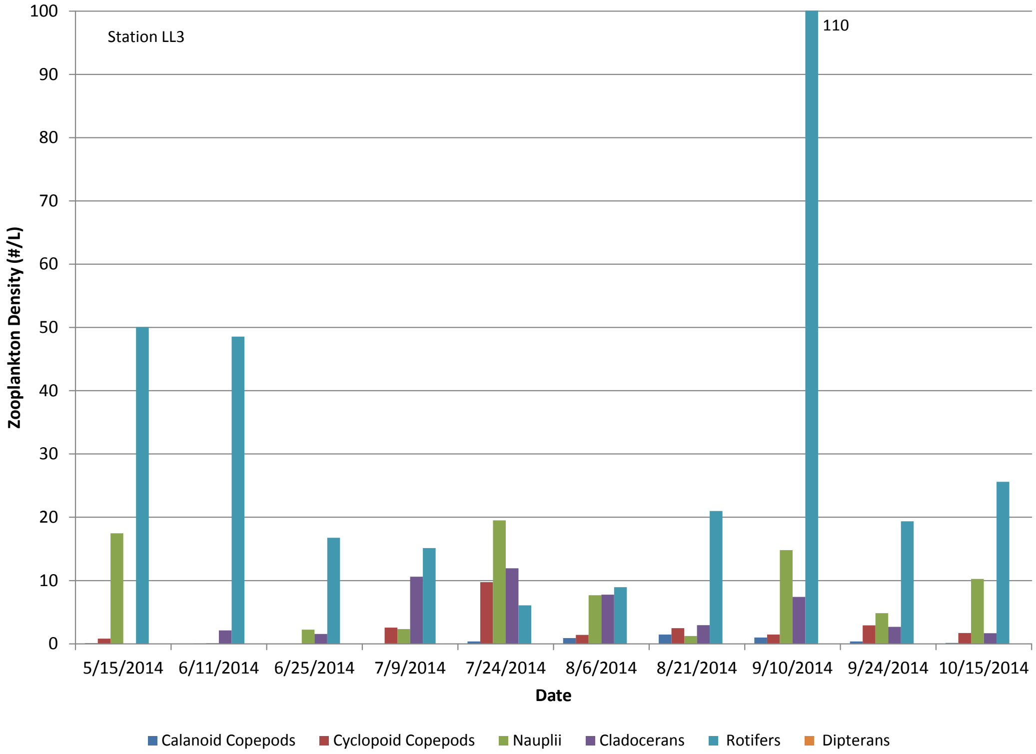

Figure 89. Zooplankton Density (#/L) at Station LL3, May-October 2014

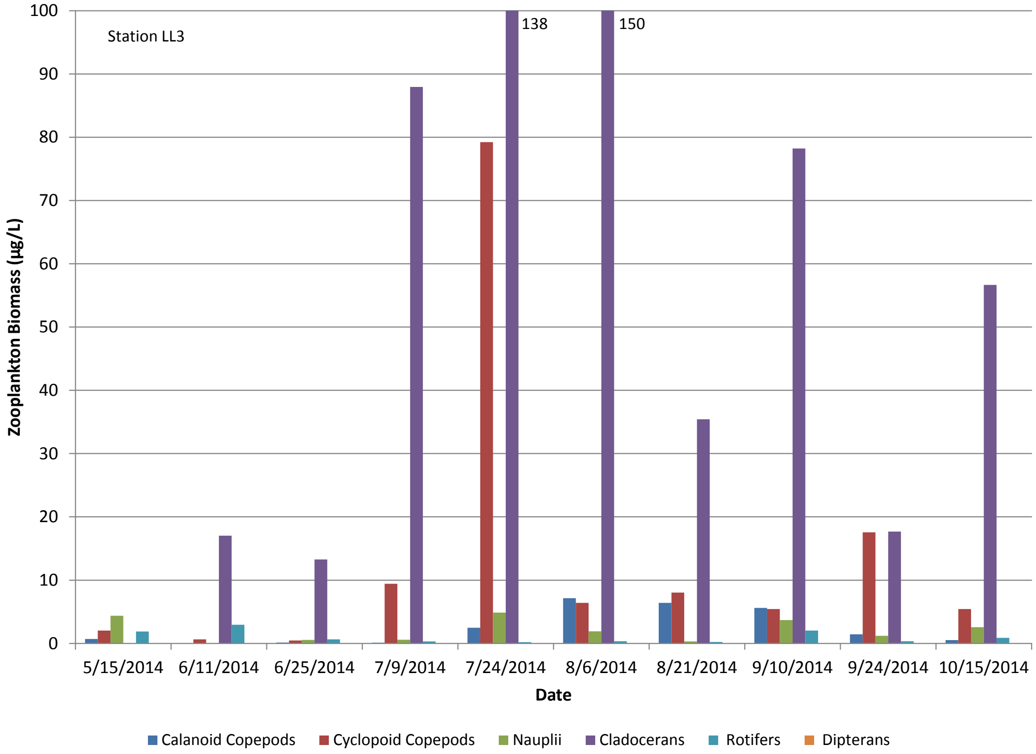

Figure 90. Zooplankton Biomass (µg/L) at Station LL3, May-October 2014

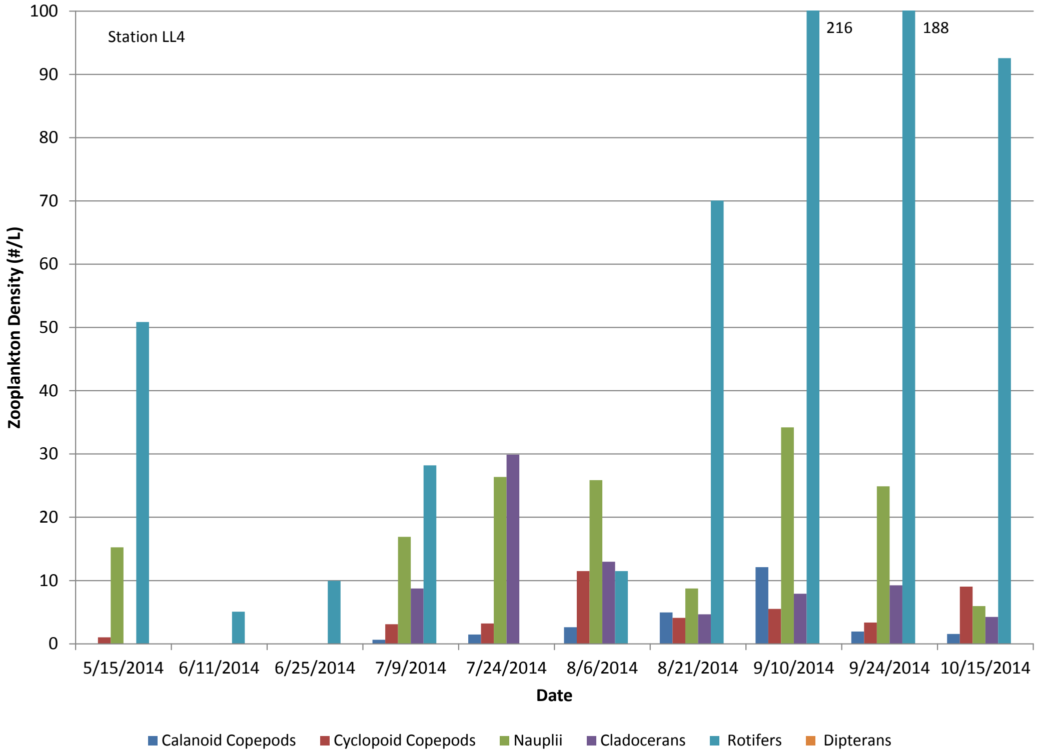

Figure 91. Zooplankton Density (#/L) at Station LL4, May-October 2014

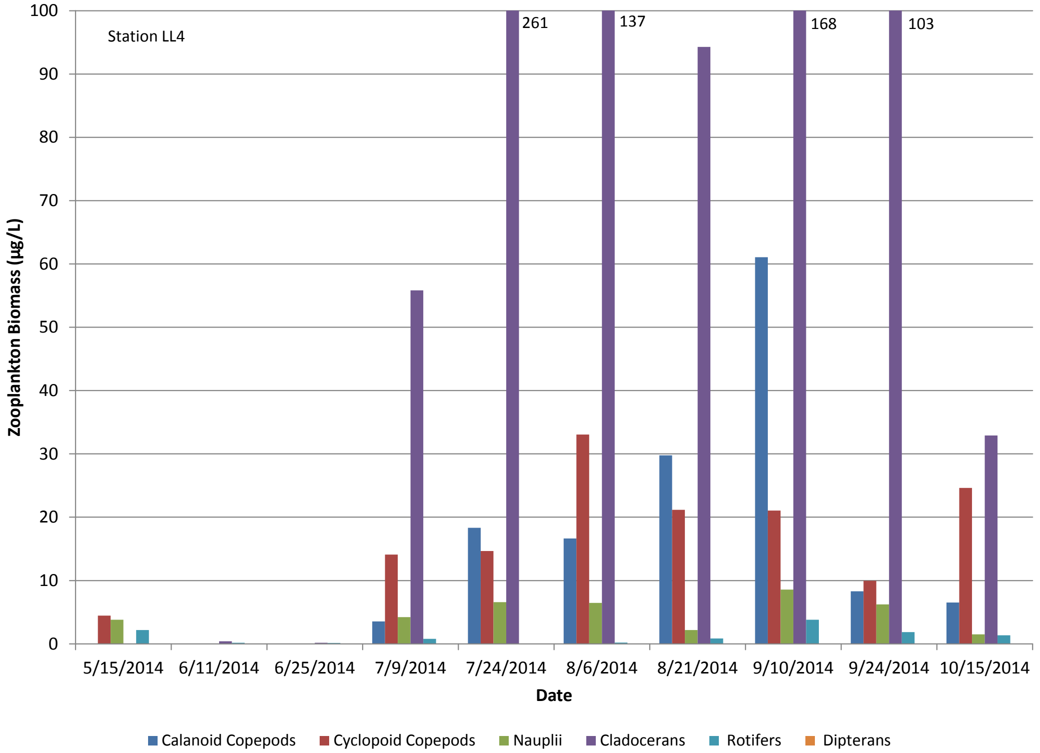

Figure 92. Zooplankton Biomass (µg/L) at Station LL4, May-October 2014

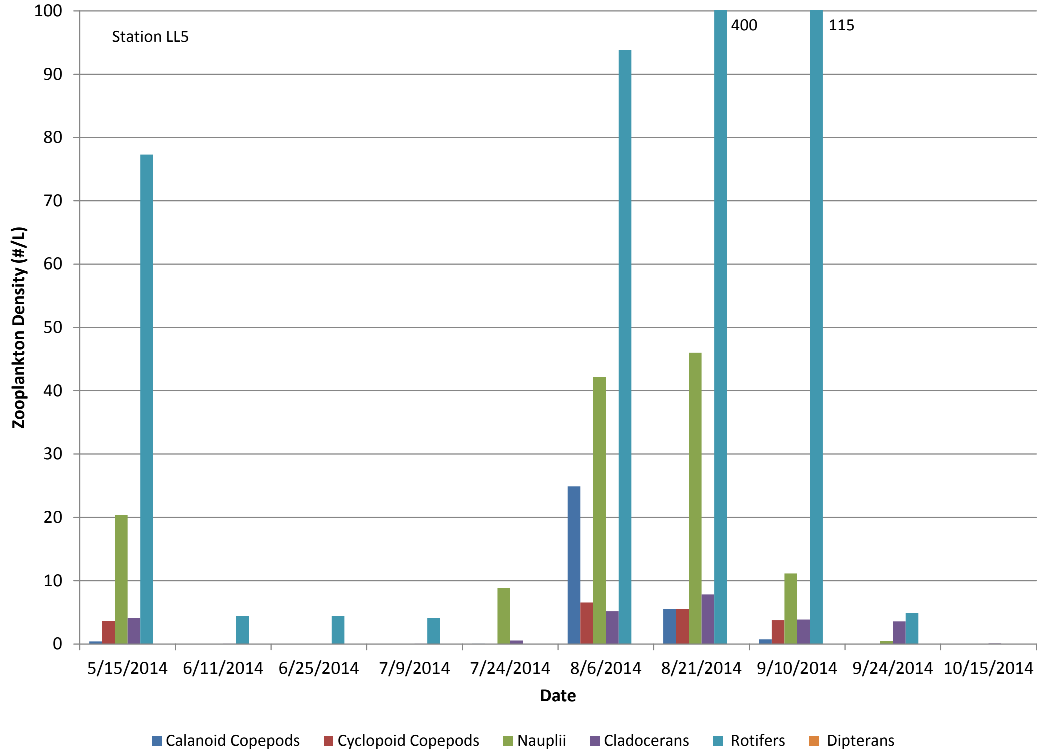

Figure 93. Zooplankton Density (#/L) at Station LL5, May-October 2014

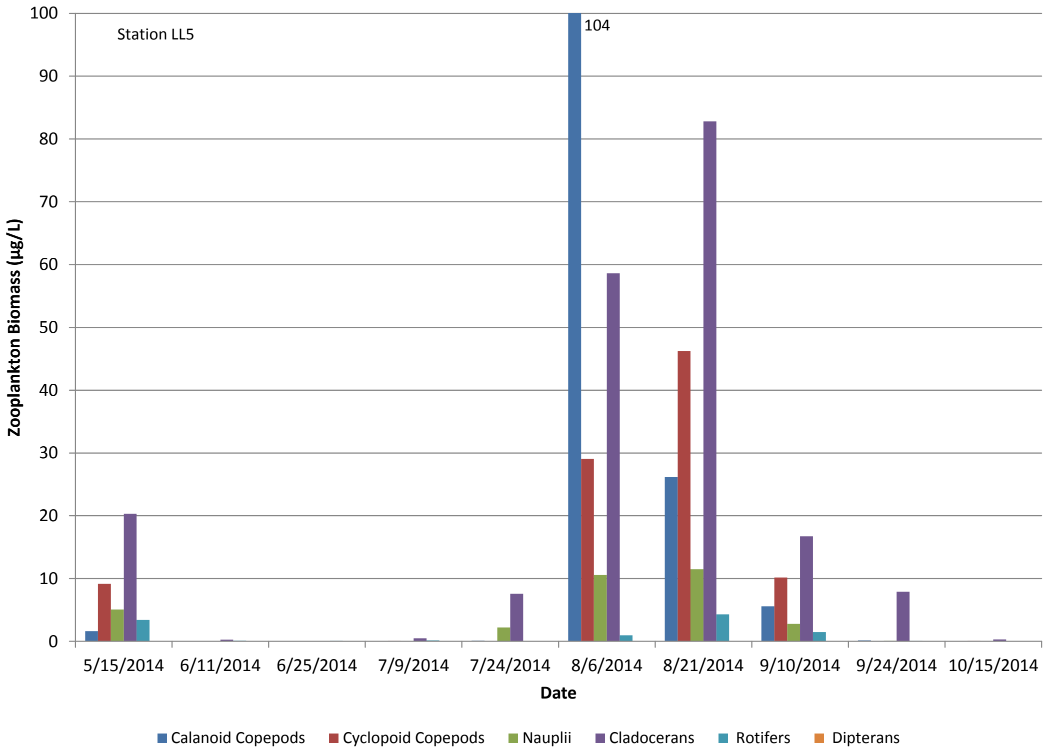

Figure 94. Zooplankton Biomass (µg/L) at Station LL5, May-October 2014

3.2.9 SPOKANE RIVER AT NINE MILE BRIDGE AND LITTLE SPOKANE RIVER NEAR MOUTH

Ecology monitors water quality in the Spokane River and Little Spokane River a short distance upstream of its confluence with Lake Spokane. The Spokane River at Nine Mile Bridge station, (54A090) is located approximately 0.1 mile downstream of Nine Mile Dam at River Mile (RM) 58. According to Ecology's River and Stream Water Quality Monitoring website, this station is a "basin" station with data collected during 2014 (January – November data are presented in this report).

Ecology's Little Spokane River near Mouth station (55B070), which is located on the Little Spokane River at RM 1.1, is a long-term station, according to its website. Sampling efforts at these two stations were conducted by Ecology in accordance with the Stream Ambient Monitoring QAPP.

Water quality data available for the Spokane River at Nine Mile Bridge for 2014 are summarized below in Tables 13 and 14. The data are preliminary and have not been finalized by Ecology. Shaded values indicate exceedance of water quality standards or a strong contrast with historical results, according to Ecology's website.

Table 13. Spokane River at Nine Mile Bridge In-Situ Water Quality Data, 2014

Date	Temperature (°C)	Dissolved Oxygen (mg/L)	pH	Conductivity (µmhos/cm)
1/7/2014	4.8	11.8	7.82	156
2/4/2014	3.7	12	7.83	155
3/4/2014	3.7	12.4	7.74	133
4/8/2014	7.4	12.5	**7.52**	78
5/6/2014	8.7	12.3	**7.60**	66
6/3/2014	16.7	9.8	7.88	81
7/8/2014	19	**8.6**	7.98	148
8/5/2014	17.5	**9.1**	8.42	254
9/9/2014	15.3	**9.5**	8.40	237
10/7/2014	No data	9.8	8.16	189
11/4/2014	10.5	9.7	8.00	190

Note: Shaded values indicate an exceedance of water quality standards or strong contrast to historical results.

Table 14. Spokane River at Nine Mile Bridge Conventional Water Quality Data, 2014

Date	Total Phosphorus (µg/L)	Soluble Reactive Phosphorus (µg/L)	Total Reactive Phosphorus (µg/L)	Total Nitrogen (µg/L)	NO_3+NO_2 (µg/L)
1/7/2014	25.0	17.9	19.3	1,030	933
2/4/2014	24.0	17.4	18.6	997	919
3/4/2014	20.8	9.9	10.3	726	652
4/8/2014	12.2	5.0	5.3	306	239
5/6/2014	14.1	4.2	5.1	230	169
6/3/2014	12.0	4.3	4.2	349	284
7/8/2014	9.5	5.8	6.2	853	793
8/5/2014	14.9	8.1	9.8	1,730	1,570
9/9/2014	14.0	8.4	8.0	1,770	1,740
10/7/2014	12.0	7.1	7.1	1,190	1,150
11/4/2014	14.0	9.9	10.5	1,180	1,120

Note: Shaded values indicate an exceedance of water quality standards or strong contrast to historical results.

Water quality data available for the Little Spokane River for 2014 are summarized below in Tables 15 and 16. The data are preliminary and have not been finalized by Ecology. Shaded values indicate exceedance of water quality standards or a strong contrast with historical results, according to Ecology's website.

Table 15. Little Spokane River near Mouth In-Situ Water Quality Data, 2014

Date	Temperature (°C)	Dissolved Oxygen (mg/L)	pH	Conductivity (µmhos/cm)
1/7/2014	5.4	10.5	8.21	276
2/4/2014	4.5	10.7	8.23	276
3/4/2014	6.3	10.8	8.12	271
4/8/2014	12.3	**9.2**	7.98	210
5/6/2014	11.8	**8.8**	8.03	211
6/3/2014	**16.6**	**9.0**	8.36	253
7/8/2014	**17.0**	no data	8.25	274
8/5/2014	16.0	**9.0**	8.29	286
9/9/2014	12.8	**9.5**	8.33	288
10/7/2014	**11.7**	**9.3**	8.17	287
11/4/2014	9.5	**9.3**	8.15	292

Note: Shaded values indicate an exceedance of water quality standards or strong contrast to historical results.

Table 16. Little Spokane River near Mouth Conventional Water Quality Data, 2014

Date	Total Phosphorus (µg/L)	Soluble Reactive Phosphorus (µg/L)	Total Reactive Phosphorus (µg/L)	Total Nitrogen (µg/L)	NO_3+NO_2 (µg/L)
1/7/2014	17.5	14.2	14.3	1,440	1,420
2/4/2014	23.7	15.8	17.6	1,400	1,390
3/4/2014	24.9	14.7	15.5	1,360	1,310
4/8/2014	36.4	16.8	19.7	871	733
5/6/2014	11.9	**3.7**	4.0	**77**	**16**
6/3/2014	22.2	11.2	11.1	1,080	950
7/8/2014	15.9	11.2	11.3	1,150	1,040
8/5/2014	9.7	9.0	9.3	1,210	1,100
9/9/2014	10.5	6.9	7.7	1,210	1,180
10/7/2014	13.8	7.7	7.8	1,220	1,170
11/4/2014	13.0	10.7	11.3	1,400	1,180

Note: Shaded values indicate an exceedance of water quality standards or strong contrast to historical results.

Total N and nitrate+nitrite-N are high in both the Spokane and Little Spokane Rivers in late summer. Those levels, 1,100 to 1,700 TN, with most being nitrate+nitrite, roughly match the levels in the metalimnion and hypolimnion of the lacustrine zone. This suggests that plunging river inflows were the source of the high summer N concentrations, with groundwater being an important contributor.

3.2.10 SPOKANE RIVER DOWNSTREAM OF LONG LAKE DAM

This site is also a "basin" station with data collected during October 2009 through September 2010 (Water Year 2010); however, Ecology did not conduct monitoring during 2014.

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4. DISCUSSION

4.1 Dissolved Oxygen Assessment

Data collected during the past five years indicate an improvement in the reservoir's DO resource from reduced inflow TP. The reservoir's DO has steadily improved since 85% of point-source effluent phosphorus was removed in 1977. That is shown in Figure 95, which was modified from Patmont (1987). During 1972 to 1977, minimum volume-weighted hypolimnetic (below 15 m) DO ranged from 0.2 to 3.4 mg/L, with a mean of 1.4 mg/L. After phosphorus removal, there was a gradual improvement in minimum volume-weighted hypolimnetic DO, increasing to means of 2.5 mg/L during 1978 to 1981, and to 4.5 mg/L during 1982 to 1985 as inflow TP declined to 20 µg/L (Patmont 1987). Almost three generations later, minimum volume-weighted hypolimnetic DO averaged 6.5 mg/L during 2010 to 2014 at inflow TPs averaging 14.2 µg/L during the same period. That progression is evident in Figure 95.

Some of the variability about the line in Figure 95 is likely due to water inflow and residence time – higher inflows (shorter residence times) produced 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 1960 to 1985. Nevertheless, it appears the principal control on minimum volume-weighted hypolimnetic DO immediately before and after phosphorus reduction was inflow TP, as shown in Figure 95, in contrast to residence time (Figure 96). Recently, minimum volume-weighted hypolimnetic DO appears to be dependent on residence time. Minimum volume-weighted hypolimnetic DO during 2010-2014 ranged from slightly less than 6 mg/L to nearly 8 mg/L, while summer volume-weighted riverine TP (surrogate for flow-weighted inflow TP) ranged from 12.5 to 19 µg/L, and appear to be unrelated to each other. However, it appears minimum volume-weighted hypolimnetic DO was more related to June-October water residence time, which ranged from about 24 to 37 days during 2010, 2013 and 2014, with the lowest minimum volume-weighted hypolimnetic DOs, and about 14 to 19 days in 2011 and 2012 when minimum volume-weighted hypolimnetic DOs were highest (Figures 95 and 96).

While DO conditions have improved in Lake Spokane since 85% of point-source effluent phosphorus was removed in 1977, data collected in 2014 indicate DO levels do not meet the surface water quality standard in the hypolimnion during portions of the summer critical season.

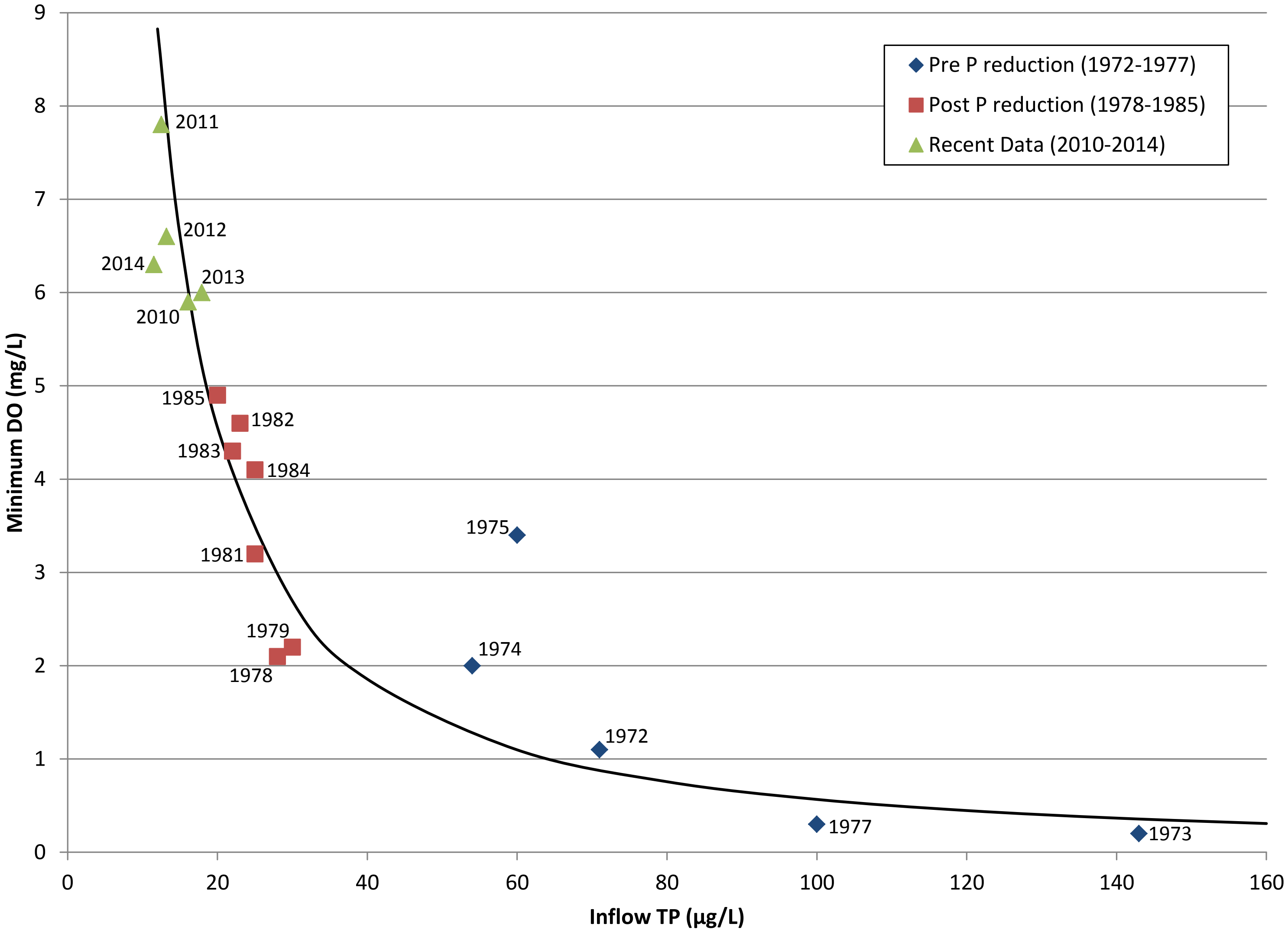

Figure 95. June-October Volume-Weighted Mean Inflow TP Concentrations related to Minimum Volume-Weighted Hypolimnetic DO Concentrations before and after Advanced Wastewater Treatment. Concentrations from 1972 through 1985 from observed loading at Nine Mile Dam (Patmont 1987). Mean inflow TP Concentrations from 2010-2014 were taken as Volume-Weighted Mean TP Concentrations at Station LL5, in lieu of loading data from Nine Mile Dam.

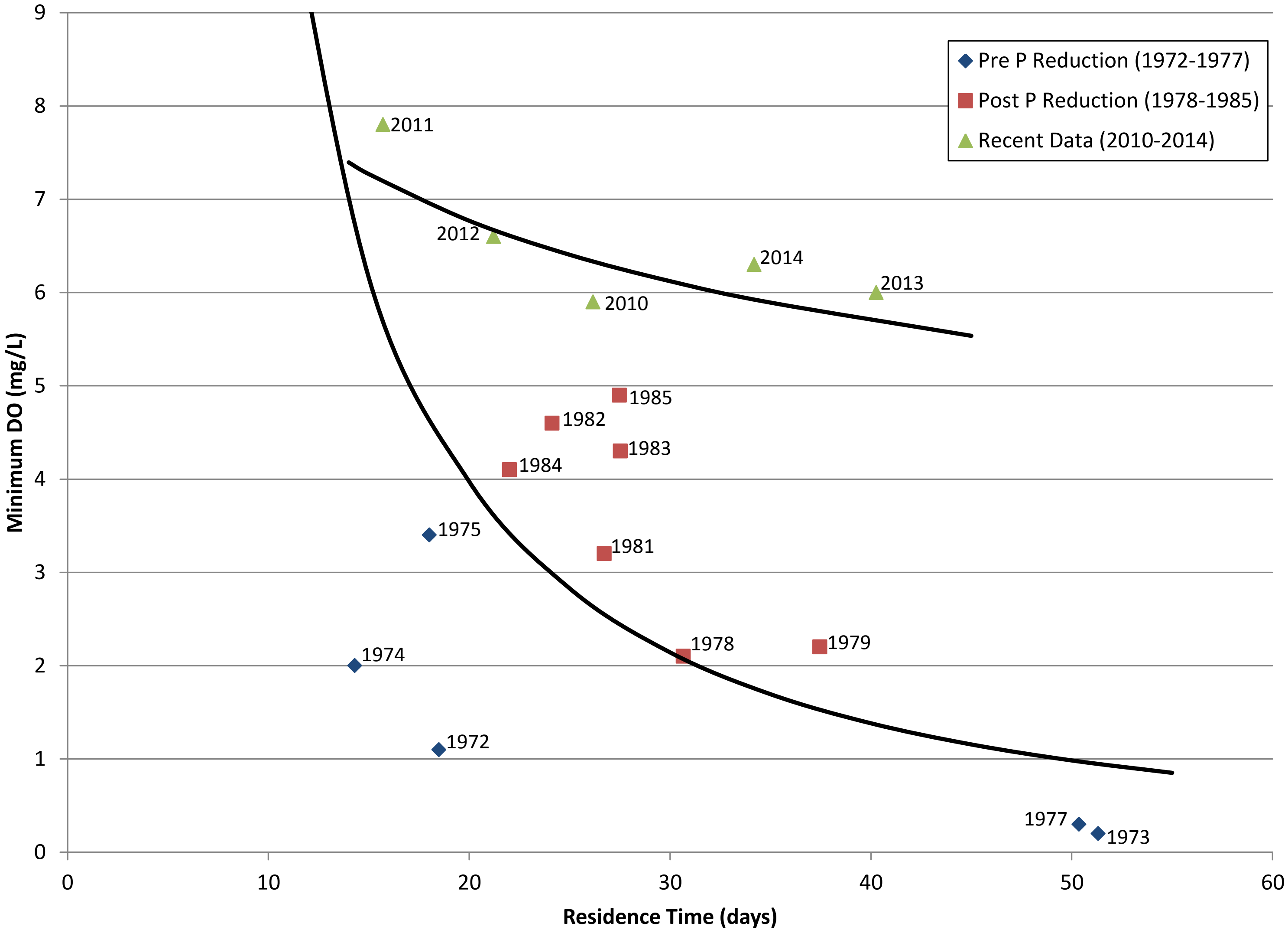

Figure 96. Mean hydraulic residence time (June-October) related to minimum v-w hypolimnetic (below 15 m) DO before and after advanced TP reduction in 1977. Residence time was calculated using reservoir outflows gaged by USGS (1972-1985) and Avista (2010-2014) at Long Lake Dam. Equation for line for all years: $y = 389.01x^{-1.519}$, $r^2 = 0.30$. Equation for line for 2010-2014: $y = 14.2x^{-0.248}$, $r^2 = 0.69$.

4.1.1 DO AND FISH HABITAT

The following section provides a cursory review of fish habitat in Lake Spokane and how it might be affected by DO and temperature conditions, based upon select literature sources, as well as the data collected at the six lake stations. To obtain site specific water quality limitations on fish habitat in Lake Spokane, a more thorough analysis would need to be completed.

Fish can be “squeezed” in summer between epilimnetic water that is too warm and deeper layers that are sufficiently cool but with DO that is too low. The threat to cold water species can be assessed by determining the depth intervals with temperature and DO that are within the optimum ranges for growth. Based upon USFWS, 1984, for rainbow trout, the maximum of the optimum temperature for growth is 18°C and the minimum for DO is 6 mg/L. Their preferred temperature is 14°C (Welch and Jacoby 2004). The minimum DO required is usually cited as 5 mg/L, recognizing that higher DO levels also occur (EPA 1986; USFWS 1984). Using these criteria, trout would probably avoid the epilimnion during most of the summer due to temperature that reached 25°C and prefer to seek cooler water deeper than 10 m (Figures 8 to 11). However, between 10 and 20 m, DO was usually near or above 6 mg/L during August and September, but never less than the often cited required minimum of 5 mg/L (Figures 20 to 23). These data suggest that rainbow trout are most likely inhabiting cooler water in the metalimnion and upper portions of the hypolimnion.

Using these critical maximum temperatures and minimum DOs, percent of the lake volumes acceptable for growth were computed for rainbow trout at the six stations for 2014 (Figures 97-102). Habitat volumes for temperature and DO together, as well as separately, are shown to indicate which factor was most limiting. Analysis of data from 2011, a high flow year and 2013, a low-flow year, shows that habitat was more restrictive during the low-flow year (2013) than the high-flow year (2011) (Avista 2014). Results from 2014 were similar to those from 2013, the low-flow year. It appears temperature restricted habitat far more than DO for rainbow trout at all sites. Habitat for DO showed some restriction at LL0, as in 2013, but very little restriction at other sites or years. Moreover, most of the lost habitat due to DO at LL0 was below 25 m (except for September 9th). Habitat became very restrictive for trout for at least a month during 2013 and 2014, both low-flow years, due mostly to temperature.

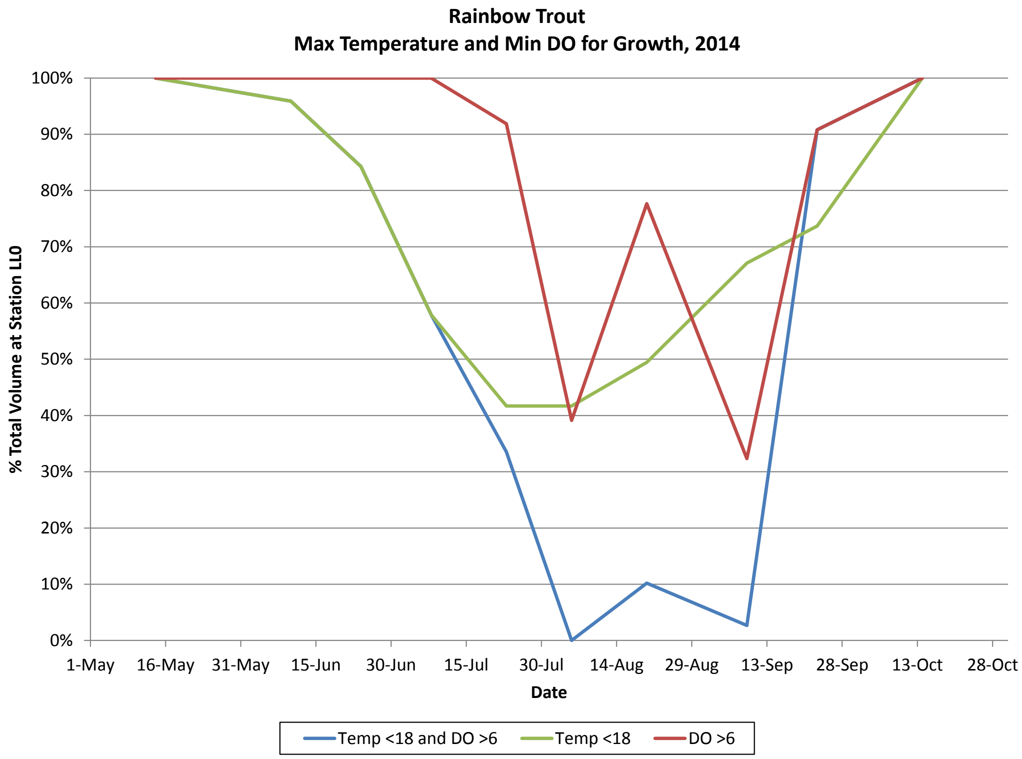

Figure 97. Habitat Conditions at Station LL0 for Rainbow Trout in 2014, Based on Maximum Temperature and Minimum DO for Growth.

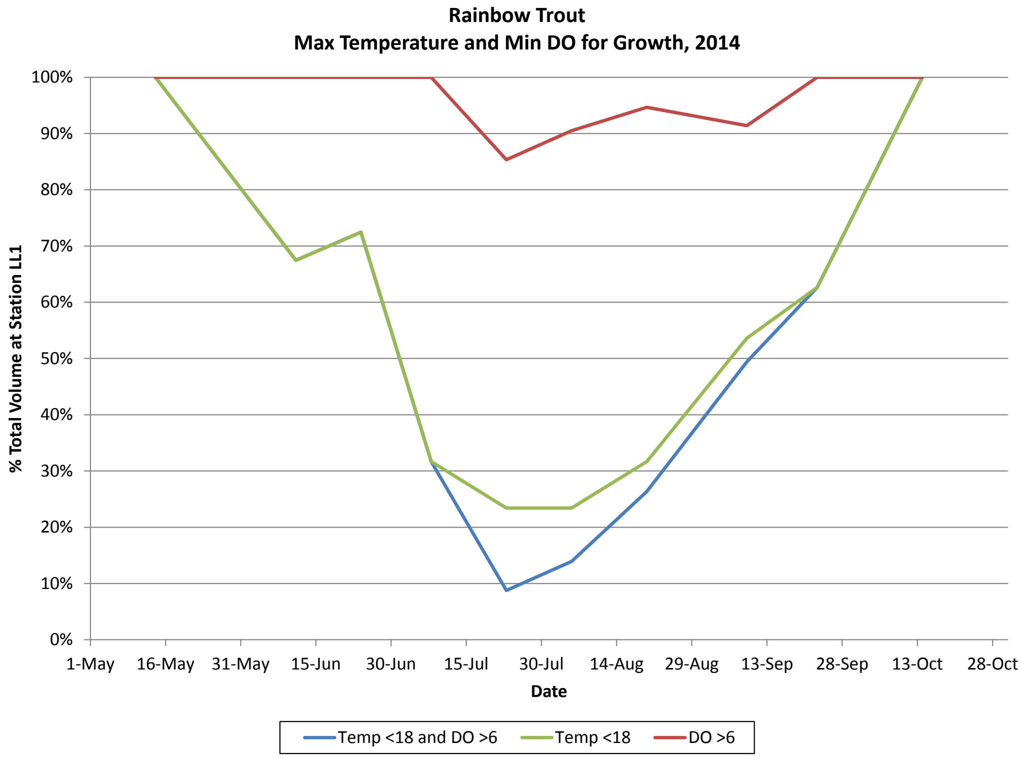

Figure 98. Habitat Conditions at Station LL1 for Rainbow Trout in 2014, Based on Maximum Temperature and Minimum DO for Growth.

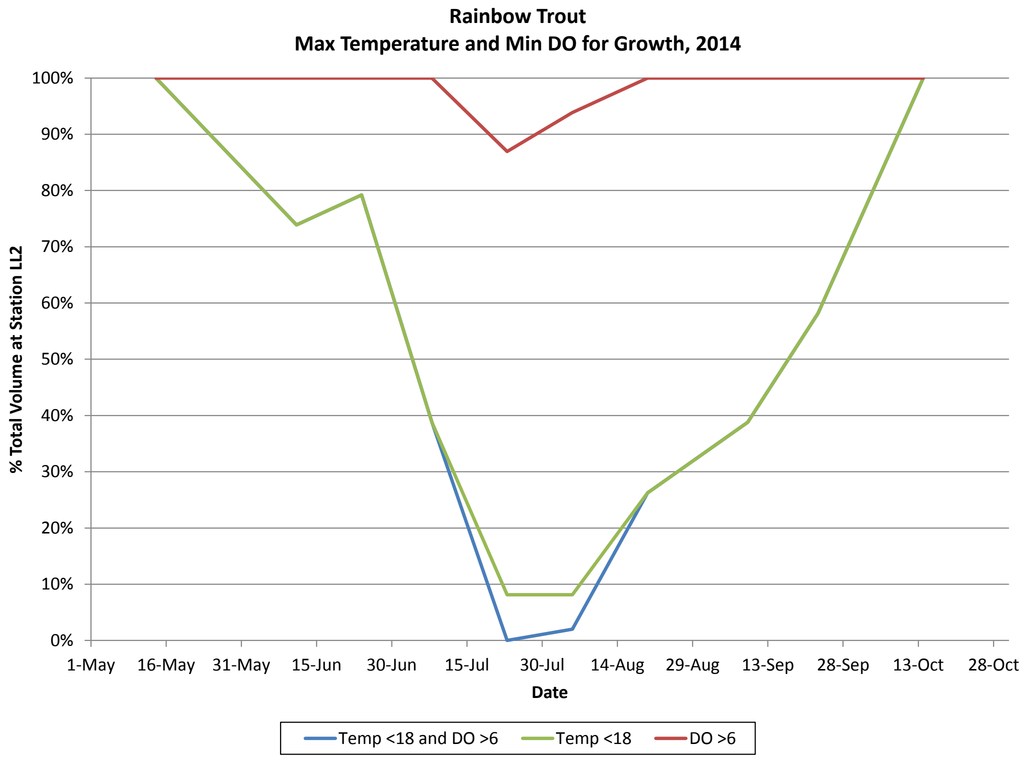

Figure 99. Habitat Conditions at Station LL2 for Rainbow Trout in 2014, Based on Maximum Temperature and Minimum DO for Growth.

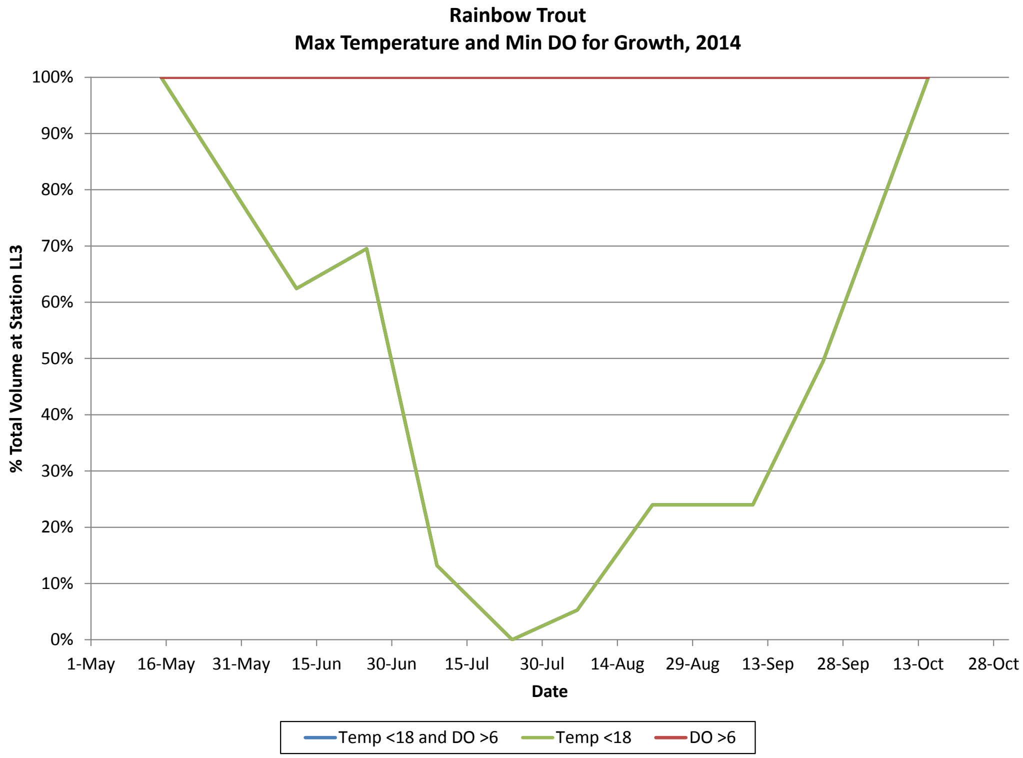

Figure 100. Habitat Conditions at Station LL3 for Rainbow Trout in 2014, Based on Maximum Temperature and Minimum DO for Growth.

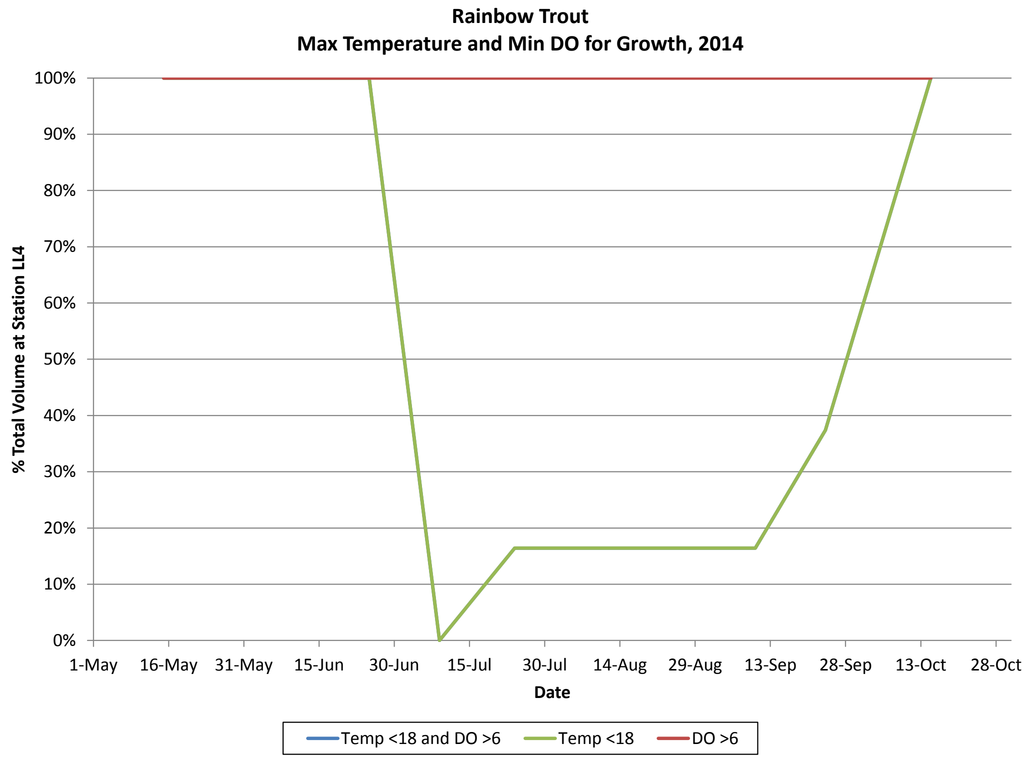

Figure 101. Habitat Conditions at Station LL4 for Rainbow Trout in 2014, Based on Maximum Temperature and Minimum DO for Growth.

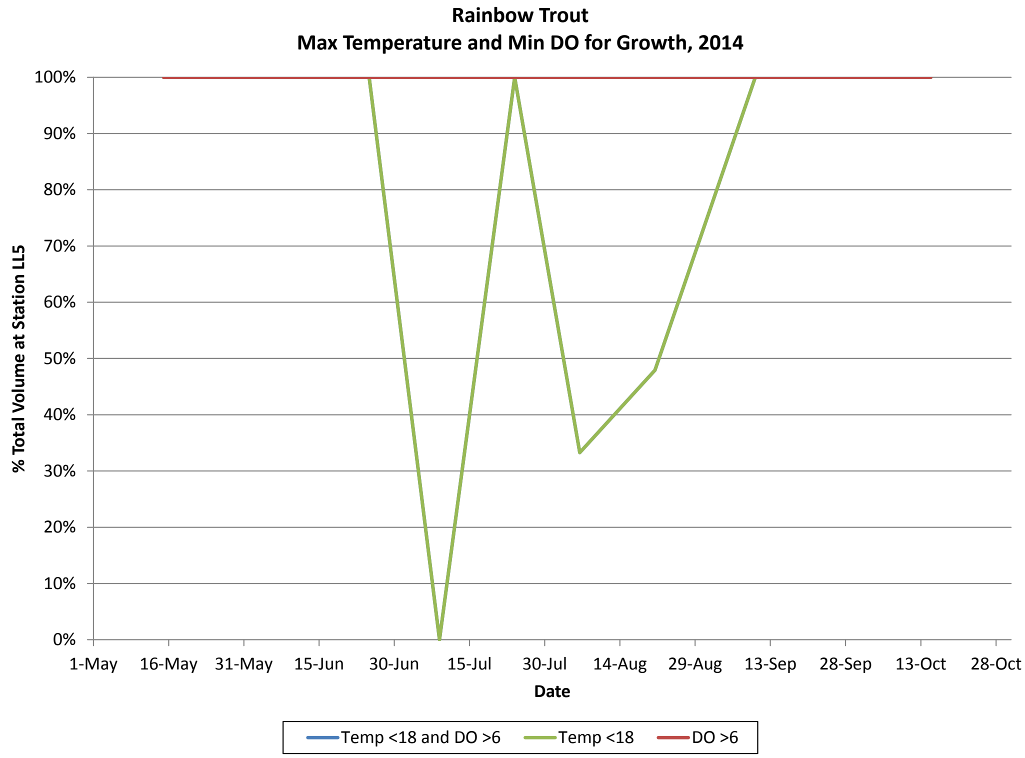

Figure 102. Habitat Conditions at Station LL5 for Rainbow Trout in 2014, Based on Maximum Temperature and Minimum DO for Growth.

4.2 Phosphorus Assessment

Summer (June to September) epilimnetic mean TP concentrations in 2014 were lower than in 2010, 2012, and 2013, but similar to those in 2011 (Figure 103). Summer mean epilimnetic TPs in 2014 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 TP decreased slightly through the reservoir in all five years with TP at station LL0 being the lowest. Area-weighted, whole-lake epilimnetic TPs averaged 11.6 ± 1.5 μg/L for the five years; a variation of only 13%.

Summer (June to September) hypolimnetic TPs also have been rather consistent the past five years – mean 23.5 ± 14%. Hypolimnetic TP was determined in the lacustrine zone for stations LL0, LL1, and LL2 for all five years (Figure 104). Hypolimnetic TP in 2012 through 2014 was calculated using samples collected at 20 m and deeper. This excludes the top 5 m of the hypolimnion, which is necessary in order to compare 2012-2014 data with those based on composite samples collected in 2010 and 2011 at various depths from 21 m and deeper. Hypolimnetic TPs calculated for stations LL0 and LL1 were volume-weighted while concentrations for station LL2 were from 1 m meter off the bottom only.

Maximum TPs in the past five years have usually been less than 35 μg/L, and the average hypolimnetic TP was 22 μg/L (May-October).

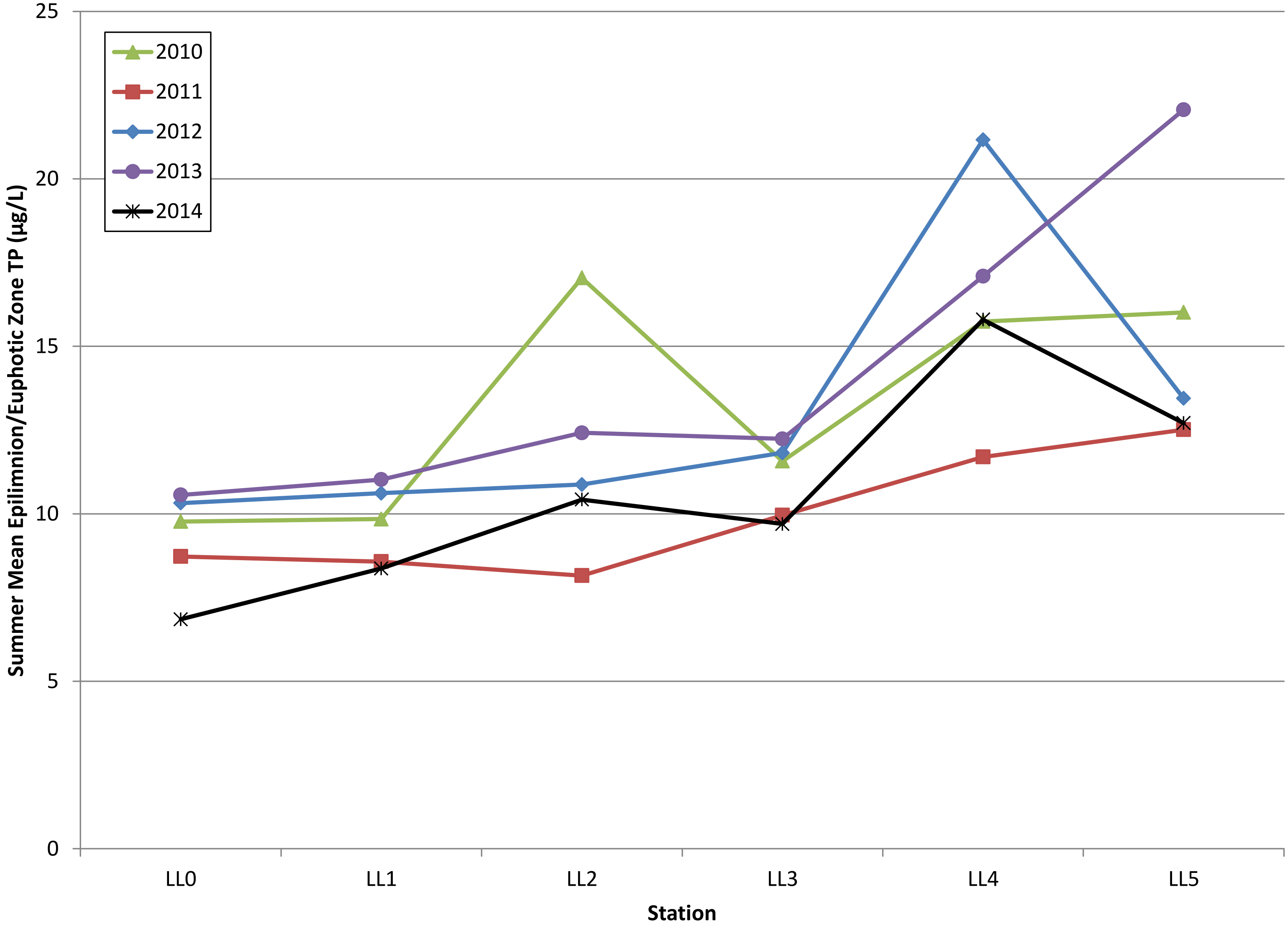

Figure 103. Summer (June-September) Mean Epilimnion/Euphotic Zone TP Concentrations, 2010-2014
(Data is presented from down-reservoir to up-reservoir left to right.)

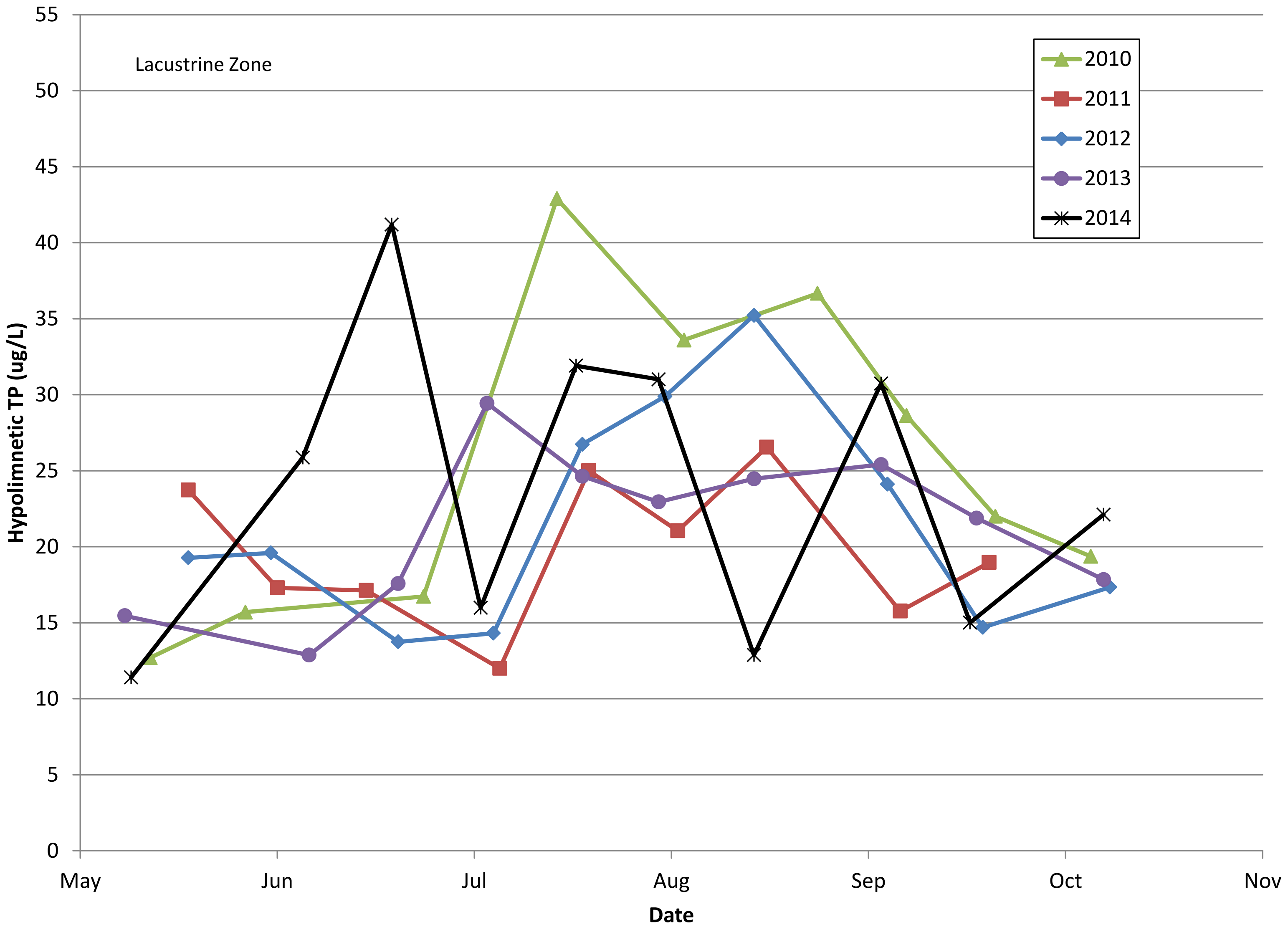

Figure 104. Lacustrine Zone Mean Hypolimnetic TP Concentrations, 2010-2014

4.3 Trophic State

Lake Spokane was at or near borderline oligotrophic-mesotrophic on average in all zones for the last 5 years, except for TP in the transition and riverine zones that averaged slightly greater than the oligotrophic-mesotrophic boundary of 10 µg/L (Tables 17 and 18). The trophic state index (TSI) values were similarly at or just slightly over the TSI of 40 - the oligo-mesotrophic boundary (Table 19). TSI values lower than 40 indicate an oligotrophic state. TSI values between 40 and 50 indicate mesotrophy.

Table 17. 2012-2014 Summer (June to September) Epilimnetic Means Compared to 2010 and 2011 Summer Euphotic Zone Means in Lacustrine, Transition, and Riverine Zones in Lake Spokane

Year	Lacustrine (0.5, 5 m)			Transition (0.5 m)			Riverine Zone (0.5 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
2011	9.1	3.3	5.8	10.8	1.9	4.7	12.5	1.4	4.8
2012	10.6	4.8	4.4	16.5	4.0	3.9	13.4	2.7	4.7
2013	11.3	3.0	5.7	14.7	5.5	3.9	22.1	3.2	4.1
2014	8.5	3.8	5.0	12.7	5.9	3.6	12.7	4.2	4.0
Average	9.9	4.0	5.2	13.7	4.4	4.0	15.3	2.9	4.2

Table 18. Trophic State Boundaries

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

Source: Nurnberg 1996

Table 19. Trophic State Index Values for Lacustrine, Transition, and Riverine Zones in Lake Spokane, 2014

2014	Lacustrine	Transition	Riverine
TSI-TP	35	41	41
TSI-Chl	44	48	45
TSI-Secchi	37	42	40
TSI-Average	38	43	42

Table 20. Total Nitrogen to Total Phosphorus ratios for 2014 by station; calculated using summer mean Epilimnion TP and TN

Station	2014 TN:TP
LL0	86.5
LL1	71.4
LL2	60.1
LL3	59.9
LL4	40.5
LL5	91.2

4.4 Quality Assurance

Quality assurance review of field and laboratory data was conducted in accordance with the guidelines and requirements outlined in the *Quality Assurance Project Plan for Lake Spokane Baseline Nutrient Monitoring* (QAPP). Replicate field measurements and laboratory samples as well as field blanks were compared to the measurement quality objectives (MQOs) as stated in the QAPP. If data warranted qualification based on the guidelines in the QAPP, qualifiers such as “J – result is considered an estimate”, were assigned to the associated data in the database prepared for Ecology’s Environmental Information Management (EIM) along with a comment describing why the data needed qualification.

In 2014 only one field measurement, pH at Station LL3 at a depth of 1 m was qualified. The value was qualified in the EIM database as “J-” meaning “estimate biased low” because the value appeared to be an outlier given the pH values at the surrounding depths. This pH value was not included in any data analysis because of this qualification.

Within the database prepared for EIM, laboratory data was qualified using the following qualifiers; “U, for non-detect”, “J+, for estimate biased high”, “J-, for estimated biased low”, or “J, for result is an estimate”. For 2014, there were 6 nutrient samples, collected early in the monitoring season (May and June), which were qualified within the database as being suspect data due to possible contamination from bottom sediments. These samples, collected from the bottom at stations LL1, LL2 and LL3, had extremely high TP concentrations. These high TP concentrations ranged from 129 to 381 µg/L which is three to nine times greater than the maximum bottom TP concentration observed in 2013. These high TP concentrations are also approximately twice as high as the maximum TP concentration observed at LL0 during 2014. Based on this and field notes during the sampling events, these bottom samples had probably been contaminated with bottom sediments during collection and therefore were not included in the data analysis for this report. Upon first receiving this suspicious data from the lab, the field crew purchased a new rope for the Van Dorn sampling apparatus to replace the older rope which apparently had stretched over time, causing an underestimation of depth.

This qualified data was not included within any data analysis due to the suspect nature of the high concentrations, several times higher than any bottom data point collected during the 5 years of monitoring. Three other nutrient samples were qualified within the database as estimates due to field replicate relative percent difference (RPDs) being outside the acceptable criteria stated in the QAPP. However, the parent sample results for these qualified samples were used in the data analysis since the results were within the expected range of concentrations and in line with other sample results at surrounding depths.

During the 2014 monitoring period, several field blank samples had TN concentrations over the detection limit. The field blank samples were collected using laboratory provided de-ionized water. The concentration of TN found in the field blank samples was just slightly over the MDL and significantly lower than the TN concentrations found in the reservoir samples. After discussion with the lab it was thought that rinsing the sampling equipment with distilled water prior to collecting the field blank may have contaminated the equipment however this would not have impacted the reservoir samples. The field crews stopped the use of distilled water in September and rinsed with only de-ionized water the remainder of the monitoring period. The subsequent field blanks did not have TN above the MDL. No reservoir TN data were qualified based on the detection of TN in the field blank due to the magnitude difference between the reservoir sample TN concentrations and the very low amount of TN detected in the field blank.

4.5 Monitoring Recommendations for 2015

Based on 2014 monitoring results, it is recommended that monitoring activities continue unchanged for 2015.

5. REFERENCES

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APPENDIX I – Lake Spokane *In Situ* Monitoring Data

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Table A-1. Station LL0 *In Situ* Water Quality Data, 2014

Date	Depth (m)	Temperature (°C)	pH	Cond (µS/cm)	DO (mg/l)	DO Sat. (%)	Winkler DO (mg/L)	Secchi Disk Depth (m)**
5/14/2014	0.5	13.35	8.22	69.3	12.69	126.5		2.6
5/14/2014	1	12.45	8.61	69.1	13.29	129.8		
5/14/2014	2	11.58	8.36	69.2	12.99	124.4		
5/14/2014	3	11.21	8.05	69.1	12.34	117.1		
5/14/2014	4	10.98	7.92	69.4	11.88	112.2		
5/14/2014	5	10.92	7.83	69.2	11.84	111.7	12.1	
5/14/2014	6	10.92	7.89	69.4	11.82	111.5		
5/14/2014	7	10.93	7.8	69.2	11.78	111.1		
5/14/2014	8	10.83	7.75	69.5	11.78	110.8		
5/14/2014	9	10.83	7.72	69.6	11.76	110.6		
5/14/2014	9*	10.83	7.71	69.3	11.79	110.9		
5/14/2014	10	10.82	7.71	69.4	11.75	110.5		
5/14/2014	12	10.83	7.76	69.4	11.78	110.8		
5/14/2014	15	10.76	7.74	69.8	11.69	109.9	11.9	
5/14/2014	18	10.72	7.72	69.6	11.65	109.4		
5/14/2014	21	10.7	7.73	69.6	11.64	109.2		
5/14/2014	24	10.7	7.73	69.3	11.68	109.4		
5/14/2014	27	10.69	7.74	69.6	11.65	109.2		
5/14/2014	30	10.67	7.73	69.6	11.72	109.9		
5/14/2014	33	10.65	7.74	69.7	11.64	109		
5/14/2014	33*	10.64	7.74	69.7	11.66	109.2		
5/14/2014	36	10.44	7.72	70.1	11.59	108.1		
5/14/2014	39	10.42	7.73	69.9	11.56	107.7		
5/14/2014	42	10.41	7.72	70.2	11.55	107.6		
5/14/2014	45	10.08	7.67	71	11.43	105.6		
5/14/2014	48	10	7.63	71.2	11.29	104.2		
6/10/2014	0.5	18.09	8.8	86.4	12.12	135.8		2.6
6/10/2014	1	17.93	8.81	86.8	12.16	135.7		
6/10/2014	2	17.39	8.74	87.2	11.92	131.4		
6/10/2014	3	17.25	8.77	86.8	11.84	130.2		
6/10/2014	4	17.22	8.69	86.9	11.74	129.2		
6/10/2014	5	17.14	8.44	87.5	11.38	125	12	
6/10/2014	6	17.12	8.56	87.5	11.41	125.3		
6/10/2014	7	17.12	8.59	87.8	11.4	125.1		
6/10/2014	8	17.12	8.56	87.8	11.4	125.1		
6/10/2014	9	17.05	8.45	87.5	11.2	122.7		
6/10/2014	9*	17.07	8.47	87.5	11.27	123.6		
6/10/2014	10	16.98	8.38	88.2	11.05	120.9		

Date	Depth (m)	Temperature (°C)	pH	Cond (µS/cm)	DO (mg/l)	DO Sat. (%)	Winkler DO (mg/L)	Secchi Disk Depth (m)**
6/10/2014	12	16.72	7.99	88.1	10.19	110.9		
6/10/2014	15	16.45	7.8	88.2	9.7	105	9.84	
6/10/2014	18	16.4	7.73	88.1	9.71	105.1		
6/10/2014	21	16.16	7.7	86.8	9.73	104.7		
6/10/2014	24	15.52	7.67	77.9	10.09	107.1		
6/10/2014	27	15.29	7.64	76.4	10.15	107.1		
6/10/2014	30	14.99	7.58	75.1	9.99	104.8		
6/10/2014	33	14.87	7.55	74.6	9.93	104		
6/10/2014	33*	14.86	7.51	74.5	9.93	103.9		
6/10/2014	36	14.75	7.51	73.7	9.9	103.4		
6/10/2014	39	14.62	7.49	73.7	9.69	100.9		
6/10/2014	42	14.48	7.44	73.7	9.36	97.1		
6/10/2014	45	14.41	7.4	74	9.1	94.3		
6/10/2014	47	14.4	7.39	74.1	9	93.3		
6/24/2014	0.5	20.38	8.18	98.9	9.51	111.2		4.8
6/24/2014	1	19.56	8.32	99.2	10.04	115.5		
6/24/2014	2	19.05	8.47	99.3	10.62	121		
6/24/2014	3	18.41	8.58	100	10.9	122.5		
6/24/2014	4	17.95	8.61	100.4	11.13	124		
6/24/2014	5	17.66	8.61	99.9	11.25	124.6	11.3	
6/24/2014	6	17.24	8.45	101.6	11.05	121.3		
6/24/2014	7	16.83	7.97	102.3	10.21	111.1		
6/24/2014	8	16.59	7.72	101.1	10.06	108.9		
6/24/2014	9	16.38	7.64	101.2	9.77	105.3		
6/24/2014	9*	16.44	7.69	101.5	9.14	98.6		
6/24/2014	10	16.29	7.62	101.9	8.96	96.4		
6/24/2014	12	16.08	7.59	103.9	8.91	95.4		
6/24/2014	15	15.83	7.61	104.8	9.16	97.6	8.92	
6/24/2014	18	15.58	7.62	105.4	9.27	98.3		
6/24/2014	21	15.4	7.65	107.9	9.3	98.2		
6/24/2014	24	15.18	7.66	106.9	9.38	98.6		
6/24/2014	27	15.11	7.67	107	9.44	99		
6/24/2014	30	14.96	7.66	107.4	9.44	98.7		
6/24/2014	33	14.86	7.65	107.9	9.36	97.7		
6/24/2014	33*	14.86	7.65	107.7	9.34	97.5		
6/24/2014	36	14.82	7.65	107.9	9.34	97.3		
6/24/2014	39	14.78	7.64	108	9.28	96.7		
6/24/2014	42	14.76	7.63	108.2	9.26	96.4		
6/24/2014	45	14.73	7.62	107.9	9.2	95.7		

Date	Depth (m)	Temperature (°C)	pH	Cond (µS/cm)	DO (mg/l)	DO Sat. (%)	Winkler DO (mg/L)	Secchi Disk Depth (m)**
6/24/2014	46	14.73	7.61	107.9	9.19	95.6		
7/8/2014	0.5	22.29	8.58	112.5	9.84	119.5		5.7
7/8/2014	1	22.12	8.7	112.3	9.97	120.6		
7/8/2014	2	21.93	8.64	112.4	10.03	120.9		
7/8/2014	3	21.57	8.71	112.6	10.64	127.5		
7/8/2014	4	20.91	8.79	114.2	11.48	135.7		
7/8/2014	5	20.07	8.76	115.6	11.68	135.9	12	
7/8/2014	6	19.54	8.74	118.6	11.75	135.1		
7/8/2014	7	19.1	8.59	123	11.29	128.7		
7/8/2014	8	18.82	8.51	117.8	11.03	125.1		
7/8/2014	9	18.61	8.43	118.6	10.78	121.7		
7/8/2014	9*	18.63	8.44	118.5	10.87	122.7		
7/8/2014	10	18.41	8.29	118.2	10.48	117.8		
7/8/2014	12	17.95	7.92	118.3	9.53	106.2		
7/8/2014	15	17.33	7.66	124.1	8.43	92.7	9.08	
7/8/2014	18	16.9	7.62	122.7	8.58	93.5		
7/8/2014	21	16.47	7.59	119	8.66	93.6		
7/8/2014	24	16.08	7.56	111.6	8.71	93.3		
7/8/2014	27	15.7	7.52	107.1	8.68	91.9		
7/8/2014	30	15.48	7.45	106.3	8.33	88		
7/8/2014	33	15.18	7.41	105.7	8.2	86.2		
7/8/2014	33*	15.19	7.4	105.7	8.24	86.6		
7/8/2014	36	15.01	7.36	106.5	7.92	83		
7/8/2014	39	14.82	7.31	107.3	7.48	77.9		
7/8/2014	42	14.71	7.27	108.1	7.07	73.5		
7/8/2014	45	14.64	7.24	108.8	6.87	71.3		
7/8/2014	46	14.63	7.24	108.9	6.83	70.9		
7/23/2014	0.5	22.94	8.67	141.8	9.3	114.6		7.7
7/23/2014	1	22.85	8.73	141.6	9.34	114.8		
7/23/2014	2	22.77	8.72	141.1	9.32	114.4		
7/23/2014	3	22.73	8.72	141.7	9.34	114.6		
7/23/2014	4	22.72	8.72	141.2	9.34	114.6		
7/23/2014	5	22.69	8.73	141.3	9.34	114.1		
7/23/2014	6	22.65	8.73	141.3	9.32	114.1		
7/23/2014	7	22.52	8.7	141.3	9.3	113.6		
7/23/2014	8	22.31	8.71	140.8	9.55	116.2		
7/23/2014	9	22.03	8.68	141.1	9.66	116.9		
7/23/2014	9*	21.93	8.68	141.6	9.65	116.6		
7/23/2014	10	19.98	7.95	165.1	8.59	99.8		

Date	Depth (m)	Temperature (°C)	pH	Cond (µS/cm)	DO (mg/l)	DO Sat. (%)	Winkler DO (mg/L)	Secchi Disk Depth (m)**
7/23/2014	12	19.57	7.74	159.8	7.65	88.1		
7/23/2014	15	18.76	7.61	136.4	7.59	86.1	6.54	
7/23/2014	18	17.76	7.5	120.9	7.35	81.7		
7/23/2014	21	17.1	7.43	120.4	7.14	78.3		
7/23/2014	24	16.59	7.39	121.2	7.09	76.9		
7/23/2014	27	16.01	7.35	114.9	7.08	75.8		
7/23/2014	30	15.58	7.27	111.5	6.24	66.3	6.06	
7/23/2014	33	15.1	7.25	106.2	6.52	68.4		
7/23/2014	33*	15.11	7.24	106.4	6.53	68.6		
7/23/2014	36	14.95	7.22	106.3	6.31	66.1		
7/23/2014	39	14.69	7.13	106.8	5.09	53		
7/23/2014	42	14.57	7.08	107.8	4.39	45.6		
7/23/2014	45	14.53	7.06	107.7	4.09	42.5		
7/23/2014	46	14.5	7.05	107.9	3.86	40		
8/5/2014	0.5	24.16	8.8	152.7	9.69	122.1		6.0
8/5/2014	1	24.16	8.81	152.9	9.68	122.1		
8/5/2014	2	24.14	8.81	152.4	9.7	122.2		
8/5/2014	3	24.08	8.83	152.5	9.88	124.3		
8/5/2014	4	22.99	9.1	150.4	12.49	154		
8/5/2014	5	22.18	8.96	153.1	11.85	143.8		
8/5/2014	6	21.31	8.78	164.7	11.43	136.4		
8/5/2014	7	20.54	8.55	170.6	10.97	128.9		
8/5/2014	8	20.13	8.24	170	9.69	112.9		
8/5/2014	9	19.63	7.87	168.1	8.31	96		
8/5/2014	9*	19.65	7.87	168.5	8.28	95.7		
8/5/2014	10	19.25	7.57	166.2	6.75	77.3		
8/5/2014	12	18.76	7.41	158.8	5.52	62.6		
8/5/2014	15	18.29	7.36	156.5	5.15	57.9	5.26	
8/5/2014	18	17.75	7.31	144.5	5.29	58.8		
8/5/2014	21	17.18	7.26	142.6	4.99	54.8		
8/5/2014	24	16.9	7.25	143.1	4.98	54.3		
8/5/2014	27	16.31	7.2	122.4	5.27	56.9		
8/5/2014	30	15.58	7.1	114.7	4.81	51.1		
8/5/2014	33	15.18	7.12	109.1	5.51	57.9	4.84	
8/5/2014	33*	15.24	7.11	110.1	5.45	57.4		
8/5/2014	36	14.89	7.08	108.3	4.99	52.1		
8/5/2014	39	14.6	6.99	108.5	3.54	36.8		
8/5/2014	42	14.48	6.96	109.2	2.92	30.2		
8/5/2014	45	14.43	6.94	110	2.67	27.6		

Date	Depth (m)	Temperature (°C)	pH	Cond (µS/cm)	DO (mg/l)	DO Sat. (%)	Winkler DO (mg/L)	Secchi Disk Depth (m)**
8/5/2014	46.5	14.41	6.93	110.2	2.56	26.4		
8/5/2014	47	14.38	6.93	110.4	2.55	26.4		
8/20/2014	0.5	23.99	9.06	157.1	10.56	133.2		4.9
8/20/2014	1	23.98	9.06	157.1	10.59	133.6		
8/20/2014	2	23.95	9.06	157.4	10.57	133.2		
8/20/2014	3	23.95	9.06	157.4	10.59	133.5		
8/20/2014	4	23.93	9.06	157.5	10.59	133.5		
8/20/2014	5	23.77	9.07	158	11.83	148.6		
8/20/2014	6	22.16	9.01	173.2	14.07	171.5		
8/20/2014	7	20.48	8.31	171.5	9.76	115.1	9.88	
8/20/2014	8	19.43	7.71	179.7	5.46	63.1		
8/20/2014	9	18.82	7.52	198	5.15	58.7		
8/20/2014	9*	18.82	7.46	197.8	4.94	56.4		
8/20/2014	10	18.5	7.48	209.6	5.53	42.6		
8/20/2014	12	18.24	7.57	232.3	6.44	72.5		
8/20/2014	15	17.89	7.59	232.5	6.37	71.3		
8/20/2014	18	17.65	7.57	227.8	6	66.8		
8/20/2014	21	17.49	7.53	226.6	5.8	64.4		
8/20/2014	24	17.26	7.48	207.6	5.5	60.8	5.42	
8/20/2014	27	16.69	7.4	164.6	4.29	46.8		
8/20/2014	30	15.7	7.28	121.2	3.08	32.9		
8/20/2014	33	15.26	7.2	112.6	4.02	42.6		
8/20/2014	33*	15.26	7.15	112.5	4.08	43.2		
8/20/2014	36	14.79	7.12	109.4	3.84	40.3		
8/20/2014	39	14.53	7.05	109.6	2.46	25.6		
8/20/2014	42	14.43	6.99	110.2	1.6	16.6		
8/20/2014	45	14.35	6.95	111	1.14	11.8		
8/20/2014	46.5	14.31	6.93	110.7	1.06	11		
8/20/2014	47	14.29	6.92	110.9	0.94	9.7		
9/9/2014	0.5	19.75	8.88	192.7	10.2	118		4.3
9/9/2014	1	19.75	8.88	192.7	10.2	118		
9/9/2014	2	19.75	8.9	192.8	10.21	118.2		
9/9/2014	3	19.73	8.89	192.6	10.2	118		
9/9/2014	4	19.73	8.9	192.6	10.18	117.8		
9/9/2014	5	19.72	8.9	192.7	10.16	117.5		
9/9/2014	6	19.17	8.27	214.2	7.99	91.4		
9/9/2014	7	18.68	7.86	237.3	6.06	68.6		
9/9/2014	8	18.32	7.78	244.5	5.86	65.8		
9/9/2014	9	17.94	7.73	248.1	5.82	64.9		

Date	Depth (m)	Temperature (°C)	pH	Cond (µS/cm)	DO (mg/l)	DO Sat. (%)	Winkler DO (mg/L)	Secchi Disk Depth (m)**
9/9/2014	9*	17.91	7.71	248.3	5.82	64.8		
9/9/2014	10	17.71	7.68	245.3	5.56	61.7	5.57	
9/9/2014	12	17.45	7.65	247.4	5.57	61.5		
9/9/2014	15	17.06	7.68	258.6	6.08	66.6		
9/9/2014	18	16.84	7.63	251.6	5.27	57.4		
9/9/2014	21	16.46	7.5	229	3.71	40.1		
9/9/2014	24	15.94	7.43	198	2.72	29.1		
9/9/2014	27	15.97	7.47	221.5	4.3	46		
9/9/2014	30	15.89	7.46	211.2	3.61	38.6	4.29	
9/9/2014	33	15.56	7.36	157.1	1.41	15		
9/9/2014	33*	15.55	7.3	158	1.39	14.8		
9/9/2014	36	14.96	7.31	144.5	2.45	25.6		
9/9/2014	39	14.54	7.24	110.9	1.24	12.9		
9/9/2014	42	14.36	7.18	111.2	0	0		
9/9/2014	45	14.28	7.14	111.7	0	0		
9/9/2014	47	14.24	7.11	111.4	0	0		
9/23/2014	0.5	19.36	8.81	208.7	9.86	113.1		5.6
9/23/2014	1	19.27	8.81	209	9.9	113.5		
9/23/2014	2	18.97	8.88	207.8	10.51	119.8		
9/23/2014	3	18.89	8.88	208.3	10.48	119.2		
9/23/2014	4	18.75	8.83	209.8	10.22	115.9		
9/23/2014	5	18.4	8.66	215.8	9.4	105.9	9.75	
9/23/2014	6	18.2	8.46	220.9	8.76	98.2		
9/23/2014	7	17.96	8.05	235.1	7	78.1		
9/23/2014	8	17.65	7.88	245.3	6.25	69.4		
9/23/2014	9	17.18	7.72	252.8	5.18	56.9		
9/23/2014	9*	17.19	7.7	253	5.21	57.3		
9/23/2014	10	16.88	7.66	250.5	4.76	51.9		
9/23/2014	12	16.55	7.65	248.1	7.86	52.6		
9/23/2014	15	16.09	7.74	246.1	6.27	67.3		
9/23/2014	18	15.68	7.73	249.3	6.05	64.4		
9/23/2014	21	15.31	7.74	249.7	6.36	67.1		
9/23/2014	24	14.95	7.76	236.1	6.88	72		
9/23/2014	27	14.66	7.85	233.5	7.68	79.9		
9/23/2014	30	14.59	7.9	234.8	7.89	81.9	7.57	
9/23/2014	33	14.54	7.9	235	7.88	81.8		
9/23/2014	33*	14.54	7.91	234.8	7.92	82.2		
9/23/2014	36	14.51	7.89	234.5	7.79	80.9		
9/23/2014	39	14.5	7.89	234.2	7.79	80.8		

Date	Depth (m)	Temperature (°C)	pH	Cond (µS/cm)	DO (mg/l)	DO Sat. (%)	Winkler DO (mg/L)	Secchi Disk Depth (m)**
9/23/2014	42	14.49	7.88	234.6	7.68	79.6		
9/23/2014	45	14.47	7.84	234.2	7.45	77.2		
9/23/2014	47	14.47	7.82	234.5	7.39	76.6		
10/14/2014	0.5	15.9	8.23	223.7	8.98	96.4		6.0
10/14/2014	1	15.89	8.31	223.7	9.03	96.9		
10/14/2014	2	15.88	8.31	223.4	9.02	96.7		
10/14/2014	3	15.88	8.32	223.7	8.99	96.5		
10/14/2014	4	15.88	8.34	223.4	8.98	96.4		
10/14/2014	5	15.87	8.36	223.7	8.98	96.3	8.47	
10/14/2014	6	15.87	8.35	223.4	8.99	96.4		
10/14/2014	7	15.87	8.35	223.4	8.97	96.3		
10/14/2014	8	15.87	8.35	223.4	8.97	96.3		
10/14/2014	9	15.87	8.35	223.4	8.99	96.4		
10/14/2014	9*	15.87	8.36	223.7	8.98	96.3		
10/14/2014	10	15.87	8.36	223.8	8.98	96.3		
10/14/2014	12	15.84	8.35	223.5	8.91	95.6		
10/14/2014	15	15.53	7.99	230.4	7.54	80.3	7.97	
10/14/2014	18	15.22	7.75	232.1	6.49	68.7		
10/14/2014	21	14.52	7.71	217.2	6.29	65.6		
10/14/2014	24	14.12	7.78	205.7	7.57	78.2		
10/14/2014	27	13.92	7.86	204	8.1	83.3		
10/14/2014	30	13.79	7.86	203	8.1	83.1		
10/14/2014	33	13.7	7.87	202.1	8.23	84.2		
10/14/2014	33*	13.7	7.87	202.1	8.24	84.3		
10/14/2014	36	13.64	7.86	201.8	8.14	83.2		
10/14/2014	39	13.63	7.85	202	8.02	81.9		
10/14/2014	42	13.61	7.84	201.6	7.98	81.5		
10/14/2014	45	13.6	7.82	202.2	7.81	79.8		
10/14/2014	47	13.6	7.79	202.1	7.54	77		

*QA/QC measurement for Hydrolab
**Secchi disk depths average of 3 measurements

Table A-2. Station LL1 *In Situ* Water Quality Data, 2014

Date	Depth (m)	Temperature (°C)	pH	Cond (µS/cm)	DO (mg/l)	DO Sat. (%)	Winkler DO (mg/L)	Secchi Disk Depth (m)**
5/14/2014	0.5	14.14	7.92	70.5	12.11	122.8		2.5
5/14/2014	1	13.89	8.01	70.4	12.17	122.7		
5/14/2014	2	12.86	8	70.5	12.36	122		
5/14/2014	3	11.79	7.89	70	12.57	121		
5/14/2014	4	11.6	7.93	70	12.49	119.7		
5/14/2014	4*	11.59	7.9	70.6	12.42	119		
5/14/2014	5	11.26	7.77	70.4	12.33	117.1	12.2	
5/14/2014	6	11.17	7.76	70.3	12.22	115.9		
5/14/2014	7	11.13	7.72	70.4	12.17	115.3		
5/14/2014	8	11.04	7.71	70.2	12.13	114.7		
5/14/2014	9	10.95	7.67	70.2	12.11	114.3		
5/14/2014	10	11.01	7.69	70.4	12.13	114.6		
5/14/2014	12	10.9	7.66	70.4	12.19	114.9		
5/14/2014	15	10.85	7.7	70.1	12.13	114.2		
5/14/2014	18	10.76	7.68	70.1	11.99	112.6		
5/14/2014	21	10.69	7.65	70.2	11.91	111.7	12	
5/14/2014	21*	10.68	7.67	70.4	11.89	111.4		
5/14/2014	24	10.66	7.66	70.6	11.94	111.9		
5/14/2014	27	10.65	7.66	70.3	11.91	111.6		
5/14/2014	30	10.62	7.67	70.5	11.77	110.2		
5/14/2014	33	10.54	7.64	70.3	11.58	108.2		
6/11/2014	0.5	19.62	8.67	84.8	10.62	122		3.9
6/11/2014	1	19.45	8.31	84.5	10.64	121.9		
6/11/2014	2	19.33	8.52	84.6	10.62	121.2		
6/11/2014	3	19.26	8.27	84.8	10.61	121		
6/11/2014	4	19.17	8.59	84.8	10.62	120.9		
6/11/2014	5	19.03	8.33	84.9	10.73	121.9	11	
6/11/2014	6	17.53	8.27	92.4	10.49	115.5		
6/11/2014	7	17.38	8.14	89.3	10.34	113.5		
6/11/2014	8	17.21	8.12	89.1	10.11	110.5		
6/11/2014	9	16.87	7.99	91.1	9.9	107.5		
6/11/2014	10	16.75	7.98	92.7	9.86	106.8		
6/11/2014	12	16.55	7.87	91.5	9.64	104		
6/11/2014	15	16.35	7.73	88.6	9.56	102.7		
6/11/2014	18	16.2	7.67	85.9	9.45	101.1		
6/11/2014	21	16.08	7.6	84.1	9.44	100.8	10.1	
6/11/2014	24	15.93	7.57	83.1	9.45	100.6		
6/11/2014	27	15.38	7.56	78.6	9.59	100.9		

Date	Depth (m)	Temperature (°C)	pH	Cond (µS/cm)	DO (mg/l)	DO Sat. (%)	Winkler DO (mg/L)	Secchi Disk Depth (m)**
6/11/2014	30	14.93	7.55	75.1	9.32	97.1	8.94	
6/11/2014	33	14.49	7.49	75	8.05	83		
6/24/2014	0.5	19.98	8.49	101.1	10.02	116.3		3.9
6/24/2014	1	19.98	8.5	101.5	10.06	116.7		
6/24/2014	2	19.81	8.56	101.2	10.24	118.5		
6/24/2014	3	19.47	8.59	101.2	10.45	120.1		
6/24/2014	4	18.37	8.67	100.7	10.86	122		
6/24/2014	4*	18.41	8.66	100.2	10.84	121.9		
6/24/2014	5	17.95	8.58	100.5	10.66	118.7	11	
6/24/2014	6	17.31	8.5	102.1	10.59	116.4		
6/24/2014	7	16.95	8.29	102.7	10.25	111.8		
6/24/2014	8	16.57	8.17	102.5	10.19	110.2		
6/24/2014	9	16.33	8.06	102.8	10.02	107.9		
6/24/2014	10	16.23	7.97	103.4	9.95	106.9		
6/24/2014	12	15.99	7.88	104.8	9.77	104.5		
6/24/2014	15	15.78	7.85	105	9.8	104.3		
6/24/2014	18	15.64	7.83	104.3	9.82	104.2		
6/24/2014	21	15.38	7.79	103.6	9.8	103.5	9.78	
6/24/2014	21*	15.36	7.76	103.2	9.77	103.1		
6/24/2014	24	15.12	7.74	104.4	9.63	101.1		
6/24/2014	27	14.88	7.72	104.6	9.65	100.7		
6/24/2014	30	14.68	7.65	106.6	9.39	97.6		
6/24/2014	33	14.63	7.61	107.5	9.11	94.6		
7/8/2014	0.5	23.46	8.62	115.2	9.29	115.3		5.2
7/8/2014	1	23.43	8.61	115.2	9.52	118.1		
7/8/2014	2	23.15	8.65	115	10.04	124		
7/8/2014	3	22.59	8.71	115.3	10.59	129.3		
7/8/2014	4	22.11	8.76	115.5	11.13	134.6		
7/8/2014	4*	22.09	8.75	115.9	10.72	129.7		
7/8/2014	5	20.2	8.74	131.6	11.9	138.7	10.9	
7/8/2014	6	19.45	8.47	140	10.98	126.1		
7/8/2014	7	19.03	8.27	134.7	10.42	118.6		
7/8/2014	8	18.86	8.1	137.7	9.85	111.8		
7/8/2014	9	18.35	7.8	137.6	8.73	98		
7/8/2014	10	18.21	7.73	132.3	8.83	98.8		
7/8/2014	12	18.07	7.72	127.3	8.88	99.1		
7/8/2014	15	17.51	7.63	119.6	8.73	96.3		
7/8/2014	18	17.05	7.57	122.1	8.42	92.1		
7/8/2014	21	16.79	7.54	124.2	8.31	90.3	8.29	

Date	Depth (m)	Temperature (°C)	pH	Cond (µS/cm)	DO (mg/l)	DO Sat. (%)	Winkler DO (mg/L)	Secchi Disk Depth (m)**
7/8/2014	21*	16.71	7.54	124.1	8.3	90.1		
7/8/2014	24	16.29	7.49	120.3	8.14	87.6		
7/8/2014	27	15.81	7.43	114.4	7.97	84.9		
7/8/2014	30	15.54	7.33	113.1	7.21	76.3		
7/8/2014	33	15.2	7.25	111.2	6.27	65.9		
7/23/2014	0.5	23.32	8.71	144	9.25	114.8		7.1
7/23/2014	1	23.26	8.72	144.3	9.26	114.7		
7/23/2014	2	22.99	8.72	144.6	9.26	114.1		
7/23/2014	3	22.82	8.71	144.5	9.29	114.1		
7/23/2014	4	22.71	8.71	144.8	9.32	114.3		
7/23/2014	4*	22.7	8.71	144.2	9.33	114.4		
7/23/2014	5	22.55	8.68	145	9.32	113.9	8.48	
7/23/2014	6	22.44	8.68	144.9	9.34	114		
7/23/2014	7	22.39	8.66	145.5	9.29	113.3		
7/23/2014	8	21.23	8.5	150.2	10.12	120.6		
7/23/2014	9	20.13	7.94	170.7	8.36	97.4		
7/23/2014	10	19.96	7.85	172.4	8.05	93.5		
7/23/2014	12	19.54	7.73	172.2	7.41	85.4		
7/23/2014	15	18.93	7.62	157.4	7.15	81.3		
7/23/2014	18	18.04	7.49	136.9	6.95	77.7		
7/23/2014	21	16.93	7.32	122.1	6.07	66.3	6.32	
7/23/2014	21*	16.97	7.31	122.1	6.08	66.5		
7/23/2014	24	16.43	7.25	121.3	5.59	60.4		
7/23/2014	27	16	7.16	121	4.48	48		
7/23/2014	30	15.7	7.1	119.4	3.44	36.6		
7/23/2014	33	15.46	7.06	118.4	3.1	32.9		
8/5/2014	0.5	25.13	8.68	154.7	9.14	117.3		6.6
8/5/2014	1	24.9	8.69	155.1	9.25	118.1		
8/5/2014	2	24.52	8.72	154.3	9.3	118		
8/5/2014	3	24.33	8.78	153.7	9.87	124.8		
8/5/2014	4	23.75	8.94	153	11.51	143.8		
8/5/2014	4*	23.8	8.94	153.1	11.45	143.4		
8/5/2014	5	22.59	8.95	156.2	12.02	147.1	10.6	
8/5/2014	6	21.74	8.81	167.4	11.56	139.1		
8/5/2014	7	21.35	8.56	176.7	10.52	125.6		
8/5/2014	8	20.04	7.99	178.5	8.64	100.6		
8/5/2014	9	19.41	7.59	186.4	6.62	76.1		
8/5/2014	10	19.13	7.53	193	6	68.6		
8/5/2014	12	18.84	7.8	220.2	7.51	85.3		

Date	Depth (m)	Temperature (°C)	pH	Cond (µS/cm)	DO (mg/l)	DO Sat. (%)	Winkler DO (mg/L)	Secchi Disk Depth (m)**
8/5/2014	15	18.47	7.76	216.4	7.32	82.5		
8/5/2014	18	17.97	7.67	211.5	6.89	76.9		
8/5/2014	21	17.48	7.67	218.4	6.98	77.1	6.86	
8/5/2014	21*	17.51	7.68	217.7	6.97	77.1		
8/5/2014	24	17.09	7.64	215.5	6.93	76		
8/5/2014	27	16.5	7.32	174.5	4.54	49.2		
8/5/2014	30	15.92	7.1	132.1	2.85	30.4		
8/5/2014	33	15.36	6.95	120.6	0.69	7.3		
8/20/2014	0.5	24.05	8.99	161.9	10.59	133.8		4.3
8/20/2014	1	24.02	9.02	161.4	10.55	133.2		
8/20/2014	2	23.99	9.03	161.6	10.71	135.1		
8/20/2014	3	23.93	9.04	161.1	10.72	135.1		
8/20/2014	4	23.92	9.04	160.2	10.72	135.1		
8/20/2014	4*	23.91	9.04	160.7	10.71	134.9		
8/20/2014	5	23.82	9.04	163	11.06	139.1	8.83	
8/20/2014	6	22.39	8.78	191.5	12.51	153.1		
8/20/2014	7	20.54	8.31	189.5	10.03	118.5		
8/20/2014	8	19.74	7.77	195.5	7.24	84.2		
8/20/2014	9	19.27	7.62	205.9	6.12	70.5		
8/20/2014	10	18.92	7.6	222.5	6.12	70		
8/20/2014	12	18.41	7.68	240.4	6.73	76.2		
8/20/2014	15	18.01	7.73	253	6.87	77.1		
8/20/2014	18	17.63	7.8	255.9	7.25	80.7	7.22	
8/20/2014	21	17.35	7.71	253.6	6.69	74.1		
8/20/2014	21*	17.35	7.72	253.8	6.75	74.8		
8/20/2014	24	17.17	7.76	255.6	7.24	79.9		
8/20/2014	27	16.87	7.68	250.4	6.68	73.2		
8/20/2014	30	16.53	7.45	219.7	3.7	40.3		
8/20/2014	33	15.45	7.3	136.4	0	0		
9/9/2014	0.5	20.1	8.93	190.2	9.96	116		4.5
9/9/2014	1	20.11	8.94	190.5	9.93	115.8		
9/9/2014	2	20.05	8.95	190.4	9.94	115.7		
9/9/2014	3	19.96	8.94	189.8	9.95	115.6		
9/9/2014	4	19.94	8.95	190	9.96	115.7		
9/9/2014	4*	19.95	8.95	189.9	9.93	115.4		
9/9/2014	5	19.93	8.95	190.6	9.97	1156.8	9.57	
9/9/2014	6	19.89	8.97	190.1	9.99	115.9		
9/9/2014	7	19.78	8.96	189.9	9.99	115.6		
9/9/2014	8	18.21	7.9	249.3	5.88	66		

Date	Depth (m)	Temperature (°C)	pH	Cond (µS/cm)	DO (mg/l)	DO Sat. (%)	Winkler DO (mg/L)	Secchi Disk Depth (m)**
9/9/2014	9	17.94	7.84	252	5.94	66.3		
9/9/2014	10	17.7	7.76	253.1	5.97	66.3		
9/9/2014	12	17.26	7.79	252.3	6.45	71		
9/9/2014	15	17.08	7.79	252.9	6.38	70		
9/9/2014	18	16.83	7.83	256.4	6.59	71.8		
9/9/2014	21	16.53	7.94	257.4	7.25	78.5	6.53	
9/9/2014	21*	16.56	7.95	257.4	7.15	77.5		
9/9/2014	24	16.18	8.02	255.6	7.75	83.4		
9/9/2014	27	15.68	8.07	255.2	8.25	87.8		
9/9/2014	30	15.2	8.08	256.8	8.5	89.5		
9/9/2014	33	15.09	8.05	257.5	8.39	88.2		
9/23/2014	0.5	19.18	8.79	211	9.98	114.2		5.4
9/23/2014	1	19.15	8.8	210.9	9.98	114.1		
9/23/2014	2	19.16	8.8	211.1	9.95	113.8		
9/23/2014	3	19.12	8.8	211.1	9.95	113.7		
9/23/2014	4	18.78	8.8	211.3	10.03	113.8		
9/23/2014	4*	17.77	8.81	211.2	10	113.5		
9/23/2014	5	18.59	8.78	212	9.93	112.3	9.81	
9/23/2014	6	18.38	8.64	216.1	9.36	105.4		
9/23/2014	7	17.88	8.27	224	7.89	87.9		
9/23/2014	8	17.64	8.17	225.2	7.62	54.5		
9/23/2014	9	17.31	8	231.2	6.87	75.7		
9/23/2014	10	16.89	7.86	239.9	6.39	69.8		
9/23/2014	12	16.4	7.79	245.4	6.19	66.9		
9/23/2014	15	15.97	7.8	241	6.54	70		
9/23/2014	18	15.45	7.91	239.4	7.57	80.1		
9/23/2014	21	15.17	8.09	232.6	8.5	89.4	7.66	
9/23/2014	21*	15.17	8.09	232.6	8.52	89.7		
9/23/2014	24	14.91	8.09	233.3	8.63	90.3		
9/23/2014	27	14.75	8.06	234.2	8.58	89.4		
9/23/2014	30	14.61	8	235	8.3	86.3		
9/23/2014	33	14.57	7.93	235	7.71	80.1		
10/14/2014	0.5	15.85	8.35	218.3	9.06	97.1		4.9
10/14/2014	1	15.85	8.34	218.6	9.04	97		
10/14/2014	2	15.85	8.34	218.6	9.01	96.6		
10/14/2014	3	15.85	8.37	218.6	9.07	97.3		
10/14/2014	4	15.85	8.35	218.6	9.04	97		
10/14/2014	4*	15.86	8.35	218.6	9	96.5		
10/14/2014	5	15.86	8.34	218.3	8.98	96.3	8.58	

Date	Depth (m)	Temperature (°C)	pH	Cond (µS/cm)	DO (mg/l)	DO Sat. (%)	Winkler DO (mg/L)	Secchi Disk Depth (m)**
10/14/2014	6	15.85	8.34	218.4	9.01	96.6		
10/14/2014	7	15.86	8.35	218.6	8.98	96.3		
10/14/2014	8	15.85	8.33	218.5	8.95	96		
10/14/2014	9	15.84	8.31	218.9	8.87	95.1		
10/14/2014	10	15.82	8.3	218.8	8.83	94.7		
10/14/2014	12	15.78	8.22	219.4	8.6	92		
10/14/2014	15	15.12	7.85	220.1	8.94	73.3		
10/14/2014	18	14.84	7.8	214.5	7.22	75.8		
10/14/2014	21	14.35	7.9	205.2	8.36	86.8	7.94	
10/14/2014	21*	14.36	7.91	205	8.36	86.8		
10/14/2014	24	14.23	7.91	202.9	8.48	87.7		
10/14/2014	27	14.15	7.91	202.6	8.5	87.9		
10/14/2014	30	13.9	7.85	201.6	8.17	84		
10/14/2014	33	13.81	7.72	202.6	7.34	75.3		

*QA/QC measurement for Hydrolab
**Secchi disk depths average of 3 measurements

Table A-3. Station LL2 *In Situ* Water Quality Data, 2014

Date	Depth (m)	Temperature (°C)	pH	Cond (µS/cm)	DO (mg/l)	DO Sat. (%)	Winkler DO (mg/L)	Secchi Disk Depth (m)**
5/14/2014	0.5	12.37	7.75	70.9	12.15	118.4		2.2
5/14/2014	1	11.95	7.77	71	12.18	117.6		
5/14/2014	2	11.81	7.77	71	12.11	116.5		
5/14/2014	3	11.69	7.72	71.2	12.08	116		
5/14/2014	4	11.56	7.74	71.3	12.02	115		
5/14/2014	5	11.52	7.7	71.1	12	114.7	12	
5/14/2014	5*	11.48	7.65	71	12	114.7		
5/14/2014	6	11.46	7.67	71.1	11.97	114.3		
5/14/2014	7	11.4	7.64	71.2	11.96	114		
5/14/2014	8	11.37	7.61	71.1	11.91	113.5		
5/14/2014	9	11.3	7.67	71.1	11.93	113.5		
5/14/2014	10	11.26	7.65	71.4	11.89	113		
5/14/2014	12	11.18	7.65	71	11.9	112.9		
5/14/2014	15	11.15	7.66	71.3	11.92	113	11.7	
5/14/2014	18	11.02	7.66	70.8	11.98	113.2		
5/14/2014	21	10.94	7.65	70.9	12.01	113.3		
5/14/2014	24	10.75	7.63	70.5	11.89	111.6		
5/14/2014	24*	10.77	7.63	70.6	11.93	112.1		
5/14/2014	25	10.77	7.62	71	11.85	111.3		
6/11/2014	0.5	19.37	8.69	87.1	10.97	125.4		3.7
6/11/2014	1	19.13	8.67	86.8	11.02	125.4		
6/11/2014	2	19.02	8.73	87.1	10.96	124.4		
6/11/2014	3	18.71	8.56	89.6	11.09	125.1		
6/11/2014	4	18.56	8.65	91.2	11.1	124.8		
6/11/2014	5	17.89	8.38	96	10.63	117.9	10.8	
6/11/2014	6	17.56	8.2	98.4	10.28	113.2		
6/11/2014	7	17.36	8.09	99.4	10.04	110.1		
6/11/2014	8	17.03	7.97	100.8	9.76	106.4		
6/11/2014	9	16.97	7.89	100.2	9.76	106.2		
6/11/2014	10	16.88	7.87	99.4	9.75	105.9		
6/11/2014	10*	16.87	7.85	99.7	9.77	106.1		
6/11/2014	12	16.7	7.8	99	9.7	105		
6/11/2014	15	16.43	7.75	95.6	9.64	103.7	10.2	
6/11/2014	18	16.29	7.72	91.5	9.48	101.7		
6/11/2014	21	15.89	7.61	87.8	9.2	97.9		
6/11/2014	24	15.23	7.57	78.7	9.21	96.6	10	
6/11/2014	25	15.02	7.52	77.3	8.96	93.5		
6/24/2014	0.5	20.56	8.5	101.7	9.92	116.5		3.9

Date	Depth (m)	Temperature (°C)	pH	Cond (µS/cm)	DO (mg/l)	DO Sat. (%)	Winkler DO (mg/L)	Secchi Disk Depth (m)**
6/24/2014	1	20.57	8.54	101.4	9.95	116.9		
6/24/2014	2	19.41	8.75	100.7	10.96	125.7		
6/24/2014	3	18.35	8.83	100.7	11.44	128.5		
6/24/2014	4	17.69	8.76	100.9	11.36	125.9		
6/24/2014	5	17.36	8.7	102.1	11.45	126	11.1	
6/24/2014	5*	17.34	8.7	102.2	11.32	124.5		
6/24/2014	6	17.22	8.59	103.3	11.12	122.1		
6/24/2014	7	17.05	8.42	106.4	10.81	118.2		
6/24/2014	8	16.87	8.35	107.7	10.74	117		
6/24/2014	9	16.81	8.28	108.3	10.59	115.2		
6/24/2014	10	16.56	8.18	109.6	10.5	113.6		
6/24/2014	12	16.03	7.99	111.6	10.03	107.3		
6/24/2014	15	15.9	7.92	110.7	9.97	106.3	10	
6/24/2014	18	15.72	7.86	108.5	9.77	103.9		
6/24/2014	21	15.43	7.78	105.1	9.67	102.1		
6/24/2014	24	15	7.73	102.7	9.65	101		
6/24/2014	24*	15	7.72	102.2	9.66	101.1		
6/24/2014	25	14.83	7.61	104.2	8.98	93.7		
7/8/2014	0.5	24.35	8.54	118.3	9.62	121.4		4.2
7/8/2014	1	24.09	8.57	117.7	9.76	122.7		
7/8/2014	2	23.56	8.66	117.6	10.25	127.5		
7/8/2014	3	22.92	8.68	117.5	10.43	128.2		
7/8/2014	4	20.85	8.64	137.1	11.57	136.6		
7/8/2014	5	20.5	8.66	137.6	11.67	136.9	11.6	
7/8/2014	5*	20.52	8.67	137.3	11.69	137.1		
7/8/2014	6	19.72	8.36	141.8	10.71	123.7		
7/8/2014	7	19.11	8.07	142.1	9.87	112.6		
7/8/2014	8	18.84	7.9	142.5	9.28	105.3		
7/8/2014	9	18.63	7.8	143.7	8.96	101.2		
7/8/2014	10	18.34	7.71	141.7	8.6	96.6		
7/8/2014	12	18	7.63	134.1	8.48	94.5		
7/8/2014	15	17.34	7.59	118.5	8.61	94.7	8.78	
7/8/2014	18	16.79	7.51	123.8	8.26	89.8		
7/8/2014	21	16.48	7.46	123.4	7.98	86.2		
7/8/2014	24	15.96	7.32	119.7	6.96	74.4		
7/8/2014	24*	16	7.31	119.6	7.02	75.1		
7/8/2014	25	15.75	7.24	118	6.23	66.2		
7/23/2014	0.5	23.71	8.81	142.2	9.35	116.8		5.9
7/23/2014	1	23.59	8.8	142.3	9.38	116.9		

Date	Depth (m)	Temperature (°C)	pH	Cond (µS/cm)	DO (mg/l)	DO Sat. (%)	Winkler DO (mg/L)	Secchi Disk Depth (m)**
7/23/2014	2	23.59	8.8	142.8	9.39	117.1		
7/23/2014	3	23.47	8.8	142.9	9.39	116.9		
7/23/2014	4	23.28	8.75	145.6	9.35	115.9		
7/23/2014	5	21.82	8.35	164.6	9.02	108.8	7.76	
7/23/2014	5*	22.06	8.39	163.3	8.89	107.7		
7/23/2014	6	20.81	8.07	175.5	8.53	100.8		
7/23/2014	7	20.4	7.97	179.6	8.23	96.5		
7/23/2014	8	20.33	7.95	178.4	8.17	95.7		
7/23/2014	9	19.93	7.84	186.1	7.63	88.6		
7/23/2014	10	19.7	7.77	180.7	7.36	85.1		
7/23/2014	12	19.46	7.75	182.2	7.17	82.5		
7/23/2014	15	19.16	7.68	179.8	6.82	78	6.96	
7/23/2014	18	18.57	7.54	164.4	6.22	70.3		
7/23/2014	21	17.54	7.35	137.8	5.48	60.6		
7/23/2014	24	16.78	7.19	128.4	3.87	42.2		
7/23/2014	24*	16.76	7.18	128.6	3.82	41.6		
7/23/2014	25	16.58	7.15	128.6	3.5	37.9		
8/5/2014	0.5	24.75	8.79	154.8	9.57	121.9		6.1
8/5/2014	1	24.68	8.8	154.9	9.56	121.7		
8/5/2014	2	24.5	8.82	154.7	9.63	122.1		
8/5/2014	3	24.34	8.82	154.5	9.63	121.7		
8/5/2014	4	24.27	8.83	154.5	9.72	1228		
8/5/2014	5	23.31	8.97	156.2	11.75	145.8		
8/5/2014	5*	23.33	8.98	156	11.8	146.4		
8/5/2014	6	21.97	8.79	171	11.29	136.5		
8/5/2014	7	21.03	8.37	183.6	9.53	113.1		
8/5/2014	8	20.3	7.98	190.4	8.32	97.3		
8/5/2014	9	19.6	7.8	203.4	7.43	85.7		
8/5/2014	10	19.24	7.74	208.3	7.18	82.2	7	
8/5/2014	12	18.67	7.94	237.3	7.9	89.4		
8/5/2014	15	18.33	7.98	243.2	7.98	89.8	7.38	
8/5/2014	18	18.15	7.91	242.7	7.76	86.9		
8/5/2014	21	17.8	7.73	233.1	6.97	77.5		
8/5/2014	24	17.05	7.56	230.7	5.94	65.1		
8/5/2014	24*	16.99	7.55	230.6	5.93	64.8		
8/5/2014	25	16.89	7.46	229.2	5.08	55.4		
8/20/2014	0.5	24.31	8.98	165.3	10.28	130.5		3.8
8/20/2014	1	24.32	8.99	165.1	10.3	130.7		
8/20/2014	2	24.27	8.99	165.2	10.33	131		

Date	Depth (m)	Temperature (°C)	pH	Cond (µS/cm)	DO (mg/l)	DO Sat. (%)	Winkler DO (mg/L)	Secchi Disk Depth (m)**
8/20/2014	3	24.16	9	165.2	10.44	132.1		
8/20/2014	4	23.9	9.05	163	10.67	134.4		
8/20/2014	5	22.45	8.73	200.4	12.24	149.8	8.31	
8/20/2014	5*	22.28	8.69	201.2	11.73	143.4		
8/20/2014	6	21.43	8.36	214.8	9.67	116.3		
8/20/2014	7	20.58	7.99	223	8.26	97.6		
8/20/2014	8	19.67	7.81	228.4	7.37	85.5		
8/20/2014	9	19.23	7.75	232.6	6.91	79.4		
8/20/2014	10	18.87	7.71	236.3	6.69	76.4		
8/20/2014	12	18.47	7.75	246.6	6.86	77.7		
8/20/2014	15	17.9	7.93	254.3	7.74	86.6		
8/20/2014	18	17.55	7.98	258.1	8.17	90.8		
8/20/2014	21	16.84	7.95	268.4	8.17	89.5		
8/20/2014	24	16.68	7.88	270.4	7.76	84.7	6.7	
8/20/2014	24*	16.69	7.88	270.1	7.78	84.9		
8/20/2014	25	16.68	7.87	270.6	7.74	84.5		
9/9/2014	0.5	20.19	8.89	190.4	9.91	115.7		4.2
9/9/2014	1	20.09	8.9	190.5	9.92	115.6		
9/9/2014	2	19.98	8.9	190.4	9.89	115		
9/9/2014	3	19.95	8.9	190.9	9.91	115.2		
9/9/2014	4	19.88	8.91	190.7	9.95	115.4		
9/9/2014	5	19.85	8.91	191.3	9.92	114.9	9.69	
9/9/2014	5*	19.87	8.91	190.9	9.91	114.9		
9/9/2014	6	19.84	8.9	191.7	9.9	114.8		
9/9/2014	7	19.83	8.88	191.8	9.75	113		
9/9/2014	8	19.78	8.8	196.1	9.51	110.2		
9/9/2014	9	18.92	8.08	233.6	6.95	79.2		
9/9/2014	10	18.41	7.85	245.8	5.97	67.3		
9/9/2014	12	17.97	7.78	249.3	6.07	67.8		
9/9/2014	15	17.32	7.89	250.6	6.92	76.2	6.29	
9/9/2014	18	16.63	8.12	240	8.27	89.8		
9/9/2014	21	15.52	8.15	242.1	9.09	96.4		
9/9/2014	24	15.23	8.08	247	8.71	91.8		
9/9/2014	24*	15.21	8.08	246.9	8.73	92		
9/9/2014	25	15.19	8.07	247.6	8.64	91		
9/23/2014	0.5	19.04	8.73	214.2	9.72	110.9		6.4
9/23/2014	1	18.94	8.74	213.6	9.79	111.5		
9/23/2014	2	18.84	8.74	214.4	9.79	111.2		
9/23/2014	3	18.81	8.73	214.9	9.77	110.9		

Date	Depth (m)	Temperature (°C)	pH	Cond (µS/cm)	DO (mg/l)	DO Sat. (%)	Winkler DO (mg/L)	Secchi Disk Depth (m)**
9/23/2014	4	18.76	8.72	214.8	9.77	110.9		
9/23/2014	5	18.6	8.74	214.7	9.89	111.8	9.56	
9/23/2014	5*	18.61	8.74	214.4	9.9	111.9		
9/23/2014	6	18.51	8.69	216	9.71	109.6		
9/23/2014	7	18.22	8.52	217.3	8.91	100		
9/23/2014	8	17.68	8.34	217.1	7.95	88.2		
9/23/2014	9	17.23	8.36	216.2	8.16	89.7		
9/23/2014	10	17.01	8.35	217.2	8.18	89.5		
9/23/2014	12	16.57	8.16	225.7	7.58	82.2		
9/23/2014	15	15.73	8.2	230.5	8.75	93.2	7.66	
9/23/2014	18	15.34	8.21	234.7	9.15	96.6		
9/23/2014	21	15.11	8.12	236.6	8.73	91.8		
9/23/2014	24	15.06	8.09	236.2	8.51	89.3		
9/23/2014	24*	15.06	8.08	236.2	8.48	89.1		
9/23/2014	25	15.05	8.07	236.3	8.48	89		
10/14/2014	0.5	16.03	8.55	215.2	9.67	104.1		4.4
10/14/2014	1	16.04	8.55	215	9.68	104.2		
10/14/2014	2	16.03	8.55	215.2	9.66	104		
10/14/2014	3	16.04	8.54	215.2	9.67	104.1		
10/14/2014	4	16.02	8.54	215.1	9.57	103		
10/14/2014	5	15.96	8.49	215.7	9.4	101	9	
10/14/2014	5*	15.96	8.49	215.5	9.42	101.2		
10/14/2014	6	15.92	8.46	214.6	9.24	99.2		
10/14/2014	7	15.74	8.4	211.9	9.15	97.9		
10/14/2014	8	15.34	8.3	208.9	9.04	95.8		
10/14/2014	9	14.83	8.19	205.2	8.99	94.3		
10/14/2014	10	14.78	8.16	205.3	8.99	94.1		
10/14/2014	12	14.57	8.11	204.3	8.98	93.6		
10/14/2014	15	14.2	8.03	202.5	8.92	92.3	8.56	
10/14/2014	18	14.14	8.04	201.9	9.01	93.1		
10/14/2014	21	14.06	8.07	201.8	9.24	95.3		
10/14/2014	24	14.02	7.95	201.9	8.63	89		
10/14/2014	24*	14.02	7.94	202.4	8.63	88.9		
10/14/2014	25	14.02	7.93	201.9	8.58	88.4		

*QA/QC measurement for Hydrolab
**Secchi disk depths average of 3 measurements

Table A-4. Station LL3 *In Situ* Water Quality Data, 2014

Date	Depth (m)	Temperature (°C)	pH	Cond (µS/cm)	DO (mg/l)	DO Sat. (%)	Winkler DO (mg/L)	Secchi Disk Depth (m)**
5/15/2014	0.5	12.49	7.63	71.7	11.68	115		1.9
5/15/2014	1	12.44	7.65	72	11.71	115.1		
5/15/2014	2	12.44	7.57	72	11.66	114.7		
5/15/2014	3	12.43	7.66	72	11.68	114.9		
5/15/2014	4	12.41	7.72	71.9	11.68	114.8		
5/15/2014	5	12.4	7.71	71.7	11.69	114.9	10.8	
5/15/2014	6	12.41	7.7	71.7	11.68	114.8		
5/15/2014	7	12.41	7.7	71.9	11.68	114.8		
5/15/2014	8	12.41	7.7	72.1	11.69	114.8		
5/15/2014	9	12.41	7.73	72.1	11.69	114.8		
5/15/2014	9*	12.4	7.74	71.9	11.67	114.6		
5/15/2014	10	12.4	7.77	72.1	11.69	114.8	11	
5/15/2014	12	12.4	7.75	72	11.68	114.7		
5/15/2014	15	12.4	7.73	72	11.71	115		
5/15/2014	18	12.4	7.73	71.9	11.64	114.4		
5/15/2014	19	12.4	7.72	71.9	11.64	114.3		
6/11/2014	0.5	19.11	8.46	90.1	10.45	118.8		3.0
6/11/2014	1	19.11		90.3	10.41	118.4		
6/11/2014	2	18.81	8.26	92.6	10.41	117.6		
6/11/2014	3	18.32	8.43	98.6	10.25	114.7		
6/11/2014	4	18.16	8.4	100.3	10.17	113.5		
6/11/2014	5	17.86	8.29	101.4	10.1	112	10.3	
6/11/2014	6	17.71	8.17	102.7	10.02	110.8		
6/11/2014	7	17.5	8.1	103.9	9.93	109.2		
6/11/2014	8	17.52	8.05	103.7	9.9	109		
6/11/2014	9	17.46	7.97	104.2	9.92	109.1		
6/11/2014	9*	17.38	8.06	104.6	9.84	108		
6/11/2014	10	17.42	8.02	104	9.86	108.3	10.1	
6/11/2014	12	17.34	7.99	104.6	9.82	107.7		
6/11/2014	15	17.26	7.91	105	9.77	106.9		
6/11/2014	18	17.1	7.9	105.7	9.58	104.5		
6/11/2014	19	17.1	7.81	105.7	9.61	104.9		
6/25/2014	0.5	20.09	8.49	102.5	10.18	118.4		4.3
6/25/2014	1	20.01	8.54	102.6	10.22	118.7		
6/25/2014	2	19.84	8.55	103.2	10.25	118.7		
6/25/2014	3	18.58	8.46	115.6	10.99	124		
6/25/2014	4	17.96	8.34	123.5	10.59	117.9		
6/25/2014	5	17.85	8.27	124.8	10.42	115.8	10.3	

Date	Depth (m)	Temperature (°C)	pH	Cond (µS/cm)	DO (mg/l)	DO Sat. (%)	Winkler DO (mg/L)	Secchi Disk Depth (m)**
6/25/2014	6	17.28	8.14	126.3	10.23	112.4		
6/25/2014	7	17.21	8.09	127.7	10	109.7		
6/25/2014	8	17.2	8.08	127.9	9.98	109.4		
6/25/2014	9	17.15	8.07	127.7	9.98	109.4		
6/25/2014	9*	17.15	8.07	127.8	9.99	109.4		
6/25/2014	10	16.99	8.05	124.6	10.09	110.1	10.1	
6/25/2014	12	16.83	7.98	125.9	9.87	107.4		
6/25/2014	15	16.3	7.82	121.1	9.38	100.9		
6/25/2014	18	15.92	7.71	115.3	9.06	96.7		
6/25/2014	19	15.81	7.63	114.9	8.62	91.7		
7/9/2014	0.5	24.73	8.53	119.6	9.25	118.2		4.2
7/9/2014	1	24.63	8.55	119.3	9.23	117.7		
7/9/2014	2	23.52	8.55	125.9	10.09	126		
7/9/2014	3	22.87	8.5	131.6	10.22	126		
7/9/2014	4	21.07	8.29	145.7	9.9	118		
7/9/2014	5	19.96	8.11	150	9.56	111.4	10.1	
7/9/2014	6	19.72	8	150.5	9.23	107.1		
7/9/2014	7	19.7	7.99	150.7	9.26	107.3		
7/9/2014	8	19.58	7.89	148.7	8.86	102.5		
7/9/2014	9	19.54	7.88	148	8.8	101.6		
7/9/2014	9*	19.53	7.88	148	8.8	101.7		
7/9/2014	10	19.39	7.84	146.7	8.66	99.8	8.92	
7/9/2014	12	18.35	7.73	142.5	8.45	95.4		
7/9/2014	15	17.13	7.57	119.6	8.14	89.5		
7/9/2014	18	16.61	7.33	120.8	6.54	71.1		
7/9/2014	19	16.53	7.28	121.5	6.21	67.4		
7/24/2014	0.5	22.67	8.59	160.1	8.94	108.8		4.1
7/24/2014	1	22.67	8.59	160.5	8.93	108.6		
7/24/2014	2	22.66	8.59	160.5	8.96	109		
7/24/2014	3	22.66	8.6	160.4	8.93	108.6		
7/24/2014	4	22.66	8.6	160.3	8.93	108.7		
7/24/2014	5	22.66	8.6	160.3	8.94	108.7	7.86	
7/24/2014	6	22.63	8.57	160.9	8.89	108.1		
7/24/2014	7	22.66	8.6	160.4	8.97	109		
7/24/2014	8	21.8	8.24	178.3	8.46	101.2		
7/24/2014	9	20.19	8.06	193.4	7.9	91.6		
7/24/2014	9*	19.64	8.03	197.9	7.91	90.7		
7/24/2014	10	19.51	8.02	198.9	7.92	90.6	8.82	
7/24/2014	12	19.56	8.02	198.2	7.88	90.2		

Date	Depth (m)	Temperature (°C)	pH	Cond (µS/cm)	DO (mg/l)	DO Sat. (%)	Winkler DO (mg/L)	Secchi Disk Depth (m)**
7/24/2014	15	19.05	8.04	202.8	8.01	90.8		
7/24/2014	18	18.59	8.06	207	8.14	91.4		
7/24/2014	19	18.44	8.06	208.1	8.18	91.5		
8/6/2014	0.5	24.79	8.81	157.4	9.99	127.2		5.0
8/6/2014	1	24.81	8.81	157.4	10.03	127.7		
8/6/2014	2	24.8	8.83	157.3	10.02	127.7		
8/6/2014	3	24.69	8.8	156.9	10.02	127.3		
8/6/2014	4	24.23	8.87	156.6	10.76	135.6		
8/6/2014	5	23.27	8.96	164.8	12.53	155	8.72	
8/6/2014	6	21.92	8.38	203.4	9.75	117.6		
8/6/2014	7	21.37	8.25	209.3	9.29	110.9		
8/6/2014	8	20.26	8.18	223.5	8.75	102.1		
8/6/2014	9	19.7	8.02	231.3	8.25	95.3		
8/6/2014	9*	19.71	8.01	231.4	8.15	94.1		
8/6/2014	10	19.49	8.17	235	8.8	101.2		
8/6/2014	12	18.51	8.17	250.2	9.1	102.5		
8/6/2014	15	18.15	8.11	254.7	8.8	98.5	8.44	
8/6/2014	18	18.03	8.08	255.3	8.54	95.4		
8/6/2014	19	18.01	8.06	255.3	8.49	94.7		
8/21/2014	0.5	24.09	8.98	169.9	10.56	132.7		3.4
8/21/2014	1	24.1	9	169.9	10.56	132.8		
8/21/2014	2	24.1	9	169.5	10.59	133		
8/21/2014	3	24.08	9	169.7	10.65	133.8		
8/21/2014	4	24.05	8.99	169.6	10.61	133.2		
8/21/2014	5	22.64	8.63	199.9	10.14	123.9	9.14	
8/21/2014	6	21.42	8.41	212.1	8.97	107.1		
8/21/2014	7	20.07	7.88	232.7	7	81.4		
8/21/2014	8	19.37	7.75	241.4	6.63	76		
8/21/2014	9	18.8	7.82	247.7	7	79.4		
8/21/2014	9*	18.63	7.88	249.4	7.24	81.8		
8/21/2014	10	18.45	7.96	252.3	7.76	87.3	6.76	
8/21/2014	12	18	8.08	257.7	8.36	93.2		
8/21/2014	15	17.28	8.1	266	8.6	94.5		
8/21/2014	18	16.84	8.07	270.5	8.52	92.8		
8/21/2014	19	16.85	8.06	270	8.47	92.3		
9/10/2014	0.5	20.06	8.75	192.2	10.06	116.3		3.3
9/10/2014	1	20.07	8.9	191.8	10.1	116.8		
9/10/2014	2	20.06	8.93	192.5	10.12	117		
9/10/2014	3	20.05	8.93	193.1	10.06	116.3		

Date	Depth (m)	Temperature (°C)	pH	Cond (µS/cm)	DO (mg/l)	DO Sat. (%)	Winkler DO (mg/L)	Secchi Disk Depth (m)**
9/10/2014	4	20.05	8.93	193.1	9.89	114.4		
9/10/2014	5	19.9	8.81	199.3	9.41	108.5		
9/10/2014	6	19.47	8.67	205.4	8.8	100.6		
9/10/2014	7	19.09	8.64	207.1	8.56	97		
9/10/2014	8	19.17	8.29	217.3	7.72	87.7		
9/10/2014	9	18.84	8.52	210.6	8.6	97		
9/10/2014	10	18.25	8.54	213.9	9.01	100.4		
9/10/2014	12	15.96	8.43	233.3	9.86	104.8		
9/10/2014	15	15.68	8.36	236.3	9.77	103.2		
9/10/2014	18	15.65	8.33	236.3	9.79	103.4		
9/10/2014	19	15.65	8.34	236.5	9.72	102.6		
9/24/2014	0.5	19.1	8.75	217.1	10.17	116.7		4.7
9/24/2014	1	19.11	8.74	217.3	10.19	116.9		
9/24/2014	2	19.11	8.75	217.2	10.22	117.3		
9/24/2014	3	19.1	8.74	217.1	10.17	116.7		
9/24/2014	4	18.77	8.74	217.3	10.24	116.7		
9/24/2014	5	18.35	8.5	219.8	8.99	101.6	9.46	
9/24/2014	6	18.12	8.55	215.8	8.94	100.5		
9/24/2014	7	17.82	8.62	214.1	9.15	102.3		
9/24/2014	8	17.58	8.62	215.8	9.39	104.5		
9/24/2014	9	17.51	8.66	216.6	9.82	109		
9/24/2014	9*	17.5	8.66	216.8	9.79	108.6		
9/24/2014	10	17.36	8.67	218.4	10.03	111	9.22	
9/24/2014	12	15.49	8.28	236.5	9.69	103.2		
9/24/2014	15	15.2	8.22	238.9	9.57	101.2		
9/24/2014	18	15.18	8.19	239.2	9.54	100.9		
9/24/2014	19	15.18	8.19	239.2	9.52	100.6		
10/15/2014	0.5	15.79	8.72	216.5	9.91	107		3.3
10/15/2014	1	15.79	8.72	216.3	9.9	106.9		
10/15/2014	2	15.82	8.72	216.3	9.9	107.1		
10/15/2014	3	15.83	8.72	216.1	9.91	107.1		
10/15/2014	4	15.83	8.72	216.6	9.87	106.7		
10/15/2014	5	15.82	8.72	216.3	9.91	107.1	9.49	
10/15/2014	6	15.81	8.71	216.3	9.84	106.4		
10/15/2014	7	15.72	8.7	214.8	9.8	105.7		
10/15/2014	8	15.19	8.69	211.7	10	106.7		
10/15/2014	9	14.92	8.65	210.9	9.98	105.8		
10/15/2014	9*	14.95	8.67	211.1	9.92	105.2		
10/15/2014	10	14.23	8.49	208.2	9.76	101.8	9.53	

Date	Depth (m)	Temperature (°C)	pH	Cond (µS/cm)	DO (mg/l)	DO Sat. (%)	Winkler DO (mg/L)	Secchi Disk Depth (m)**
10/15/2014	12	13.57	8.33	205.9	9.64	99.2		
10/15/2014	15	13.25	8.24	205.6	9.59	98		
10/15/2014	18	13.21	8.22	205.1	9.57	97.7		
10/15/2014	19	13.2	8.22	205.4	9.56	97.6		

*QA/QC measurement for Hydrolab
**Secchi disk depths average of 3 measurements

Table A-5. Station LL4 *In Situ* Water Quality Data, 2014

Date	Depth (m)	Temperature (°C)	pH	Cond (µS/cm)	DO (mg/l)	DO Sat. (%)	Secchi Disk Depth (m)**
5/15/2014	0.5	12.05	7.58	72	11.63	113.2	3.0
5/15/2014	1	11.98	7.63	72.6	11.67	113.6	
5/15/2014	2	12	7.66	72.2	11.68	113.7	
5/15/2014	3	11.95	7.67	72.3	11.7	113.8	
5/15/2014	4	11.95	7.68	72.6	11.68	113.6	
5/15/2014	4*	11.96	7.68	72.2	11.65	113.4	
5/15/2014	5	11.94	7.69	72.2	11.65	113.3	
5/15/2014	6	11.96	7.69	72.3	11.67	113.5	
5/15/2014	7	11.94	7.7	72.6	11.67	113.5	
5/15/2014	8	11.94	7.7	72.4	11.67	113.5	
6/11/2014	0.5	16.65	7.98	108	9.77	105.6	5.2
6/11/2014	1	16.62	7.98	108.4	9.8	105.9	
6/11/2014	2	16.49	8.06	108.4	9.81	105.7	
6/11/2014	3	16.41	7.93	108.7	9.75	104.8	
6/11/2014	4	16.36	8.01	109	9.78	105.1	
6/11/2014	4*	16.33	7.96	108.6	9.77	104.9	
6/11/2014	5	16.27	7.94	108.7	9.75	104.6	
6/11/2014	6	16.21	7.89	108.4	9.74	104.3	
6/11/2014	7	16.21	7.96	108.7	9.74	104.3	
6/11/2014	8	16.2	7.94	108.4	9.76	104.5	
6/25/2014	0.5	17.18	8.06	133.7	9.72	106.5	4.3
6/25/2014	1	16.95	8.06	133.8	9.74	106.3	
6/25/2014	2	16.83	8.04	133.3	9.75	106.2	
6/25/2014	3	16.81	8.05	133.3	9.74	105.9	
6/25/2014	4	16.77	8.03	133.3	9.74	105.8	
6/25/2014	4*	16.78	8.04	133.8	9.7	105.4	
6/25/2014	5	16.73	8.01	133.3	9.65	104.7	
6/25/2014	6	16.72	7.99	133.8	9.64	104.7	
6/25/2014	7	16.7	7.98	133.2	9.62	104.4	
6/25/2014	8	16.68	7.95	133.6	9.54	103.5	
7/9/2014	0.5	23.53	8.34	135.7	9.48	118.3	4.0
7/9/2014	1	23.49	8.3	136.3	9.48	118.4	
7/9/2014	2	22.99	8.31	148.3	9.58	118.4	
7/9/2014	3	20.55	8.27	156.2	9.74	114.9	
7/9/2014	4	19.9	8.12	159	9.4	109.4	
7/9/2014	4*	19.77	8.09	159.4	9.36	108.6	
7/9/2014	5	19.6	8.1	160.4	9.33	108	
7/9/2014	6	19.56	8.1	160.1	9.31	107.7	

Date	Depth (m)	Temperature (°C)	pH	Cond (µS/cm)	DO (mg/l)	DO Sat. (%)	Secchi Disk Depth (m)**
7/9/2014	7	19.55	8.1	160.5	9.38	108.4	
7/9/2014	8	19.54	8.1	160.1	9.33	107.9	
7/24/2014	0.5	22.36	8.56	158.4	9.02	109.1	3.0
7/24/2014	1	22.35	8.58	159.2	8.99	108.6	
7/24/2014	2	22.33	8.6	159.6	9.1	110	
7/24/2014	3	21.38	8.49	184.4	9.25	109.8	
7/24/2014	4	18.63	8.36	213.5	9.38	105.4	
7/24/2014	4*	18.58	8.38	214.5	9.4	105.5	
7/24/2014	5	18.11	8.33	218.3	9.33	103.7	
7/24/2014	6	17.97	8.29	218.4	9.25	102.6	
7/24/2014	7	17.96	8.26	218.4	9.12	101.2	
7/24/2014	8	17.94	8.22	218.3	8.99	99.6	
8/6/2014	0.5	24.99	8.89	162.4	10.53	134.5	3.2
8/6/2014	1	24.9	8.86	162.3	10.49	134.1	
8/6/2014	2	24.79	8.81	162	10.44	133	
8/6/2014	3	24.24	8.72	173.1	10.86	136.8	
8/6/2014	4	23.62	8.75	184.8	10.97	136.6	
8/6/2014	4*	23.58	8.76	186.1	10.98	136.7	
8/6/2014	5	21.63	8.58	218.2	10.49	125.8	
8/6/2014	6	17.77	8.3	258	9.87	109.6	
8/6/2014	7	17.69	8.31	258.2	9.94	110.1	
8/6/2014	8	17.69	8.31	257.9	9.91	109.8	
8/21/2014	0.5	23.56	9.12	172.5	11.48	142.8	1.8
8/21/2014	1	23.56	9.13	172	11.47	142.7	
8/21/2014	2	23.54	9.11	172.5	11.41	141.9	
8/21/2014	3	23.35	9	183.4	11.1	137.6	
8/21/2014	4	22.34	8.84	199.1	10.47	127.4	
8/21/2014	4*	22.24	8.83	201	10.51	127.6	
8/21/2014	5	18.77	8.53	247	10.08	114.2	
8/21/2014	6	16.67	8.34	269.4	9.89	107.3	
8/21/2014	7	16.61	8.33	269.4	9.83	106.6	
8/21/2014	8	16.51	8.28	269.2	9.56	103.4	
9/10/2014	0.5	19.56	9.12	190.6	11.62	133	1.8
9/10/2014	1	19.56	9.08	190.5	11.61	132.9	
9/10/2014	2	19.56	9.13	190.8	11.62	133	
9/10/2014	3	19.56	9.13	191.1	11.63	133.1	
9/10/2014	4	19.35	9.11	193.3	11.61	132.4	
9/10/2014	4*	19.35	9.13	193.6	11.63	132.6	
9/10/2014	5	18.92	9.06	198.5	11.44	129.3	

Date	Depth (m)	Temperature (°C)	pH	Cond (µS/cm)	DO (mg/l)	DO Sat. (%)	Secchi Disk Depth (m)**
9/10/2014	6	15.23	8.44	240.1	10.4	108.8	
9/10/2014	7	15.15	8.42	240.7	10.41	108.7	
9/10/2014	8	15.16	8.42	240.6	10.39	108.6	
9/24/2014	0.5	18.89	9.11	203.2	12.06	137.7	2.4
9/24/2014	1	18.88	9.12	202.9	12.07	137.8	
9/24/2014	2	18.87	9.11	203.2	12.05	137.6	
9/24/2014	3	18.43	9	206.9	11.43	129.4	
9/24/2014	4	17.16	8.86	220.1	11.56	127.5	
9/24/2014	4*	17.11	8.84	221.1	11.47	126.4	
9/24/2014	5	14.99	8.3	239.3	9.92	104.4	
9/24/2014	6	14.85	8.27	239.7	9.92	104.1	
9/24/2014	7	14.84	8.27	240	9.91	104	
9/24/2014	8	14.83	8.26	239.8	9.89	103.8	
10/15/2014	0.5	14.31	8.88	210.7	10.73	112.3	2.5
10/15/2014	1	14.28	8.87	210	10.73	112.2	
10/15/2014	2	13.7	8.73	208.9	10.45	107.8	
10/15/2014	3	12.78	8.31	205.3	9.81	99.2	
10/15/2014	4	12.69	8.28	205	9.74	98.3	
10/15/2014	4*	12.71	8.28	205.4	9.76	98.5	
10/15/2014	5	12.63	8.25	204.7	9.7	97.7	
10/15/2014	6	12.63	8.26	204.9	9.64	97.2	
10/15/2014	7	12.63	8.25	205.2	9.68	97.5	
10/15/2014	8	12.63	8.25	205.2	9.65	97.2	

*QA/QC measurement for Hydrolab

**Secchi disk depths average of 3 measurements

Table A-6. Station LL5 *In Situ* Water Quality Data, 2014

Date	Depth (m)	Temperature (°C)	pH	Cond (µS/cm)	DO (mg/l)	DO Sat. (%)	Secchi Disk Depth (m)**
5/15/2014	0.5	11.94	7.75	73.5	12	116.7	2.8
5/15/2014	1	11.94	7.74	73.8	12.01	116.8	
5/15/2014	2	11.94	7.69	74	11.94	116.1	
5/15/2014	3	11.93	7.77	73.7	11.97	116.4	
5/15/2014	4	11.94	7.74	73.8	11.94	116.1	
5/15/2014	5	11.94	7.76	73.8	11.94	116	
6/11/2014	0.5	16.26	7.99	109.1	9.96	106.8	4.8
6/11/2014	1	16.22	7.85	109.2	9.96	106.7	
6/11/2014	2	16.22	7.4	109.1	9.95	106.6	
6/11/2014	3	16.26	7.98	109.1	9.91	106.2	
6/11/2014	4	16.25	7.64	109.3	9.92	106.4	
6/11/2014	5	16.22	7.73	109.1	9.92	106.3	
6/25/2014	0.5	16.44	7.98	134	9.7	104.8	4.6
6/25/2014	1	16.35	7.96	133.4	9.7	104.5	
6/25/2014	2	16.31	7.96	133.8	9.73	104.7	
6/25/2014	3	16.24	7.95	133.3	9.73	104.6	
6/25/2014	4	16.23	7.98	133.4	9.79	105.2	
6/25/2014	5	16.23	7.97	133.4	9.74	104.6	
7/9/2014	0.5	19.77	8.11	165.2	8.68	100.8	4.6
7/9/2014	1	19.71	8.09	165.1	8.67	100.5	
7/9/2014	2	19.72	8.11	165.3	8.69	100.8	
7/9/2014	3	19.68	8.14	165.3	8.73	101.1	
7/9/2014	4	19.67	8.14	164.9	8.7	100.8	
7/9/2014	5	19.63	8.14	164.7	8.72	101	
7/24/2014	0.5	17.3	8.23	225.8	9.06	99	4.1
7/24/2014	1	17.29	8.28	225.8	9.07	99.2	
7/24/2014	2	17.27	8.3	225.8	9.06	99	
7/24/2014	3	17.24	8.27	225.9	9.05	98.8	
7/24/2014	4	17.21	8.27	225.9	9.06	98.9	
7/24/2014	5	17.21	8.28	225.9	9.06	98.8	
8/6/2014	0.5	24.13	8.82	175.8	10.44	131.3	4.1
8/6/2014	1	24.09	8.81	175.9	10.44	131.3	
8/6/2014	2	18.55	8.33	252.5	9.38	105.8	
8/6/2014	3	17.84	8.28	262.1	9.09	101.1	
8/6/2014	4	17.81	8.28	262.2	9.08	100.9	
8/6/2014	5	17.76	8.28	262.1	9.06	100.6	
8/21/2014	0.5	23.27	9.21	178.4	11.88	147.1	1.6
8/21/2014	1	23.15	9.21	180	11.98	147.9	

Date	Depth (m)	Temperature (°C)	pH	Cond (µS/cm)	DO (mg/l)	DO Sat. (%)	Secchi Disk Depth (m)**
8/21/2014	2	17.28	8.35	256.9	9.38	103.1	
8/21/2014	3	16.38	8.21	268.8	9.11	98.2	
8/21/2014	4	16.34	8.2	268.1	9.07	97.7	
8/21/2014	5	16.29	8.2	267.6	9.08	97.7	
9/10/2014	0.5	15.22	8.67	235.5	10.16	106.3	4.1
9/10/2014	1	15.18	8.58	237	10.1	105.6	
9/10/2014	2	15.18	8.47	236.5	10.14	106	
9/10/2014	3	15.1	8.4	239.2	10.04	104.8	
9/10/2014	4	15.02	8.34	241.2	9.96	103.7	
9/10/2014	5	14.94	8.31	242.1	9.8	101.9	
9/24/2014	0.5	14.93	8.29	244.4	9.71	102.2	4.4
9/24/2014	1	14.95	8.27	244.4	9.7	102	
9/24/2014	2	14.88	8.27	244.8	9.73	102.2	
9/24/2014	3	14.83	8.23	244.3	9.58	100.5	
9/24/2014	4	14.82	8.21	244	9.55	100.2	
9/24/2014	5	14.79	8.21	245	9.53	99.9	
10/15/2014	0.5	12.49	8.21	204.1	9.68	97.3	4.8
10/15/2014	1	12.49	8.2	204	9.69	97.3	
10/15/2014	2	12.49	8.2	203.9	9.65	96.9	
10/15/2014	3	12.49	8.2	204.2	9.69	97.3	
10/15/2014	4	12.49	8.19	203.9	9.68	97.3	
10/15/2014	5	12.48	8.2	204.3	9.66	97	

*QA/QC measurement for Hydrolab
**Secchi disk depths average of 3 measurements

APPENDIX II – Lake Spokane Laboratory Monitoring Data

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Table B-1. Lake Spokane Lab Data, 2013

Station LL0

Date	TP (µg/L)				
	0.5 m	5 m	15 m	30 m	B-1
5/14/2014	9.7	12.4	11.0	11.8	10.4
6/10/2014	10.2	11.8	8.3	8.6	70.1
6/24/2014	3.6	7.2	7.3	11.9	31.0
7/8/2014	4.2	5.2	5.9	10.1	22.6
7/23/2014	4.7	5.0	4.9	24.1	35.3
8/5/2014	4.1	10.8	5.9	35.4	46.4
8/20/2014	5.1	6.1	4.9	9.0	14.8
9/9/2014	8.2	15.1	12.0	37.3	46.2
9/23/2014	4.2	4.1	2.4	13.6	19.3
10/14/2014	5.5	6.4	6.0	13.3	24.7

Date	SRP (µg/L)				
	0.5 m	5 m	15 m	30 m	B-1
5/14/2014	1.0	1.0	1.0	1.1	2.2
6/10/2014	1.0	1.0	1.0	4.7	12.1
6/24/2014	1.0	2.0	5.3	5.8	8.2
7/8/2014	1.0	1.0	1.1	7.0	20.0
7/23/2014	1.1	1.0	1.1	23.9	34.7
8/5/2014	1.0	4.7	1.0	27.6	38.7
8/20/2014	1.0	1.0	1.0	1.3	3.3
9/9/2014	1.2	1.2	7.1	25.8	37.9
9/23/2014	1.0	1.0	1.3	10.9	11.6
10/14/2014	1.0	1.0	1.2	9.8	14.2

Date	Chl (µg/L)		
	0.5 m	5 m	15 m
5/14/2014	5.9	6.4	4.3
6/10/2014	8.0	11.7	3.7
6/24/2014	0.8	3.2	1.6
7/8/2014	1.6	2.7	4.8
7/23/2014	1.1	1.1	2.1
8/5/2014	1.1	4.3	4.8
8/20/2014	3.5	3.2	1.1
9/9/2014	5.1	5.1	1.3
9/23/2014	3.2	4.3	1.8
10/14/2014	2.9	2.4	2.1

Date	TPN (µg/L)				
	0.5 m	5 m	15 m	30 m	B-1
5/14/2014	264	263	263	258	304
6/10/2014	382	379	399	330	525
6/24/2014	340	343	477	506	527
7/8/2014	470	566	668	558	661
7/23/2014	713	551	854	575	559
8/5/2014	597	572	1004	614	568
8/20/2014	618	628	1649	964	658
9/9/2014	810	809	1749	1669	661
9/23/2014	835	867	1599	1564	1541
10/14/2014	1538	1552	1163	1303	1413

Date	NO3+NO2 (µg/L)				
	0.5 m	5 m	15 m	30 m	B-1
5/14/2014	102	181	181	183	182
6/10/2014	202	217	300	219	211
6/24/2014	298	304	429	473	481
7/8/2014	385	414	537	477	475
7/23/2014	459	488	680	538	545
8/5/2014	489	461	833	574	555
8/20/2014	427	439	1319	886	554
9/9/2014	690	693	1499	1206	581
9/23/2014	809	822	985	986	985
10/14/2014	1015	1023	1077	1112	1065

Station LL1

Date	TP (µg/L)			
	0.5 m	5 m	20 m	B-1
5/14/2014	9.6	11.3	21.8	**129.1**
6/10/2014	7.2	10.7	7.5	**210.2**
6/24/2014	5.9	7.7	8.3	**130.5**
7/8/2014	3.9	5.0	7.5	30.0
7/23/2014	4.8	7.2	8.8	64.4
8/5/2014	5.0	14.8	13.9	53.0
8/20/2014	5.9	6.4	6.7	24.4
9/9/2014	26.7	12.8	18.1	29.6
9/23/2014	4.5	5.5	6.4	11.3
10/14/2014	20.1	8.5	13.0	19.3

Date	SRP (µg/L)			
	0.5 m	5 m	20 m	B-1
5/14/2014	1.0	1.0	1.0	3.2
6/10/2014	1.0	1.0	1.0	22.7
6/24/2014	1.2	1.2	3.7	24.4
7/8/2014	1.1	1.3	4.0	25.2
7/23/2014	1.0	1.1	8.7	61.0
8/5/2014	1.0	1.0	13.7	52.6
8/20/2014	1.0	1.0	1.0	1.8
9/9/2014	1.4	12.0	12.0	9.0
9/23/2014	1.0	1.0	3.6	5.5
10/14/2014	1.0	1.0	10.4	9.3

Date	Chl (µg/L)		
	0.5 m	5 m	20 m
5/14/2014	3.7	5.9	4.3
6/10/2014	4.8	9.6	1.1
6/24/2014	1.6	5.9	1.6
7/8/2014	1.1	3.7	2.7
7/23/2014	2.7	2.7	1.1
8/5/2014	0.5	2.1	0.5
8/20/2014	3.2	3.7	1.1
9/9/2014	4.5	4.0	0.5
9/23/2014	3.7	4.5	0.5
10/14/2014	2.7	2.1	0.5

Date	TPN (µg/L)			
	0.5 m	5 m	20 m	B-1
5/14/2014	267	274	275	464
6/10/2014	465	354	330	651
6/24/2014	339	375	450	530
7/8/2014	443	494	665	655
7/23/2014	526	624	777	689
8/5/2014	607	645	1532	756
8/20/2014	668	711	1670	1562
9/9/2014	775	757	1712	1885
9/23/2014	848	932	1439	1575
10/14/2014	1679	1394	1681	1309

Date	NO3+NO2 (µg/L)			
	0.5 m	5 m	20 m	B-1
5/14/2014	168	185	193	195
6/10/2014	175	250	282	216
6/24/2014	305	316	422	434
7/8/2014	396	408	577	463
7/23/2014	497	509	648	594
8/5/2014	484	489	1164	719
8/20/2014	450	458	1420	1133
9/9/2014	616	617	1417	1400
9/23/2014	813	846	976	977
10/14/2014	947	954	1196	1054

Station LL2

Date	TP (µg/L)			
	0.5 m	5 m	15 m	B-1
5/14/2014	11.2	11.5	18.0	**149.3**
6/10/2014	9.0	9.9	11.1	**163.3**
6/24/2014	6.6	22.7	7.9	65.1
7/8/2014	5.3	10.2	7.2	17.2
7/23/2014	4.1	5.8	9.6	35.9
8/5/2014	6.8	7.2	21.7	24.0
8/20/2014	6.6	12.7	6.6	13.8
9/9/2014	7.5	9.6	6.9	29.4
9/23/2014	37.5	5.3	6.7	21.4
10/14/2014	9.2	10.6	13.5	34.2

Date	SRP (µg/L)			
	0.5 m	5 m	15 m	B-1
5/14/2014	1.5	1.8	2.3	5.4
6/10/2014	1.0	1.0	1.0	16.8
6/24/2014	1.0	1.5	2.4	11.5
7/8/2014	1.5	2.8	5.8	16.1
7/23/2014	1.0	1.0	10.4	35.0
8/5/2014	1.0	1.0	9.3	20.2
8/20/2014	1.0	1.0	1.0	1.0
9/9/2014	1.7	1.8	1.3	3.8
9/23/2014	1.6	1.0	1.0	6.1
10/14/2014	1.0	1.0	3.6	7.3

Date	Chl (µg/L)		
	0.5 m	5 m	15 m
5/14/2014	3.2	4.8	4.8
6/10/2014	3.7	7.5	2.7
6/24/2014	1.1	8.0	2.7
7/8/2014	2.1	9.1	2.1
7/23/2014	1.6	1.6	0.5
8/5/2014	1.1	2.7	0.5
8/20/2014	3.7	6.4	2.1
9/9/2014	3.5	4.8	1.3
9/23/2014	2.0	3.4	2.5
10/14/2014	4.5	4.3	1.3

Date	TPN (µg/L)			
	0.5 m	5 m	15 m	B-1
5/14/2014	272	305	332	1482
6/10/2014	319	361	433	738
6/24/2014	298	359	475	497
7/8/2014	463	738	756	732
7/23/2014	532	656	1039	697
8/5/2014	614	706	1734	1398
8/20/2014	638	816	1744	1674
9/9/2014	731	764	1546	1816
9/23/2014	1085	950	1233	1538
10/14/2014	1082	906	1052	1198

Date	NO3+NO2 (µg/L)			
	0.5 m	5 m	15 m	B-1
5/14/2014	190	195	196	200
6/10/2014	199	215	364	256
6/24/2014	288	333	459	421
7/8/2014	404	542	609	552
7/23/2014	438	590	912	570
8/5/2014	473	499	1335	1214
8/20/2014	420	524	1413	1203
9/9/2014	563	608	1359	1327
9/23/2014	849	853	962	972
10/14/2014	837	835	1038	1054

Station LL3

Date	TP (µg/L)			
	0.5 m	5 m	10 m	B-1
5/15/2014	16.7	23.8	21.7	28.6
6/11/2014	10.2	8.2	10.1	381.1
6/25/2014	5.3	8.4	9.6	23.1
7/9/2014	6.2	7.9	12.5	20.9
7/24/2014	7.7	20.7	7.8	17.2
8/6/2014	7.5	11.0	16.6	19.1
8/21/2014	9.4	10.9	9.8	27.8
9/10/2014	22.2	15.4	30.3	34.7
9/24/2014	9.2	10.5	22.5	16.9
10/15/2014	9.1	10.0	13.0	17.2

Date	SRP (µg/L)			
	0.5 m	5 m	10 m	B-1
5/15/2014	1.0	1.3	1.6	1.8
6/11/2014	1.6	1.1	1.2	7.4
6/25/2014	1.0	1.0	1.0	7.6
7/9/2014	2.2	3.2	7.3	15.4
7/24/2014	1.0	1.7	1.3	3.9
8/6/2014	1.0	1.7	1.3	9.5
8/21/2014	1.1	1.1	2.1	9.5
9/10/2014	1.0	1.1	1.7	1.5
9/24/2014	1.0	1.3	1.3	5.6
10/15/2014	2.3	2.1	2.6	5.6

Date	Chl (µg/L)		
	0.5 m	5 m	10 m
5/15/2014	3.7	3.2	4.3
6/11/2014	4.0	2.7	1.6
6/25/2014	2.1	4.0	3.2
7/9/2014	2.7	3.2	1.6
7/24/2014	2.7	2.1	4.3
8/6/2014	1.6	2.7	6.9
8/21/2014	7.5	8.5	No data: bottle leaked during shipment
9/10/2014	6.7	8.3	25.4
9/24/2014	4.5	4.8	13.9
10/15/2014	5.9	6.4	6.1

Date	TPN (µg/L)			
	0.5 m	5 m	10 m	B-1
5/15/2014	397	382	427	327
6/11/2014	339	401	471	1138
6/25/2014	299	548	565	519
7/9/2014	511	853	888	678
7/24/2014	822	751	1134	1999
8/6/2014	650	704	1501	1750
8/21/2014	522	586	1727	1795
9/10/2014	638	786	848	1887
9/24/2014	866	1188	1066	1859
10/15/2014	855	779	921	1340

Date	NO3+NO2 (µg/L)			
	0.5 m	5 m	10 m	B-1
5/15/2014	187	187	197	183
6/11/2014	254	373	407	423
6/25/2014	291	544	554	434
7/9/2014	388	715	730	517
7/24/2014	743	736	1050	1458
8/6/2014	400	453	1231	1418
8/21/2014	338	377	1277	1494
9/10/2014	469	516	650	1294
9/24/2014	674	760	617	1350
10/15/2014	723	722	776	1148

Station LL4

Date	TP (µg/L)		
	0.5 m	4 m	B-1
5/15/2014	16.3	17.4	16.7
6/11/2014	8.1	8.0	9.2
6/25/2014	7.3	9.5	8.4
7/9/2014	5.2	6.8	7.1
7/24/2014	13.2	22.7	9.5
8/6/2014	13.3	18.4	9.2
8/21/2014	19.8	20.3	19.7
9/10/2014	38.6	38.0	16.7
9/24/2014	21.0	27.9	9.1
10/15/2014	18.9	9.8	10.3

Date	SRP (µg/L)		
	0.5 m	4 m	B-1
5/15/2014	1.6	1.0	7.9
6/11/2014	1.8	1.9	1.9
6/25/2014	1.3	1.1	2.0
7/9/2014	2.8	3.6	3.9
7/24/2014	1.1	3.4	4.4
8/6/2014	1.0	1.0	3.0
8/21/2014	1.6	1.7	6.8
9/10/2014	1.0	2.4	2.2
9/24/2014	1.1	1.2	2.6
10/15/2014	1.9	4.5	6.7

Date	Chl (µg/L)	
	0.5 m	4 m
5/15/2014	3.3	3.7
6/11/2014	1.3	1.1
6/25/2014	2.7	2.4
7/9/2014	1.6	2.7
7/24/2014	2.1	3.2
8/6/2014	3.7	8.0
8/21/2014	17.1	18.2
9/10/2014	20.8	19.5
9/24/2014	13.6	21.9
10/15/2014	11.7	2.4

Date	TPN (µg/L)		
	0.5 m	4 m	B-1
5/15/2014	474	615	453
6/11/2014	485	482	484
6/25/2014	629	627	642
7/9/2014	696	960	972
7/24/2014	734	998	1520
8/6/2014	619	1103	1638
8/21/2014	493	800	1772
9/10/2014	757	871	1941
9/24/2014	707	1077	1717
10/15/2014	963	1418	1484

Date	NO3+NO2 (µg/L)		
	0.5 m	4 m	B-1
5/15/2014	199	196	196

6/11/2014	447	454	450
6/25/2014	618	617	623
7/9/2014	561	819	841
7/24/2014	653	917	1527
8/6/2014	364	546	956
8/21/2014	188	411	1646
9/10/2014	353	407	1461
9/24/2014	364	616	1432
10/15/2014	723	1185	1234

Station LL5

Date	TP (µg/L)	
	0.5 m	B-1
5/15/2014	15.8	14.7
6/11/2014	9.1	9.3
6/25/2014	7.8	7.8
7/9/2014	6.7	7.4
7/24/2014	8.5	10.8
8/6/2014	15.7	9.5
8/21/2014	27.0	14.9
9/10/2014	16.3	13.2
9/24/2014	10.6	10.1
10/15/2014	8.2	9.0

Date	SRP (µg/L)	
	0.5 m	B-1
5/15/2014	1.2	1.3
6/11/2014	2.4	1.7
6/25/2014	2.3	1.9
7/9/2014	4.9	4.2
7/24/2014	5.3	4.5
8/6/2014	1.0	4.5
8/21/2014	1.9	8.8
9/10/2014	1.0	2.5
9/24/2014	4.1	3.4
10/15/2014	5.3	4.6

Date	Chl (µg/L)
	0.5 m
5/15/2014	3.2
6/11/2014	1.1

6/25/2014	2.1
7/9/2014	0.5
7/24/2014	1.6
8/6/2014	3.7
8/21/2014	18.2
9/10/2014	5.1
9/24/2014	1.1
10/15/2014	2.2

Date	TPN (µg/L)	
	0.5 m	B-1
5/15/2014	435	317
6/11/2014	473	511
6/25/2014	694	685
7/9/2014	1215	1228
7/24/2014	1675	1682
8/6/2014	954	1982
8/21/2014	544	1779
9/10/2014	1951	1890
9/24/2014	1769	1801
10/15/2014	1433	1440

Date	NO3+NO2 (µg/L)	
	0.5 m	B-1
5/15/2014	184	183
6/11/2014	464	462
6/25/2014	679	674
7/9/2014	926	920
7/24/2014	1620	1647
8/6/2014	472	1655
8/21/2014	201	1678
9/10/2014	1393	1563
9/24/2014	1488	1479
10/15/2014	1200	1245

APPENDIX III – Lake Spokane Phytoplankton Data

(See PDF of Laboratory Data)

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APPENDIX IV – Lake Spokane Zooplankton Data

(See PDF of Laboratory Data)

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APPENDIX B

Lake Spokane Carp Population Abundance and Distribution Study, 2014 Annual Report Phase I (Golder Associates 2015)

AVISTA CORPORATION

LAKE SPOKANE CARP POPULATION ABUNDANCE AND DISTRIBUTION STUDY
2014 ANNUAL REPORT
PHASE I

Prepared By:

AVISTA Golder Associates

January 29, 2015

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List of Acronyms, Abbreviations, and Definitions

%	percent
±	plus or minus
≥	greater than or equal to
Avista	Avista Corporation
carp	common carp (*Cyprinus carpio*)
CART	combined acoustic radio transmitter
CPUE	catch per unit effort
DO TMDL	Dissolved Oxygen Total Maximum Daily Load (report)
DO WQAP	Dissolved Oxygen Water Quality Attainment Plan
Ecology	Washington State Department of Ecology
Fall 2013	October through December 2013
Fall 2014	October into November 2014
FERC	Federal Energy Regulatory Commission
g	gram(s)
Golder	Golder Associates Inc.
IDs	identification numbers
kg	kilogram(s)
L	total length
mg	milligram(s)
mm	millimeter(s)
PIT	passive integrated transponder
r^2	r-squared
RKM	river kilometer
SD	standard deviation
Spring	April through June
Summer	July through September
TP	total phosphorus
WDFW	Washington Department of Fish and Wildlife
WGS84	World Geodetic System 1984
Winter	January through March
Wr	relative weight
Ws	standard weight

1.0 INTRODUCTION

Common carp (*Cyprinus carpio*), referred to in this document as carp, influence phosphorus loading and phosphorus bioavailability in Lake Spokane. Carp transfer phosphorus from lake sediment into the water column through feeding and excretion, and also cause phosphorus loadings during die-offs. In addition, carp can negatively affect native aquatic vegetation, native fauna, and popular warmwater fish like bass and panfish (crappie, perch, and sunfish) that are targeted by anglers. Avista Corporation (Avista) recognized a potential for reducing phosphorus releases within Lake Spokane by reducing the lake's carp population and worked with Golder Associates (Golder) to prepare a study plan for this purpose (Avista and Golder 2012a), which is a component of the Lake Spokane Dissolved Oxygen Water Quality Attainment Plan (DO WQAP) developed by Avista and Golder (2012b) to address its proportional level of responsibility as determined in the Spokane River and Lake Spokane Dissolved Oxygen Total Maximum Daily Load (DO TMDL).

The carp population reduction study was initiated in 2013 and actions conducted in 2013 were summarized in a 2013 annual report (Golder Associates 2014). This report summarizes the Lake Spokane Carp Population Abundance and Distribution Study tasks funded by Avista in 2014.

Avista conducted a Phase I analysis to obtain a better understanding of carp seasonal behavior, biological measures, whole-body phosphorus concentrations, and abundance as described in detail below. Given the results of Washington Department of Fish and Wildlife's 2001 warmwater fisheries survey of Lake Spokane (Osborne et al 2003; Donley 2011), which suggest carp use shallow water and primarily concentrate in the upper end of the lake, the study area focused on Lake Spokane inshore habitat generally less than 30 feet deep.

The Phase I components addressed in this report include the following four items.

1. **Carp Seasonal Behavior (movement and aggregation)**
2. **Carp Abundance**
3. **Basic Carp Biological Measures**
4. **Whole-Body Carp Phosphorus Accumulated Load**

2.0 METHODS

The methods and procedures employed during the Phase I monitoring and analysis were managed for quality control by implementing commonly-accepted procedures for capture, measurement, and analysis of fish-tissue samples. As part of this process, Avista worked with Washington Department of Fish and Wildlife (WDFW) and Washington Department of Ecology (Ecology) to obtain all required permits before sampling fish.

Golder was contracted by Avista to lead implementation of this carp population reduction study, which began in October 2013.

2.1 Carp Seasonal Behavior

2.1.1 Field Sampling and Tracking

This study was initiated with a crew being mobilized to collect and tag carp for tracking their seasonal distribution. First, a test was conducted of the boat electro-fishing system and the following day sampling was conducted to collect carp for tagging. On October 17, 2013, a crew of staff from Golder and Avista Corporation (Avista) captured 20 carp, surgically implanted combined acoustic radio transmitter (CART) tags into them, and released them after the carp had recovered from the anesthesia and could swim on their own volition. Boat electro-fishing was conducted at two sites that were selected to maximize carp captures.

A passive integrated transponder (PIT) tag was inserted in each of the 20 carp on the left side into musculature below the dorsal fin, and a 16-gram CART tag surgically implanted in its abdominal cavity through a 15-millimeter incision posterior of the anal fin. The CART tags selected for this study were Lotek Model MM-RC-11-45, which are 12 millimeters diameter, 78 millimeters long, have a dry weight of 16 grams, with an expected battery life of 736 days when programmed for 60-second (±2 seconds) interval acoustic signals and 10 to 10.5 second radio signals. Following each surgery, the carp's recovery from anesthesia and general condition was monitored, and once the surgery team determined the carp had recovered from anesthesia, the fish was released.

The Golder-Avista crew conducted range testing of the CART tags on October 16, 2013 to facilitate development of tracking procedures based on the detectability of the radio and acoustic signals from CART tags under different boat operations. Results of these tests demonstrated that radio detection worked well for tags that were shallow (even when in a weed bed), and acoustic detection was better for deep tags. Adverse effects of hydraulic noise and boat speed on acoustic detection would prevent effectively detecting locations with the motor running, and would therefore not be as efficient as long as radio detections were possible. Therefore, radio signals were tracked as long as detection levels remained at or above 75 percent of the tags. For tag detection levels of 50 percent or less in a single tracking session or less than 75 percent for two consecutive tracking sections, we planned to switch to tracking acoustic signals.

A period of approximately two weeks was allowed to give the tagged carp time to redistribute throughout Lake Spokane after the tags were implanted. The tagged carp were released on October 17, 2013. The tracking events were conducted at roughly one-week intervals during November 2013 followed by two-week intervals in December 2013 through September 2014, and one-week intervals during October 2014. Some minor adjustments were made to the tracking schedule based on availability of the tracking crew and boat.

In May 2014, the Golder-Avista crew deployed an Onset ProV2 thermograph programmed to record temperature at 15-minute intervals approximately one meter below the water surface at each of the four locations identified in Table 2-1. The thermographs were deployed to gain more information in order to better predict the spawning timeframe for the mark event. These thermographs were downloaded on tracking sessions and recovered at the end of the study period. The accuracy of each thermograph was verified before deployment and after recovery. All thermographs were placed into a water bath near 10°C and 25°C along with a certified thermometer in order to verify that the thermograph temperature was within 0.2°C of the corresponding certified thermometer temperature.

Table 2-1: Locations of near Surface Continuous Temperature Measurements

Station Code	Description	Latitude (WGS84)	Longitude (WGS84)
Felton	Felton Slough	47.848435	-117.656586
SportParad-BW	Sportsman’s Paradise Backwater	47.830768	-117.641262
Granger-Riv	Granger River	47.800871	-117.558344
Granger-BW	Granger Backwater	47.797398	-117.55911

2.1.2 Data Analysis

Plots of detection river kilometer (RKM) vs. date of detection were constructed for each CART-tagged carp. These plots were used to identify tags that stopped moving suggesting either fish mortality or shedding of the tag. Tags identified as stationary, based on movements of less than 0.5 km upstream for detections across sampling events, were omitted from further analysis starting from the first detection in the stationary time period.

All carp movement patterns were evaluated using change in RKM values along the thalweg. Movement distance was calculated as change in RKM values along the thalweg, for each pair of consecutive detections for each tag and then plotted for visual interpretation. A box plot was created to display movement for each tracking session. Plots were also created for changes in RKM vs. difference in time between detections for each season, with October through December 2013 designated as ”Fall 2013”, January through March 2014 as ”Winter 2014”, April through June 2014 as ”Spring 2014”, July through

September 2014 as ”Summer 2014”, and October into November 2014 as ”Fall 2014”. Distances moved between sessions were summarized using mean, standard deviation, median, and minimum/maximum statistics within each sampling season. Total movement was calculated by summing absolute movement distances calculated by each individual fish within each season.

Aggregation was assessed by estimating the number of fish at each RKM location for each session using fish that were within 500 m of each other. The number of fish at each RKM location at each sampling session was plotted to visualize spatial and temporal aggregation patterns. In addition, the distance between each tag and its nearest neighbor (along the thalweg) was calculated for each tracking session. Nearest neighbor data were summarized (mean, SD, median, and range) for each sampling season.

2.2 Carp Abundance

2.2.1 Field Sampling

Results of the carp tracking program guided selection of the sampling locations for a mark-recapture program aimed at estimating carp abundance in Lake Spokane (Table 2-2). Sampling locations were based on detected CART-tag locations just before each sampling program and the extent of aggregation of the CART-tagged carp.

Table 2-2: Adaptive Sampling Decision Tree

CART Tag Distribution	Marking Strategy	Recapture Strategy
Highly Clumped* (≥90%)	Mark 80% at clumped site, 20% at random sites based on habitat type	Recapture effort 80% at clumped site, 20% at random sites based on habitat type
<90% and >50% Clumped	Randomly stratify marking effort based on both CART tag distribution and habitat type. (50% effort at clumped sites)	Randomly stratify recapture effort based on both CART tag distribution and habitat type. (50% effort at clumped sites)
Random (≤50% clumped)	Randomly stratify marking effort based on habitat type, but weighted for CART tag abundance	Randomly stratify recapture effort based on habitat type, but weighted for CART tag abundance

Note: Clumped % refers to percentage of CART tags detected at a single area that can be sampled using proposed gear as a single unit.

The marking program was scheduled to target the carp spawning period to maximize the number of fish marked and the recapture program targeted sampling carp aggregations in the late summer based on the success of sampling in October 2013. The specific schedule for the marking program in June was triggered by observations of carp activity by the Golder-Avista tracking crew along with Lake Spokane shoreline residents, and the thermograph temperature records.

2.2.1 Data Analysis

The capture method for both the marking and recapture programs was boat electro-fishing following the WDFW standard boat speed of 18.3 m/minute (Bonar et al. 1993). Sampling efficiency was measured as:

Catch per unit Effort (CPUE) = Number of Carp Captured / electro-shocking time (hour)

Captured carp were processed following methods described in Section 2.3.

2.3 Basic Carp Biological Measures and Sampling

2.3.1 Field Sampling

The Golder-Avista crew collected biological measurements, including total length, fork length, and weight during the October 2013, June 2014, and September 2014 sampling programs. Table 2-3 summarizes the parameter targets for the three sampling programs.

Table 2-3: Parameter Targets for Biological Measurements and Sampling

Parameter	October 2013	June 2014	September 2014
PIT tag to uniquely identify particular fish	All	All	None
Total Length (mm)	All	All	All
Fork Length (mm)	All	100 fish across the full range of sizes	100 fish across the full range of sizes with emphasis on PIT-tagged carp
Weight (grams)	All	Target 10 non-CART-tagged carp in each 100-mm size category	Target 10 non-CART-tagged carp in each 100-mm size category with emphasis on PIT-tagged carp
Dorsal Spine for ageing	None to minimize impacts on movement evaluation	None to minimize impacts on abundance estimate	Same fish as weighed
Whole-body sample for total phosphorus (TP) analysis	None	None to minimize impacts on abundance estimate	First non-CART-tagged carp in each 100-mm size category
Sexual maturity and sex of fish	None	None to minimize impacts on abundance estimate	All fish sacrificed for other analyses

Dorsal spine samples were collected from carp in September 2014 and ageing analyses were conducted by North/South Consultants. The initial spine, which is the largest, was removed with side-cutters then placed in a labeled coin envelope. Following air drying of the dorsal spine samples, they were shipped to North/South Consultants. The spine samples were first dipped in an epoxy resin (Cold Cure™) and allowed to harden for 48 hours. Then a low-speed-sectioning saw was used to prepare two sections per spine that were between 0.50 and 0.75 mm thick. These sections were then permanently mounted to a labelled glass slide using Cytoseal-60™, and the mounted sections were viewed under a microscope with transmitted light by an experienced ageing technician. An ageing technician categorized the confidence in ageing each sample by applying characteristics in Table 2-4, and then aged the sample. As an additional quality control and quality assurance measure, an alternate ageing technician evaluated the age for a randomly-selected subset of >10 percent of the spine samples.

Table 2-4: Qualitative and Quantitative Confidence Indices for Ageing Carp Dorsal Spines

Confidence Indices	Qualitative Characteristics (Pattern Clarity)	Quantitative Characteristics (Repeatability)
Very Good	Annuli are clear with no interpretation problems	Reader always gets the same age
Good	Annuli are clear with a few easy interpretation problems	Reader would get the same age most of the time for fish <10 years, within one year for fish 11-20 years
Fair	Annuli are fairly clear with some areas presenting easy and moderate interpretation problems	Reader would be within 1 year most of the time for fish<10 years and 2-3 years for fish >10 years
Poor	Annuli are fairly unclear presenting a number of difficult interpretation problems	Reader would be within 2-3 years most of the time for fish <10 years and 4-5 years for fish >10 years
Very Poor	Annuli are very unclear presenting significant interpretation problems	Reader has little confidence in repeatability of age within 4-5 years

Whole-body carp samples were collected in September 2014 for TP analysis. These fish were humanely sacrificed and placed on ice in a cooler. At the end of each day, the fish collected were taken to a butcher shop and flash frozen. Following the September 2014 sampling program, all frozen samples were placed in a cooler with ice and shipped for next-day delivery to ALS Environmental in Kelso, Washington. ALS followed standard operating procedures for preparation and TP analysis of the whole-body tissue samples (ALS 2014, 2012).

In September 2014, the crew also determined the sexual maturity and sex of all sacrificed fish by incising their abdomen and inspecting their gonads.

2.3.2 Data Analysis

Length frequencies and weight-length regressions were performed using R. The linear relationship between fork and total length was estimated. Plots of length and weight at age were constructed for all carp that were analyzed for age (September 2014 samples). Relative weight was calculated for each captured fish. Standard weights (Ws) were calculated using the following equation developed by Bister et al. (2000) that was developed using carp data from 167 different populations:

$\log_{10}(Ws) = -4.639 + 2.920 * \log_{10}(L)$

where Ws is the standard weight, and L is the total length (mm).

Relative weight (Wr) for each carp was calculated by dividing its measured weight by its standard weight and multiplying by 100 (i.e., Wr = W / Ws * 100).

Total phosphorus concentrations for Lake Spokane carp were compiled with literature values for carp fed and used to refine the estimate of RP accumulated in Lake Spokane carp.

3.0 RESULTS

3.1 Carp Seasonal Behavior

The Golder-Avista crew captured 20 carp, surgically implanted CART tags into them, and released them after the carp had recovered from the anesthesia and could swim on their own volition in October 2013. The boat electro-fishing system was tested on October 16, 2013. The following day, a site near Sportsman's Paradise was sampled and another site located near the Lake Forest Community (referred to as Felton Slough) was sampled (Figure 3-1). The October 17 average catch per unit effort (CPUE) was 27.9 carp per hour.[1] Total lengths of the 20 CART-tagged carp ranged from 590 to 795 millimeters (23.2 to 31.3 inches). Ten of the 20 carp weighed more than 5.0 kilograms, kg, (11.0 pounds), which was the upper limit for the scale used. All carp with fork lengths greater than 625 millimeters (24.6 inches) weighed greater than 5 kg (11.0 pounds). The minimum carp weight was 3.2 kg (7.2 pounds) resulting in the 16-gram Lotek Model MM-RC-11-45 CART tag being 0.5% of the weight for this carp and less for all other carp.

Fish-specific detections ranged from 53 percent to 100 percent of the tracking sessions. Data of 15 of the 20 CART tagged carp were collected throughout the study period (Attachment A). Two CART tags ceased being detected during the study; tag IDs 14 and 30 were last detected on August 6, 2014 and June 20, 2014, respectively. In addition, three fish (tag IDs 18, 26, 28) were determined to have died or shed their tags on June 9, June 20, and July 12, respectively (Figure 3-2).

There were no apparent relationships between time differences and RKM differences between detections in any seasons of this study (Figure 3-3). Most between-detection time differences were ≤ 20 days, although they ranged from 3 to 71 days between detections. The median time difference was 12 days, the 75th quantile was 16 days, and the mean ± SD were 12.5 ± 6.9 days.

Movement patterns changed among tracking events (Figure 3-4). Throughout most of fall 2013, movement was limited as can be seen by 50 percent of the fish (the extent of the box in the boxplot) moving less than 1 km between detections. From December 30, 2013 to February 20, 2014 which included lake level drawdown from within 1 foot of normal full pool to 13.4 feet below normal full pool, movement ranges increased, with carp moving both up- and down-reservoir from their previous locations. Throughout March, when the lake was refilled by significant inflows, to mid-July 2014, movement was somewhat variable, but remained similar across most sessions. In late July and early August 2014, movement and variability in movement increased substantially. Between July 12 and 21, fish moved mainly down-reservoir (most of the box is below 0 RKM). In comparison, by August 6, the majority of fish

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[1] Additional detail for the CPUE is provided below with CPUE for the June 2014 and September 2014 sampling programs.

moved several kilometers up-reservoir.. In late September to mid-October 2014, most fish moved down-reservoir from their previous locations.

All 20 CART tags were last accounted for and believed to still be in live carp on May 28, 2014, before the carp spawning period. During the carp spawning period of June to early July of 2014, one CART tag ceased to be detected and three CART-tagged carp were determined to have died or shed their CART tag. An additional CART tag ceased being detected in August 2014. These factors contributed to detection rates decreasing to as low as 10 active CART tags on September 23, 2014. In summer 2014, the proportion of active tags detected in a session was as low as 67 percent, but averaged 85 percent with a median of 88 percent. Fall 2014 active tag detections were as low as 73 percent in a session, but averaged 85 percent and had a median of 87 percent.

When plotted by season (Figure 3-5), movement in winter 2014 had slightly wider distribution (seen as wider box and longer whiskers) than movement in the other four seasonal periods, which were similar to one another. For all seasons, within-season movements did not show an up- or down-reservoir movement trend as evidenced by boxplots being symmetrical around zero RKM. Median values of seasonal movement ranged from -60 to 10 m (Table 3-1). Mean movement ranged from -370 m in fall 2014 to 87 m in fall 2013.[2] Seasonal movement was least variable in spring 2014 (SD of 1,848 m) and most variable in summer 2014 (SD of 2,500 m).

Table 3-1: Seasonal Summary Statistics for CART-Tagged Carp Distances (meters) Moved along the Thalweg between Detections

Season	Mean	SD	Median	Minimum	Maximum
Fall 2013	87	2,018	0	-8,390	7,110
Winter 2014	-60	2,221	-40	-5,840	6,590
Spring 2014	35	1,848	-60	-6,920	8,370
Summer 2014	-38	2,500	10	-6,660	9,890
Fall 2014	-370	2,110	-60	-7,150	6,490

Note: Seasonal summary statistics of distances moved along the thalweg between sessions, calculated across all fish. All values are in meters.

Tagged carp were highly aggregated during most of the fall 2013 and some of the winter 2014 sessions (Figures 3-6 and 3-7). Aggregations were evident for all tracking sessions between October 30 and December 16 of 2013 when the number of detected tags at any location ranged from 6 (November 13) to 19 (November 21). Following this period, the tagged carp spread out. On February 4, carp were once again aggregated with 19 of the tagged fish at the same location (Figures 3-6 and 3-7). On March 22 of 2014, carp were aggregated again, with 18 fish found between RKM 79.7 and 80.6. From May 2014

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[2] This represents mean movement of 370 m toward Long Lake Dam in fall 2014 and 87 m away from Long Lake Dam in fall 2013. This difference may be due to fall tracking being limited to the end of October through December in 2013, but only October in 2014.

through the end of the study, aggregation was less distinctive, with a maximum of 6 tagged carp within 500 m of each other. However, the majority of fish were repeatedly detected between RKM 78 and 83.

For each season, minimum distance between fish was zero (nearest neighbor; Table 3-2), which indicates that at least two tagged fish were aggregated at least once during each season. Seasonal maximum distance to nearest neighbor ranged from 406 m in fall 2014 to 3,077 m in fall 2013, even though carp were highly aggregated during fall 2013. The high maximum distance between neighbors in fall 2013 is also the reason for the high mean and standard deviation during that season.

Table 3-2: Seasonal Summary Statistics (meters) for Estimates of Nearest Neighbor

Season	Mean	SD	Median	Minimum	Maximum
Fall 2013	96	385	0	0	3,077
Winter 2014	36	85	0	0	535
Spring 2014	33	125	6	0	1,492
Summer 2014	43	137	8	0	1,113
Fall 2014	17	56	3	0	406

Note: These statistics are based on estimates of nearest neighbor along the thalweg calculated for each tracking session.

Total movement distance within seasons varied by tag and season (Figure 3-8). Tag ID 12 had the greatest total movement recorded, with 34.1 km traveled during fall 2014. Tag ID 19 had the least total movement, with total seasonal movement ranging from 510 m in fall 2014 to 4.2 km in spring 2014.[3]

Carp spawning activity was reported for several sites, from Nine Mile Flats (most up-reservoir) to the Woody Slough shoreline (most down-reservoir; Figure 3-1). Carp spawning activity was observed during June and early July 2014 (Figure 3-9). However, no carp spawning activity was observed in the extended vegetated flats near RKM 64 (Figure 3-1), which WDFW had identified as having enhanced carp activity in late spring of other years (Whalen 2014). During the observed carp spawning activity, near surface water temperature ranged from 14.5°C to 19.3°C at Felton (mean±SD of 16.8±1.05°C), from 13.7°C to 21.8°C, with large daily fluctuations, at Granger-BW (mean±SD of 17.6±1.78°C), from 14.1°C to 18.6°C at Granger-Riv (mean±SD of 16.3±1.03°C), and from 14.6°C to 21.2°C at Sportsman's Paradise-BW (mean±SD of 17.2±1.46°C).

During the study period, near surface hourly average water temperature increased from a range of 11.5 to 12.4°C, depending on station, in early May to a range of 19.1 to 23.5°C in August. The maximum water temperature, which was recorded in July at Sportsman's Paradise, was 26.0°C. Starting in early August, near surface water temperature began declining and reached an average of 13.7 to 17.5°C, depending on station, in October.

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[3] Low detection rates for tag 19 throughout many seasons contributed to its lower total movement than other tagged carp (refer to Attachment A).

Air temperature slowly increased from May to July, and decreased from August to October. Throughout the study period, air temperature was highly variable, with mean daily temperatures fluctuating up to ~ 10°C. Within each month, the difference between minimum and maximum temperatures was greater than 20°C, with the largest range in October of 2014, when the maximum was 26.1°C and minimum was -4.4°C. The range of daily fluctuations was highest in September, with 20.5°C difference between the maximum and minimum temperatures.

The Lake Spokane inflow ranged from 1.3 kcfs to 6.8 kcfs in October 2013 through February 2014, and then increased to a high of 26.2 kcfs on March 15, 2014 (Figure 3-10). The inflow remained at 16 kcfs or greater until June 2014 and then decreased to approximately 2 kcfs in late summer. Following the typical hydrologic pattern, the reduction in inflow occurred throughout June and July, and coincided with reported carp spawning activity. From mid-July until end of October, inflows remained relatively stable.

Lake Spokane's elevation remained relatively stable within 1 foot of normal full pool from October 2013 through early December 2013. Then seasonal drawdown reduced the level to 13.4 feet below normal full pool. The lake elevation remained near this level until high inflows in March 2014 resulted in refilling the lake to with 2 feet of normal full pool. It remained near full pool throughout the remainder of this study.

Fish aggregation, as defined by ≥10 of the 20 tagged fish (Figure 3-10), was detected when mean daily air temperature ranged from -15.5°C to 8.9°C (median of -1.1°C), minimum daily air temperature ranged from -20.6°C to 5°C, and maximum daily temperature ranged from -12.8°C to 13.3°C. Fish were aggregated (≥10 tagged fish) when lake inflow ranged from 3.3 kcfs to 26.2 kcfs (mean±SD of 6.4±5.8 kcfs; median of 4.4 kcfs), and when water elevations ranged from 1522.6 feet to 1535.6 feet (mean±SD of 1530.5±5.4 ft; median of 1534.5 ft). Although this does not demonstrate a direct link between fish aggregation and Lake Spokane inflow or water elevation, the timing of two of the four aggregation dates suggests there may be a link with these environmental factors. February 4, one of the periods with 19 tagged carp aggregated, was the first tracking session following a rapid drawdown of the lake to near its minimum level. In addition, air temperature was near its lowest on this day. The March 22 carp-aggregation event followed the peak inflow event for the study period.

3.2 Carp Abundance

During the 2013 – 2014 study period, three carp sampling programs were conducted. Electro-shocking site-specific catch per unit effort (CPUE) results are displayed in Figure 3-11, and summary statistics for each sampling program are provided in Table 3-3.

Table 3-3: Catch per Unit Effort (CPUE), as carp per hour, for the Three Carp Sampling Programs

Sampling Program	Number of Sites	Mean CPUE	SD CPUE	Median CPUE	Minimum CPUE	Maximum CPUE
2013-October	3	20.1	14.5	27.2	3.4	29.7
2014-June	48	44.3	29.9	38.3	3.4	145.7
2014 September	15	6.7	8.6	6.9	0.0	28.6

The October 2013 sampling program was conducted to implant CART tags in 20 carp to enable tracking their movement as described above. This program consisted of three sampling sites, which included a test of the boat-electrofishing unit in the afternoon of October 16 followed by sampling the next day to obtain 20 carp for the CART-tag implantations. The CPUE for these three sampling sites varied widely, with a minimum of 3.4 carp per hour in Nine Mile Flats during testing of the boat-electroshocking system to 29.7 carp per hour at Felton Slough on the afternoon of October 17.

The June 2014 marking program was conducted during carp spawning on June 10 through 13, based on carp aggregating at known spawning areas and aggregation of CART-tagged carp. To increase the number of carp marked with PIT tags, additional sampling was conducted near some sites that had a large number of observed carp that were not captured on the first pass. The marking program consisted of 48 sites sampled on June 10-13 with 616 individual carp being marked with PIT tags Figure 3-11 displays CPUE by sampling area. CPUEs for this program ranged from 3.4 carp per hour at Woody Slough to 145.7 carp per hour near RKM 79 and had a median of 38.3 carp per hour. The shallow active spawning area along the left downstream bank near RKM 79 had four of the five greatest CPUEs, all of which were greater than 83 carp per hour.

The September 2014 sampling program was designed as a recapture program to be used for estimating carp abundance in the lake based on recaptures of previously marked (i.e., PIT-tagged) carp. Sample timing was aimed at capturing carp before they moved to deep water where capture efficiencies would be low. This program consisted of sampling 15 sites on September 28 and 29 resulting in a total of 26 carp being captured, with no previously PIT-tagged carp captured. CPUE was lower for this sampling program than either of the other two sampling programs. Sample site CPUE ranged from zero to 28.6 carp per hour with seven (47%) of the 15 sample sites having CPUE of zero carp per hour. Only four (27%) of the 15 sample sites had CPUE of 10 or more carp per hour (Figure 3-11). Based on the extremely low CPUE under a variety of conditions and locations,[4] it was concluded that continuing the sampling program with the end goal of providing a reliable carp population estimate was not feasible and therefore the sampling program was terminated.

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[4] In September 2014, seven areas (Figure 3-11) ranging from shallow to deep water sites were sampled between early morning and late afternoon hours.

Since no previously PIT-tagged carp were captured during the September 2014 sampling program, a standard population size estimate could not be calculated.

3.3 Basic Carp Biological Measures

Measurements of carp total length (mm), fork length (mm), and weight (g) were recorded during the three sampling programs. The scale used in October 2013 had a maximum capacity of 5000 g. Ten of the 20 fish CART tagged had weights greater than the scale's capacity and were therefore recorded as ">5000 g" and omitted from summary statistics, length-weight regressions, etc.

Table 3-4 provides summary statistics for length and weight measurements of carp captured during the October 2013, June 2014, and October 2014 sampling programs. Considerably more carp were measured and weighed in June 2013 than either of the other sampling programs; therefore, it is not surprising that the ranges for lengths and weights are smaller for the other two sets. The overall measurement ranges were 168 to 810 mm (6.6 to 31.9 inches) for total lengths, 150 to 748 mm (5.9 to 29.4 inches) for fork lengths, and 60 to 10,450 g (0.1 to 23.0 pounds) for weights. The fish sampled in June 2014 had the full range of total lengths measured with a small length-frequency peak around 220 mm (9 inches) and a large length-frequency peak around 600 to 750 mm (24 to 30 inches; Figure 3-12).

Table 3-4: Summary of Carp Length and Weight Measurements by Sampling Session

Parameter	Session	Total length	Fork length	Weight [1]
N fish	Oct 2013	20	20	10
	Jun 2014	624	125	108
	Sep 2014	26	24	22
Range (minimum – maximum; units)	Oct 2013	590 – 795 mm	545 – 705 mm	3250 – 4376 g
	Jun 2014	168 – 810 mm	150 – 748 mm	60 – 10450 g
	Sep 2014	569 – 798 mm	511 – 717 mm	2660 – 7820 g
Mean (SD); units	Oct 2013	662 (53) mm	608 (47) mm	3790 (412) g
	Jun 2014	645 (114) mm	516 (176) mm	3805 (2835) g
	Sep 2014	670 (57) mm	599 (55) mm	4547 (1434) g

Note:
[1] The scale used in October 2013 had a maximum capacity of 5 kg, so the ten carp weighing > 5 kg were omitted from this analysis.

The relationship between fork lengths and total lengths remained virtually the same for all three sampling programs and had an r2 value of 0.998 for the combination of all three sampling programs (Figure 3-13). This relationship was:

$$\text{Fork Length} = -1.588 + 0.902 * \text{Total Length}$$

The relationship between length and weight of fish measured throughout the entire study period was strong with an r^2 value of 0.985) (Figure 3-14), with:

$$\text{Weight (g)} = 2.642 \times 10^{-5} \times \text{Total Length}^{2.91}$$

The relative weight (Wr) of carp sampled during the June 2014 carp spawning period ranged from 53.2 to 177.5, with a mean±SD of 109.2±18.6 and a median of 107.8 (Figure 3-15). For comparison, the 22 fish with length and weight measurements in September 2014 had relative weights that varied much less, ranging from 91.7 to 119.2 with a mean±SD of 106.1 ± 9.0. The median relative weight for September 2014 fish was virtually the same as for June 2013 (105.0 September versus 107.8 for June). Evaluation of relative weights based on total length categories of less than 600 mm, 600-800 mm, and greater than 800 mm suggested minimal trends; the relative weight was greater than 100 for all fish greater than 800 mm total length during the June 2014 spawning period (Figure 3-15).

Relative weight of greater than 100 represents a fish that is heavier than would be expected for a given length, compared to the mean values from other populations (Bister et al. 2000). Generally, high relative weights are viewed as a sign of health. However, seasonality (especially egg development and spawning) has a profound effect on relative weight, and likely contributed to the greater variability in relative weights for carp collected during the June 2014 spawning period.

Carp age analysis was based on dorsal spine samples removed from carp captured in September 2014. NSC’s ageing technician categorized confidence indices as good for 15 (68%) and fair for 7 (32%) of the 22 samples aged. The aged fish, which had total lengths of 569 to 798 mm (22.4 to 31.4 inches) and weights of 2,660 to 7,820 g (5.9 to 17.2 pounds), were determined to have ages from 5 to 17 years (Table 3-5, Figure 3-16). Three (13.6%) fish were age 5, two fish were age 7 to 9 (9%), sixteen (72.7%) fish were age 10 to 14, and only one (4.5%) fish was age 17. The age of greater than half (5 of 9) of the females was at least 13; whereas, only one of 13 males was older than 13.

Table 3-5: Summary of Carp Age for Carp Collected in September 2014

Age	Female	Male	Total	Percent
5	1	2	3	13.6%
7	0	1	1	4.5%
9	1	0	1	4.5%
10	2	4	6	27.3%
11	0	5	5	22.7%
13	2	0	2	9.1%
14	2	1	3	13.6%
17	1	0	1	4.5%
Total	9	13	22	

Figure 3-16 displays carp length-at-age and weight-at age relationships based on 22 carp collected in September 2014. All four aged carp weighing greater than 6000 g in September were females (Figure 3-16).

3.4 Whole-Body Carp Phosphorus Concentration

Three carp collected in September 2014 were analyzed for whole-body TP concentrations to compare the TP proportion of carp in Lake Spokane with values used from a study of characteristics for carp fed different diets (Nwanna et al. 2010) and used to calculate rough estimates of TP accumulated in Lake Spokane carp. The TP proportion of the three whole-body carp from Lake Spokane ranged from 0.0039 to 0.0103 and averaged 0.0065 (Table 3-6). In comparison, the TP proportion of carp was reported as 0.0121 for carp fed a non-supplemented diet and 0.0200 for carp fed a diet supplemented with 20 g TP / kg. The average Lake Spokane TP proportion was 54 percent of the non-supplemented diet and 33 percent of the phosphorus-supplemented diet. Application of these percentages of measured TP content in Lake Spokane carp to earlier rough estimates based on literature values reduces the estimates for TP content (in the entire carp estimated population, assuming Donley's population estimate of 125,000 carp in Lake Spokane) from a range of 6,375 to 10,500 kilograms TP (Avista and Golder 2012a) to approximately 3,494 kg TP.[5]

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[5] This calculation retains the application of Lake Spokane carp population and average weights reported by (Donley 2011).

Table 3-6: Potential Total Phosphorus Load Reductions from Carp Carcass Removal

Carp Description	Dry Matter (%)	TP Proportion of Carp (decimal)	Notes
Non-Supplemented Diet	30.0	0.0121	1, 3
Phosphorus Supplemented Diet	26.4	0.0200	2, 3
Lake Spokane Sept. 2014 Fish #656: 680 mm total length Female weighing 3.93 kg	27.0	0.0103	
Lake Spokane Sept. 2014 Fish #658: 585 mm total length Male weighing 2.82 kg	25.5	0.0052	4
Lake Spokane Sept. 2014 Fish #659: 731 mm total length Female weighing 6.14 kg	31.5	0.0039	
Lake Spokane Sept. 2014 Average	28.0	0.0065	
Lake Spokane Sept. 2014 Average / Non-Supplemented Diet Carp (%)	93%	54%	
Lake Spokane Sept. 2014 Average / Phosphorus Supplemented Diet Carp (%)	106%	33%	

Notes:
1 Carp with uncontrolled diet.
2 Carp with diet supplemented with 20 g TP / kg.
3 Source: Nwanna et al. 2010a.
4 Fish ID 658 results are the average of the initial (4,520 mg/Kg phosphorus) and duplicate (5,910 mg/Kg phosphorus) analyses.

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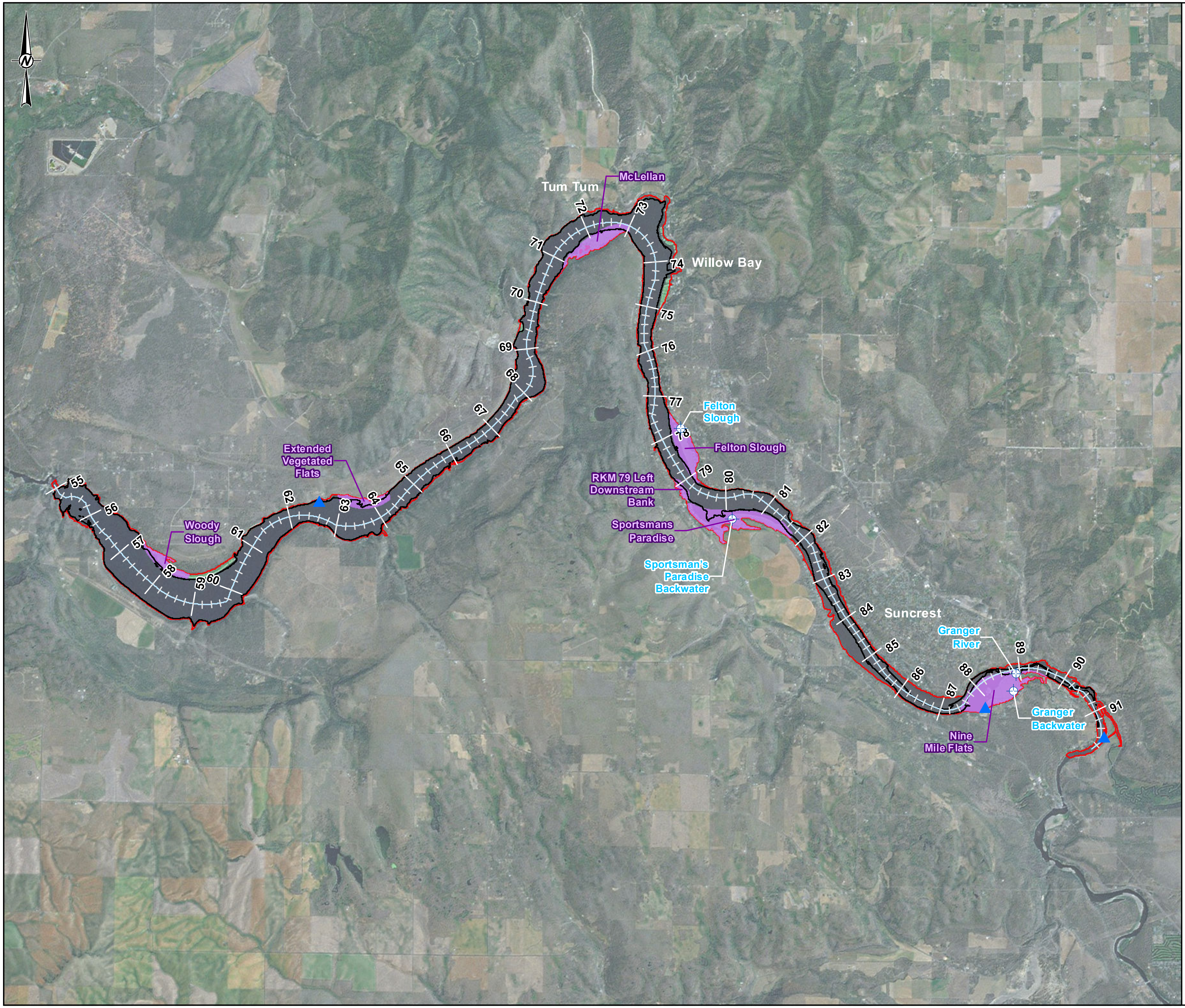
FIGURES



LEGEND

⌖ THERMOGRAPH SITE

▨ CARP SPAWNING AREA

— LONG LAKE THALWEG (KM)

— 14FT DRAW DOWN (CONTOUR 1524, DATUM: NAVD 1988)

▲ PUBLIC BOAT LAUNCH

☐ LONG LAKE HED PROJECT BOUNDARY

REFERENCES

BACKGROUND: ESRI, ARCGIS ONLINE (WORLD IMAGERY), DATE ACCESSED: 2014-01-23
STATE PARKS: WA PARKS AND REC, WA STATE PARKS, DATE ACQUIRED: 2014-01-23

0 2 4
MILES

CLIENT
AVISTA

PROJECT
LAKE SPOKANE CARP POPULATION ABUNDANCE AND DISTRIBUTION STUDY 2014 ANNUAL REPORT

TITLE
LAKE SPOKANE RIVER KILOMETERS, THERMOGRAPH SITES, AND SPAWNING AREAS

CONSULTANT
Golder Associates

YYYY-MM-DD	2015-01-26
PREPARED	GVL
DESIGN	GVL
REVIEW	BC
APPROVED	BLM

PROJECT No.	PHASE	Rev.	FIGURE
07393081-09	005	0	3-1

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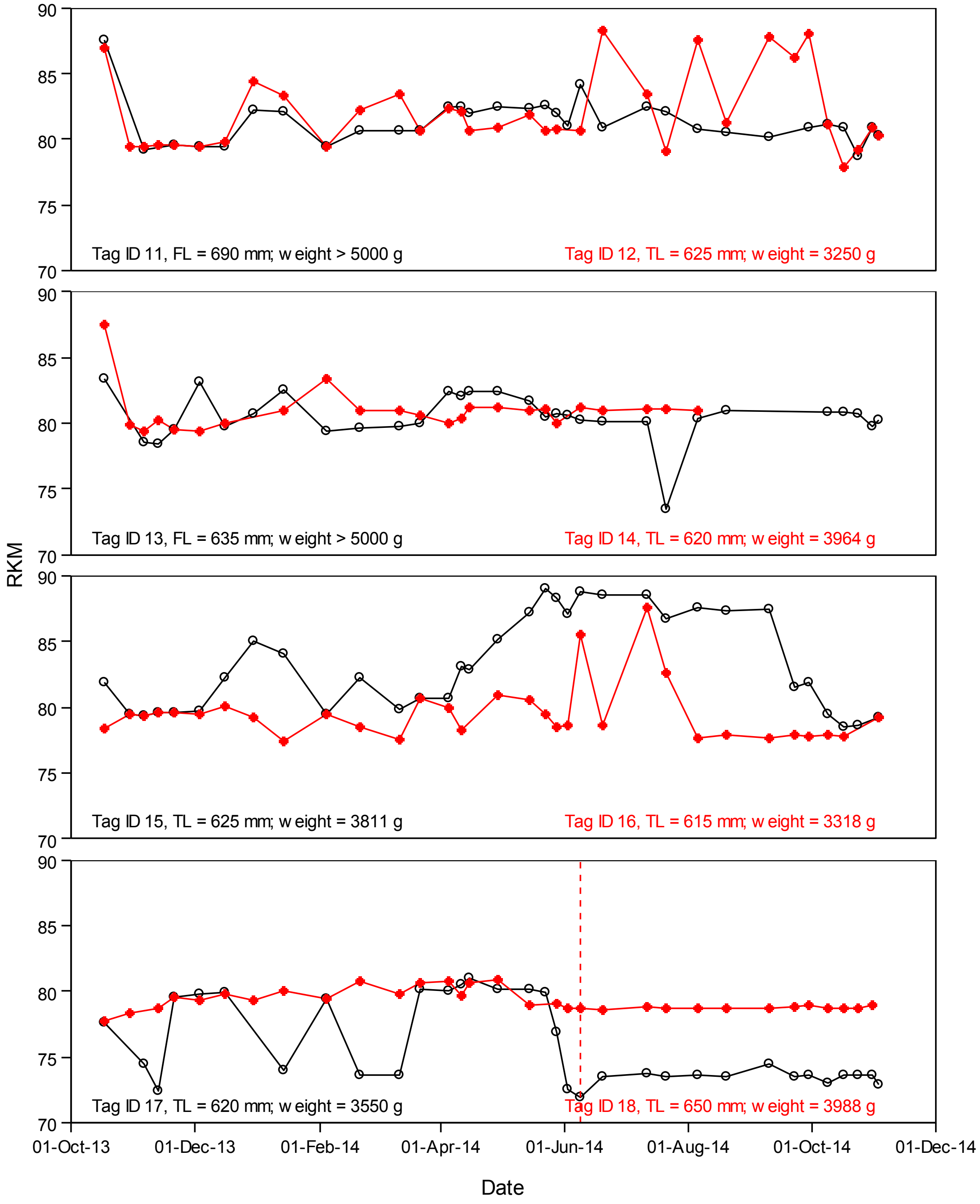

Figure 3-2A: River Kilometer (RKM) Locations at Each Tracking Session for CART-Tagged Carp, 2013-2014 Study Period for Tag IDs 11-18

Notes:

Each panel provides fish-specific details for two carp. The first point is for the CART-tagging session, and all subsequent points indicate tracking detections. Dashed vertical lines, corresponding in color to the tag, represent the time carp died or shed their tags.

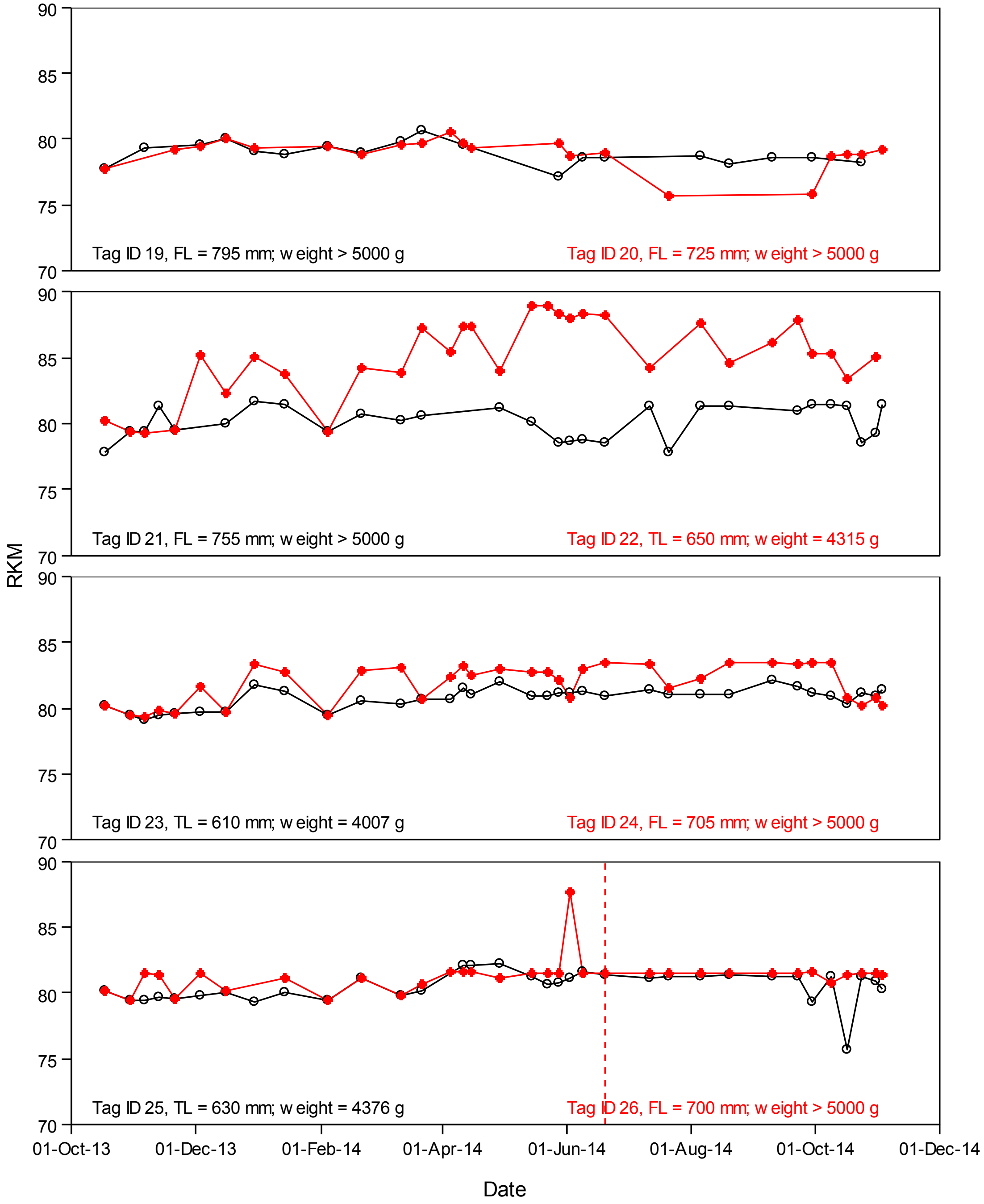

Figure 3-2B: River Kilometer (RKM) Locations at Each Tracking Session for CART-Tagged Carp, 2013-2014 Study Period for Tag IDs 19-26

Notes:

Each panel provides fish-specific details for two carp. The first point is for the CART-tagging session, and all subsequent points indicate tracking detections. Dashed vertical lines, corresponding in color to the tag, represent the time carp died or shed their tags.

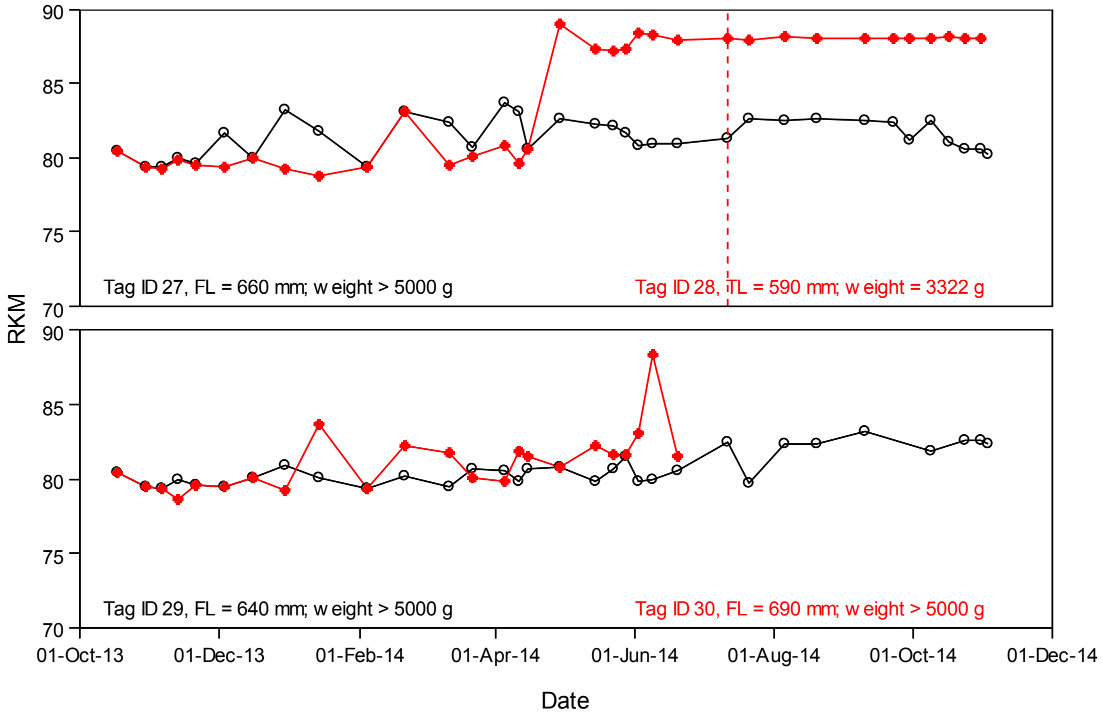

Figure 3-2C: River Kilometer (RKM) Locations at Each Tracking Session for CART-Tagged Carp, 2013-2014 Study Period for Tag IDs 27-30

Notes:

> Each panel provides fish-specific details for two carp. The first point is for the CART-tagging session, and all subsequent points indicate tracking detections. Dashed vertical lines, corresponding in color to the tag, represent the time carp died or shed their tags.

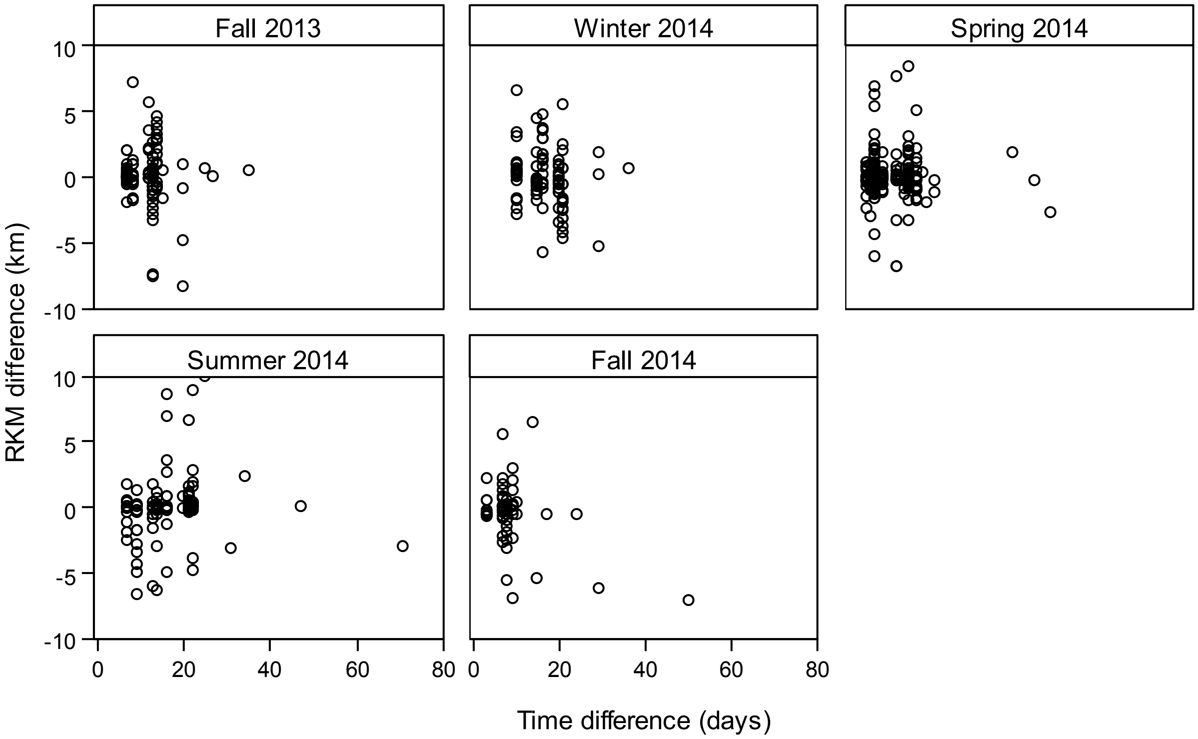

Figure 3-3: Movement of CART-Tagged Carp along the Thalweg by Season, 2013-2014 Study Period

Notes:

These are composites of change in detected river kilometers (RKM) for individual CART-tagged carp from the previous detected location, calculated along the thalweg. Therefore, RKM differences that are negative values indicate movement toward Long Lake Dam and positive values indicate movement away from Long Lake Dam.

Fall 2014 tracking was completed on November 3, 2014.

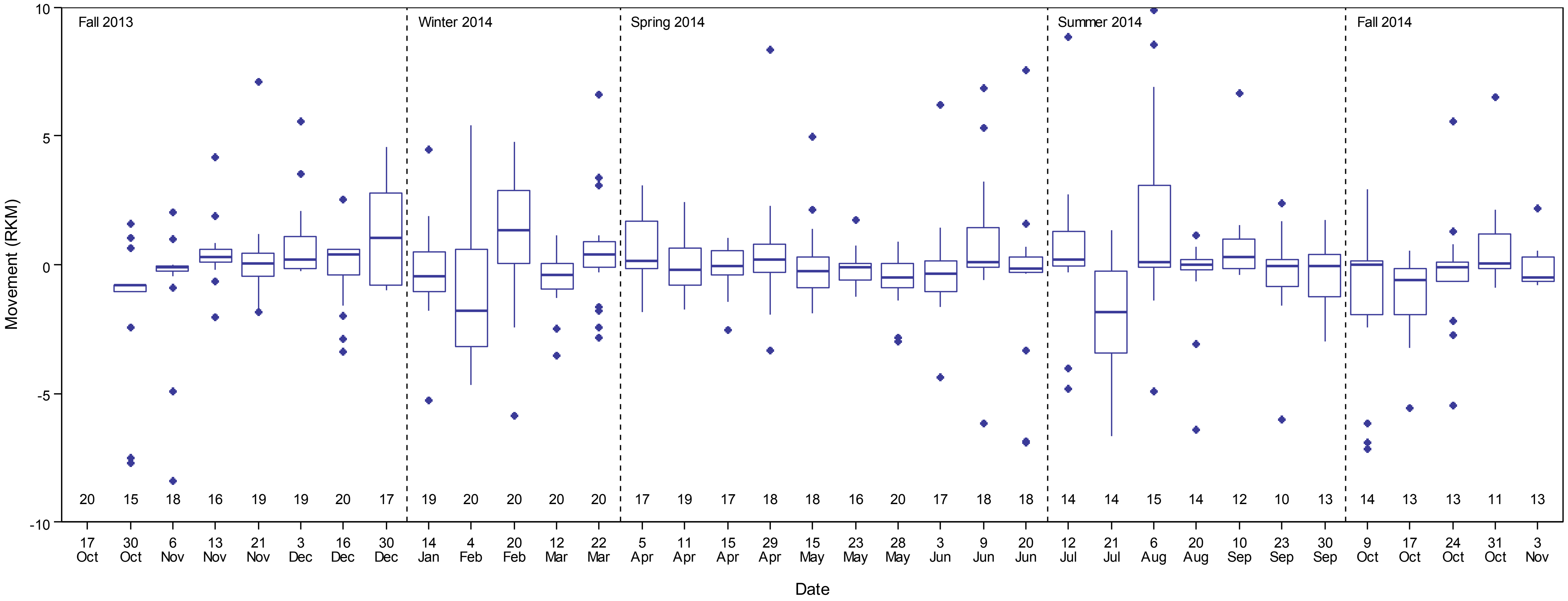

Figure 3-4: Boxplots of Movement (calculated along the thalweg) by Tracking Session with Seasons Depicted, 2013-2014 Study Period

Notes:

Movement was calculated as the change in detected river kilometers (RKM) for individual CART-tagged carp from the previous detected location. Therefore, RKM differences that are negative values indicate movement toward Long Lake Dam and positive values indicate movement away from Long Lake Dam.

Movement is shown as boxes with 25th and 75th quantiles as the bottom and top lines, respectively, the median as the bold line, whiskers extending to 1.5 times the interquartile distance, and outliers shown as individual points. The number of CART-tagged carp recorded during each tracking session is provided below each box.

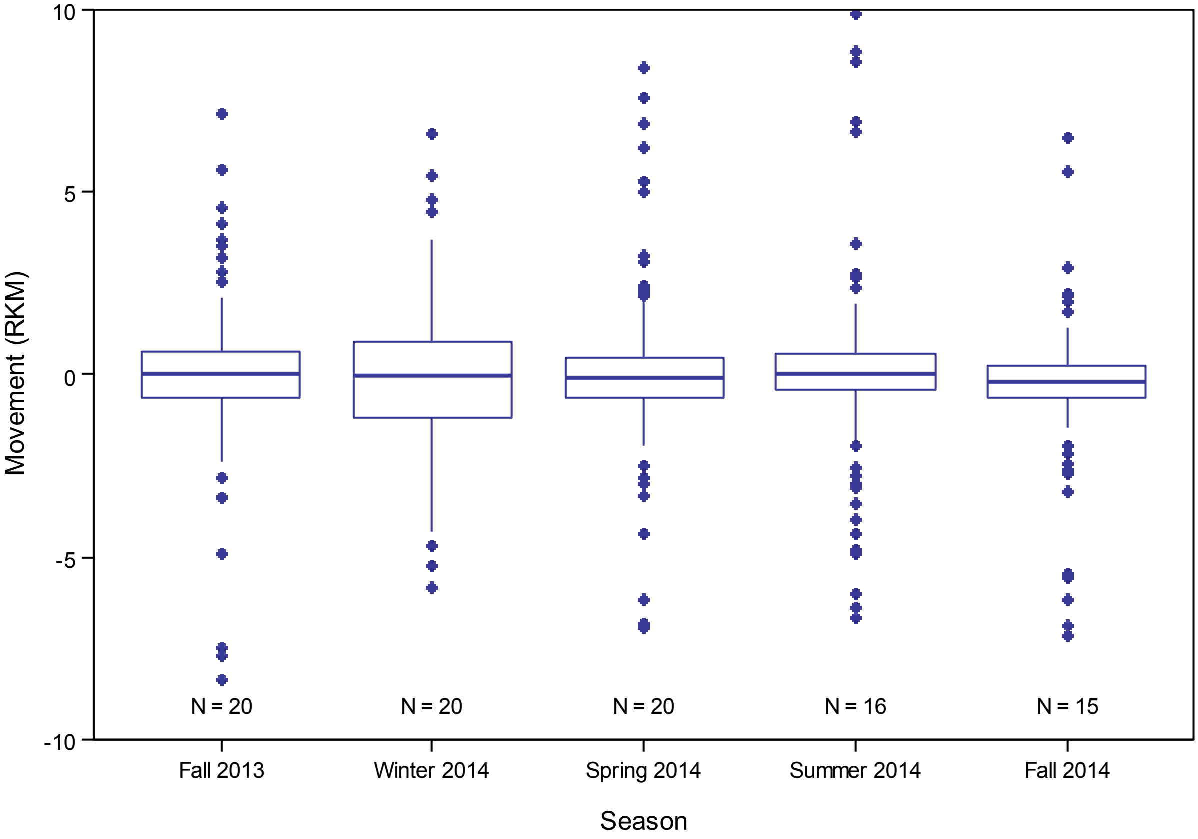

Figure 3-5: Boxplots of Distances Moved along the Thalweg between Sessions, by Season

Notes:

Movement was calculated as the change in detected river kilometers (RKM) for individual CART-tagged carp from the previous detected location. Therefore, RKM differences that are negative values indicate movement toward Long Lake Dam and positive values indicate movement away from Long Lake Dam.

Movement is shown as boxes with 25th and 75th quantiles as the bottom and top lines, respectively, the median as the bold line, whiskers extending to 1.5 times the interquartile distance, and outliers shown as individual points. The number of CART-tagged carp recorded during each tracking session is provided below each box.

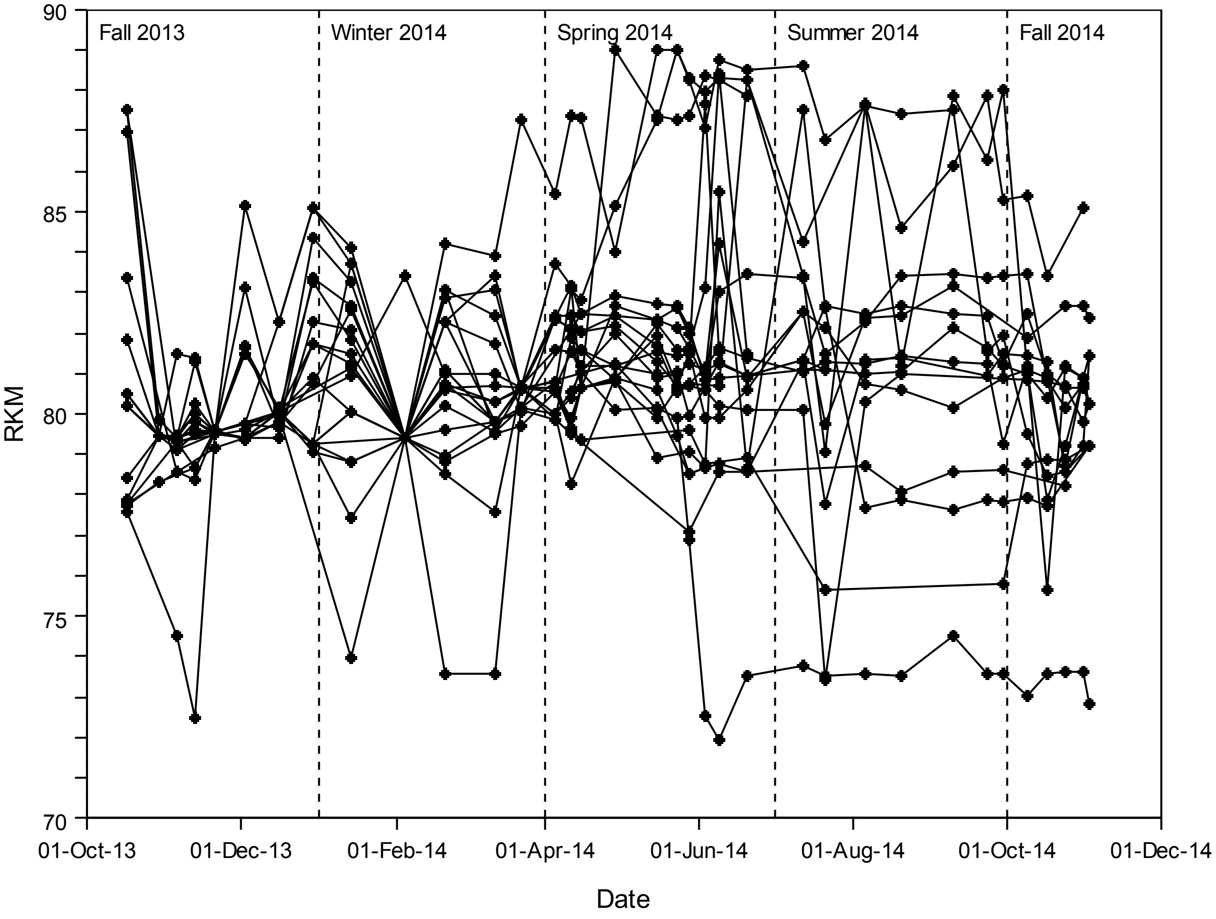

Figure 3-6. Aggregation of Distribution of CART-Tagged Carp along the Thalweg, 2013-2014 Study Period

Notes:

Each CART-tagged carp is represented by a line.

Tracking events, when fish were detected, are shown as points.

Dashed lines denote seasons.

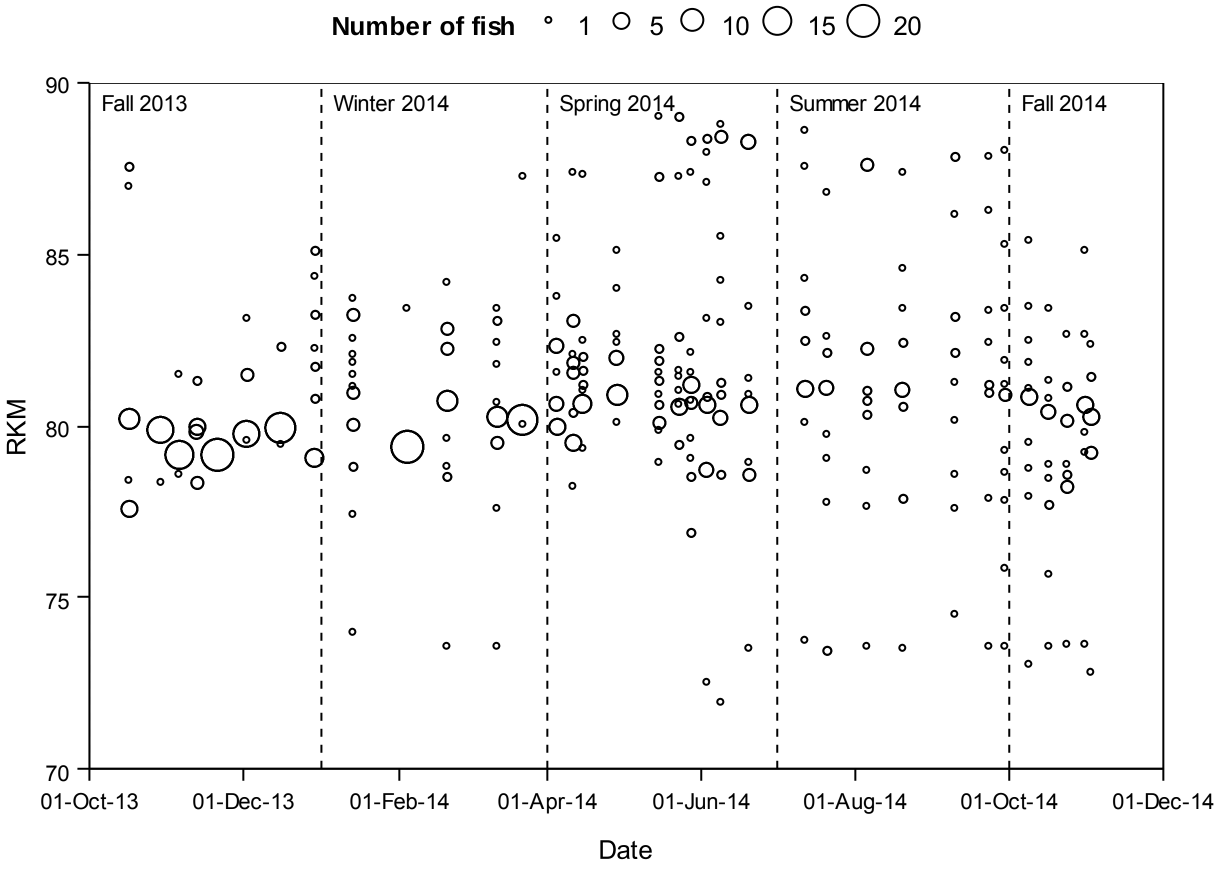

Figure 3-7. Distribution and Concentration of CART-Tagged Carp, 2013-2014 Study Period

Notes:

Bubble size is relative to number of fish observed during tracking at each location by session.

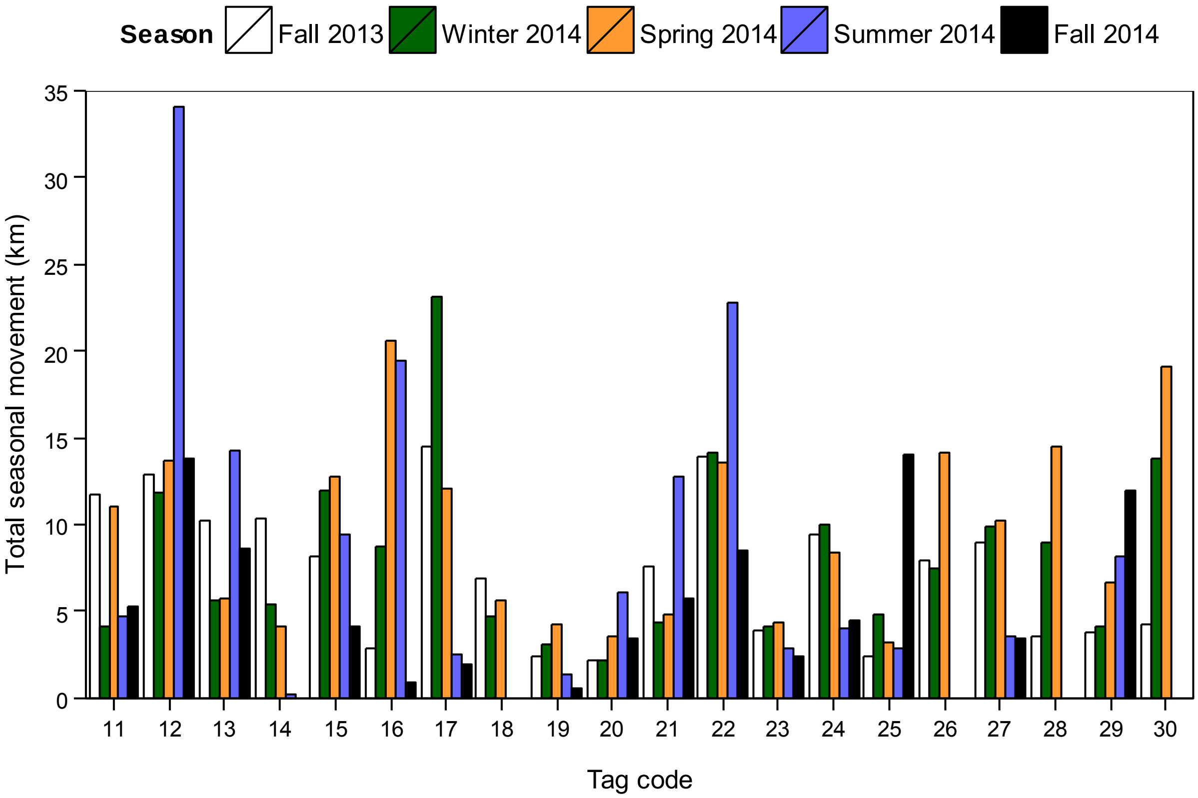

Figure 3-8. Total Movement, Calculated along the Thalweg, for Each CART-Tagged Carp by Season, 2013-2014 Study Period

Notes:

> Seasonal movement was calculated as the summed absolute values of movement between session-specific detections.

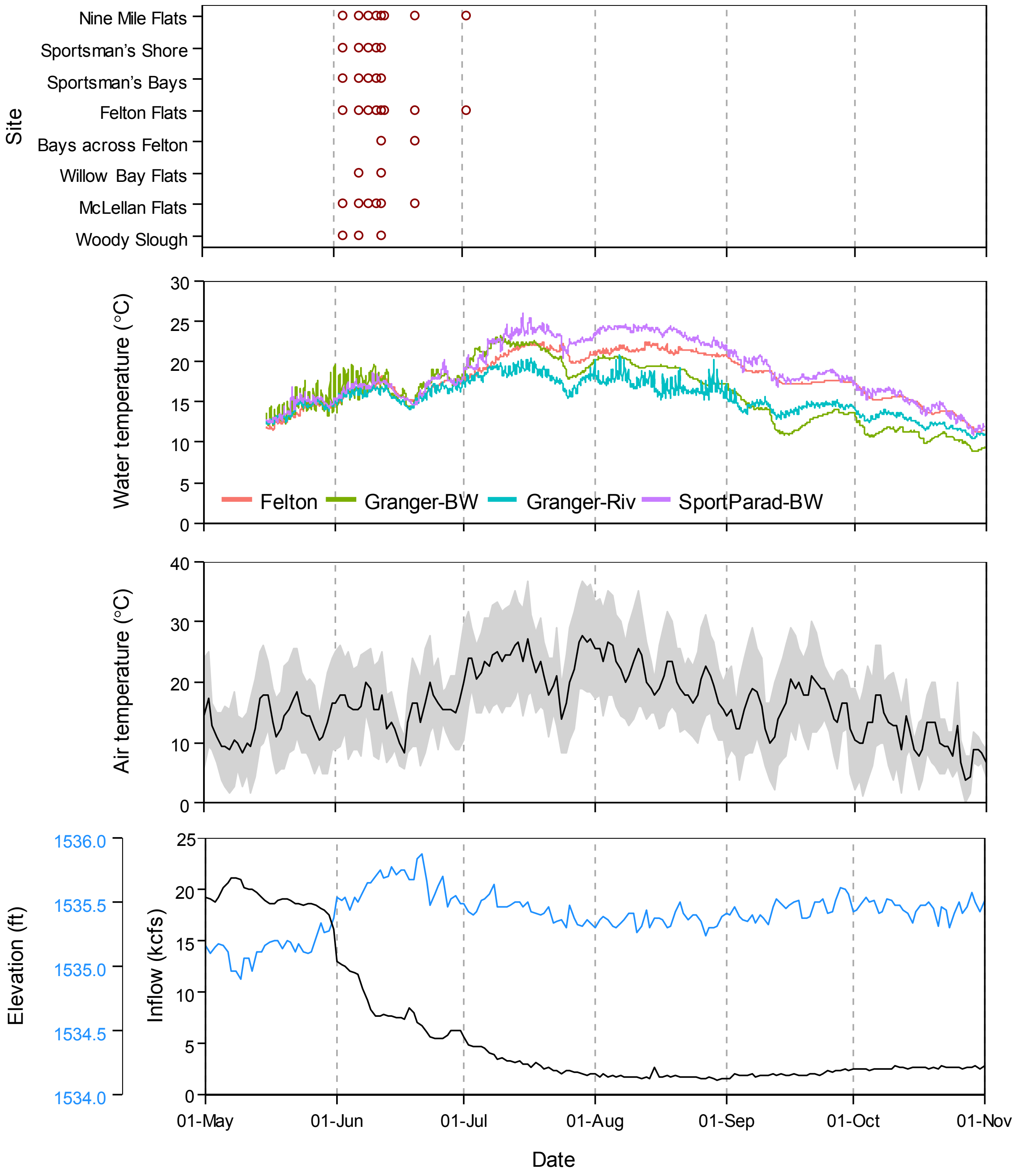

Figure 3-9. Time Series for Observed Carp Spawning Activity and Environmental Conditions, May – October of 2014

Notes:

Days with observed carp spawning activity by location (top panel), hourly water temperatures by thermograph site (second panel), Spokane International Airport air temperature with daily average as black line and range as grey ribbon (third panel), and Lake Spokane inflow and elevation (bottom panel).

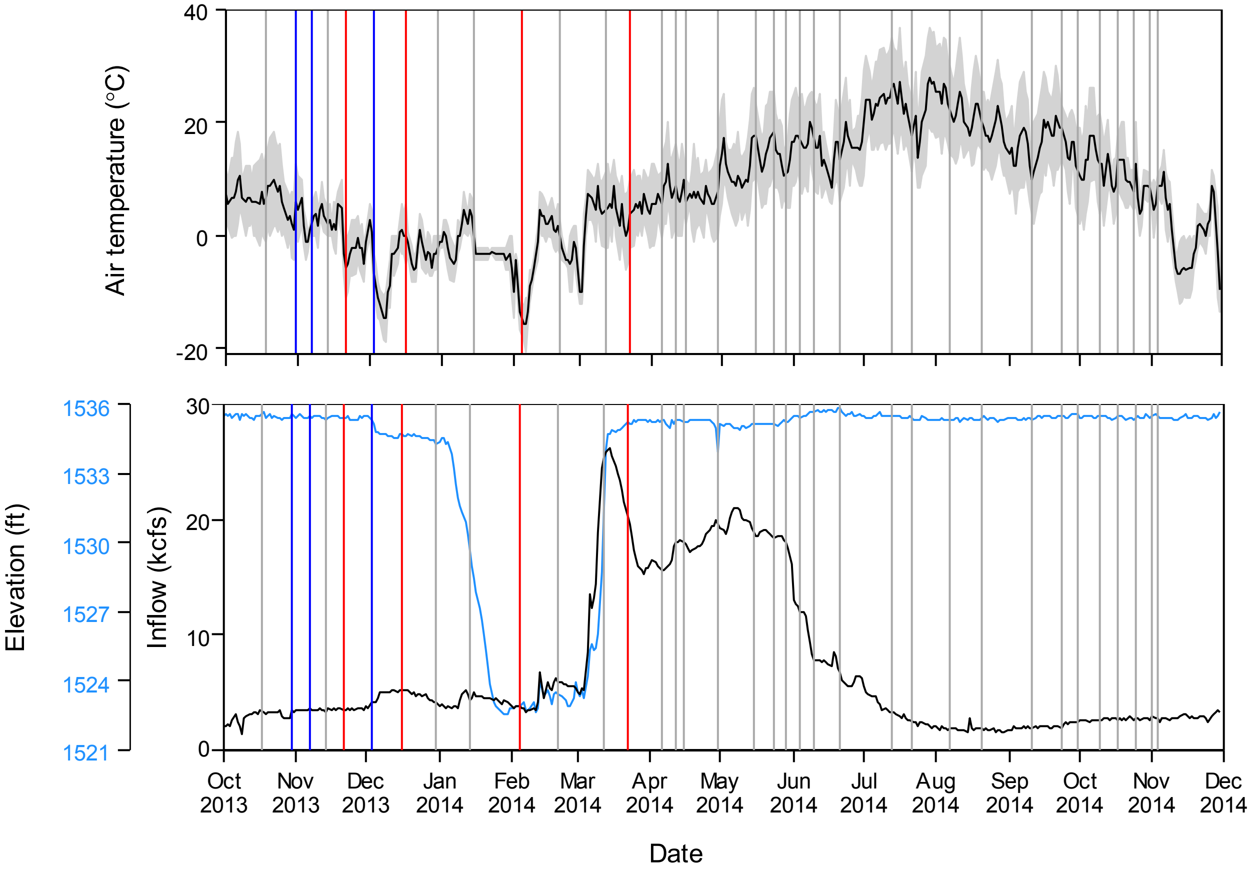

Figure 3-10. Time Series for Environmental Conditions with Relative CART-Tagged Carp Aggregation, 2013-2014 Study Period

Notes:

Spokane International Airport air temperature with daily average as black line and range as grey ribbon (top panel), and Lake Spokane inflow and elevation (bottom panel). Each vertical line represents a tracking session with its color indicating the maximum number of CART-tagged carp within 500 meters of one another. Grey lines represent <10 fish, blue lines are 10-15 fish, and red lines are >15 fish.

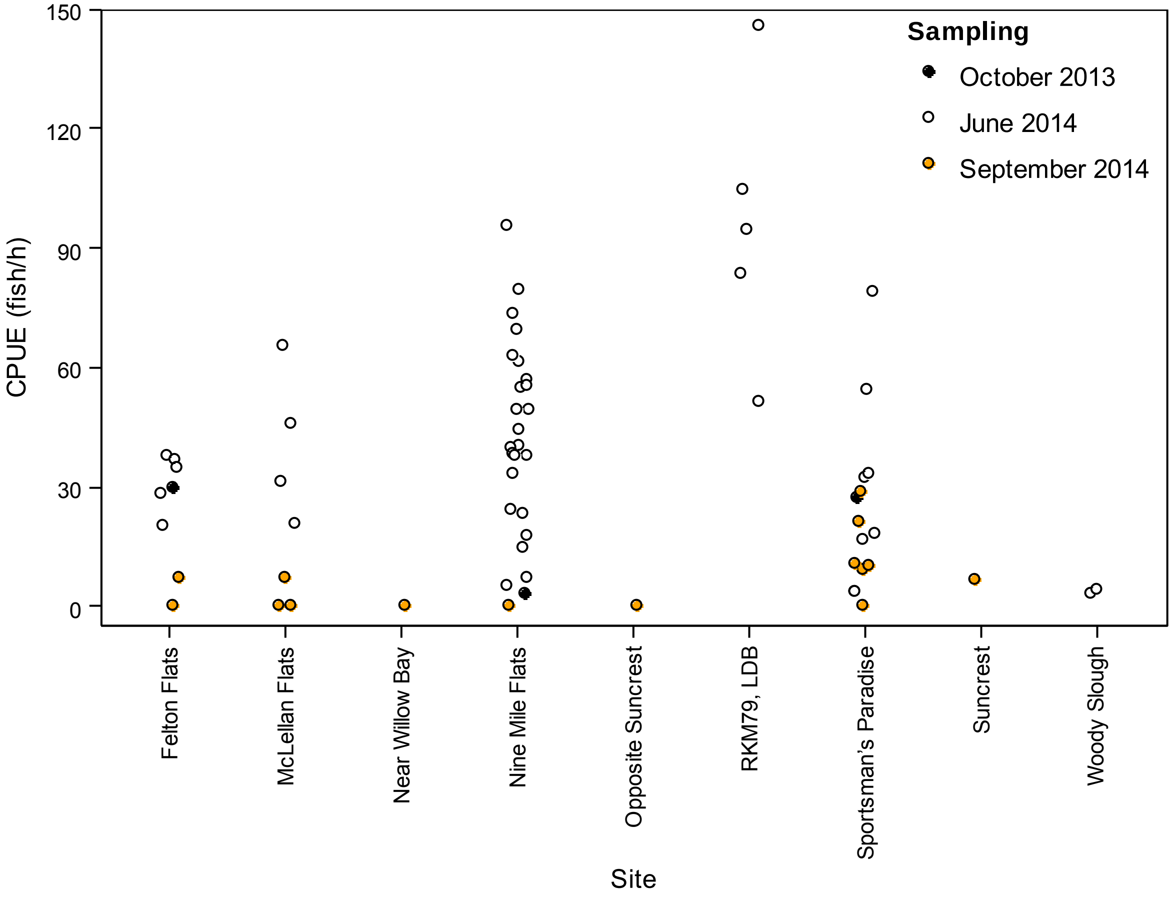

Figure 3-11. Catch per Unit Effort (CPUE) for Each Sampling Site and Period, 2013-2014 Study Period

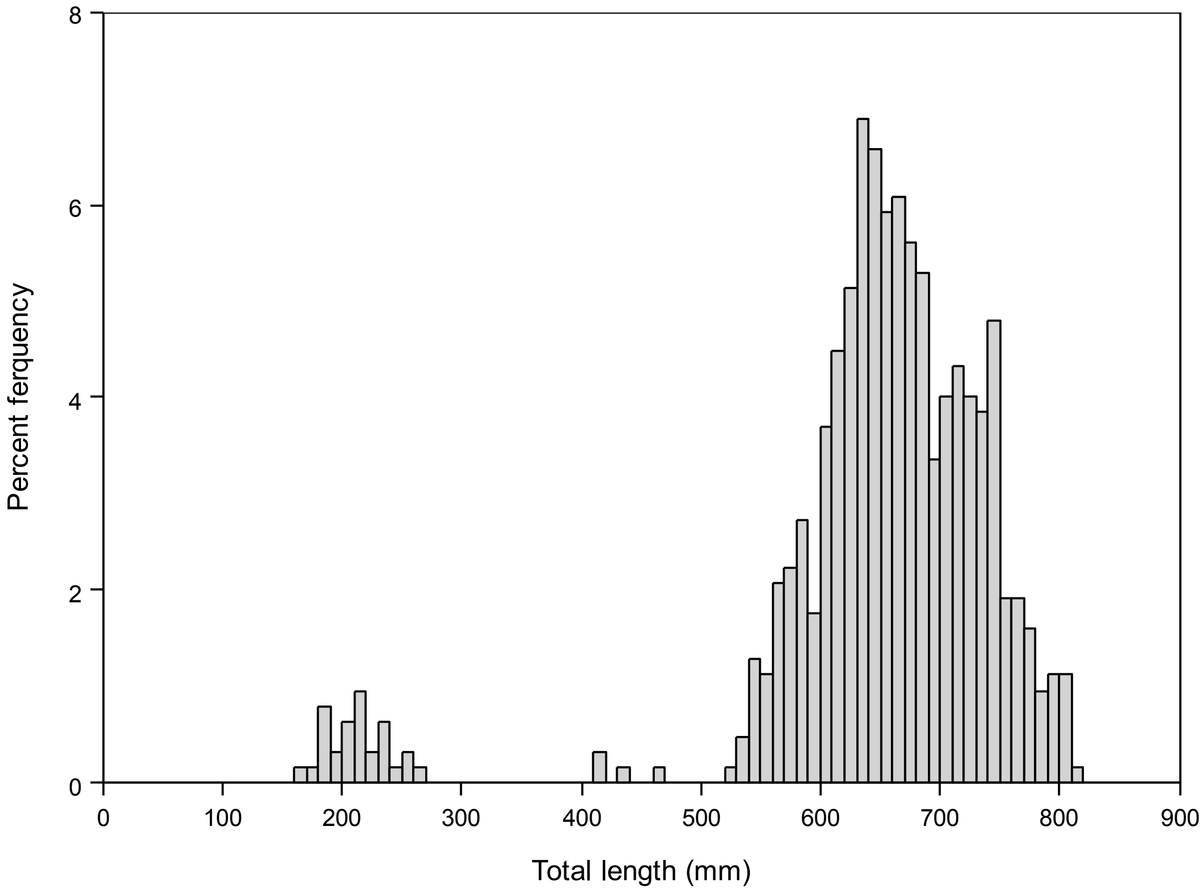

Figure 3-12. Carp Length-Frequency Distribution

Notes:

Length-frequency distribution is for the 624 carp sampled for length in June 2014.

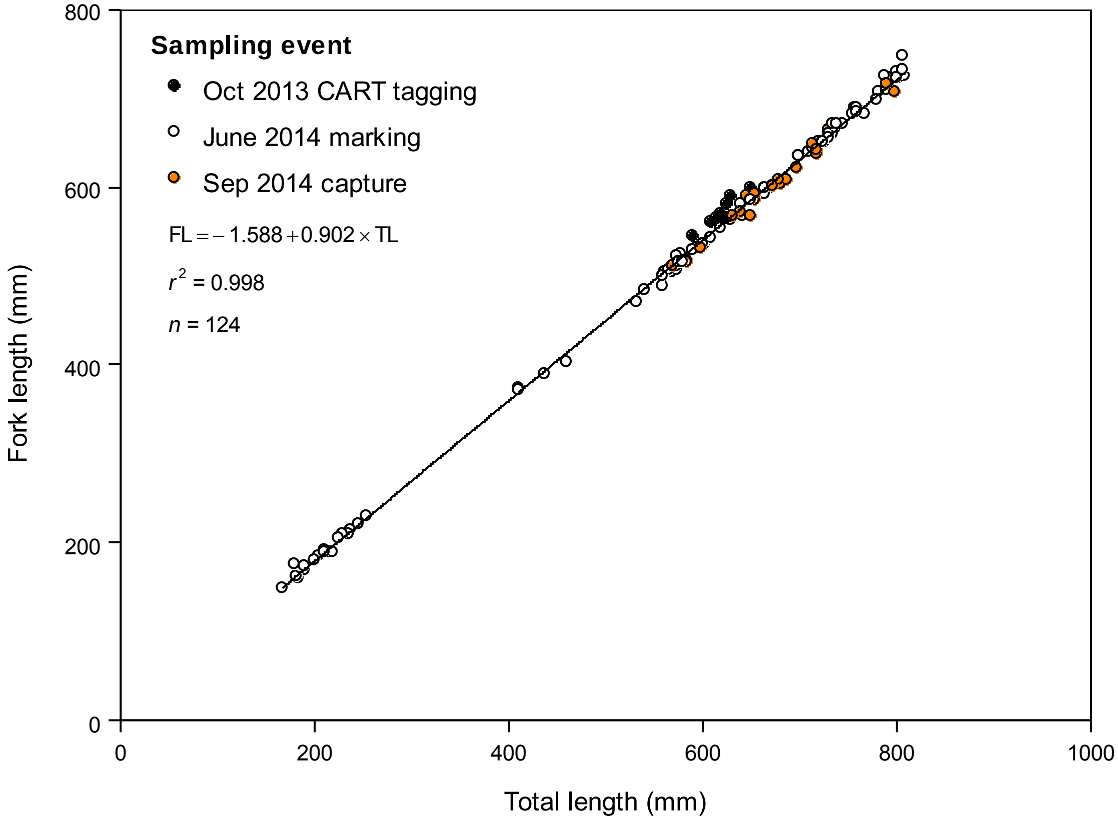

Figure 3-13. Carp Fork Length-Total Length Relationship, 2013-2014 Study Period

Note: The regression line is shown along with r^2 value and number of fish.

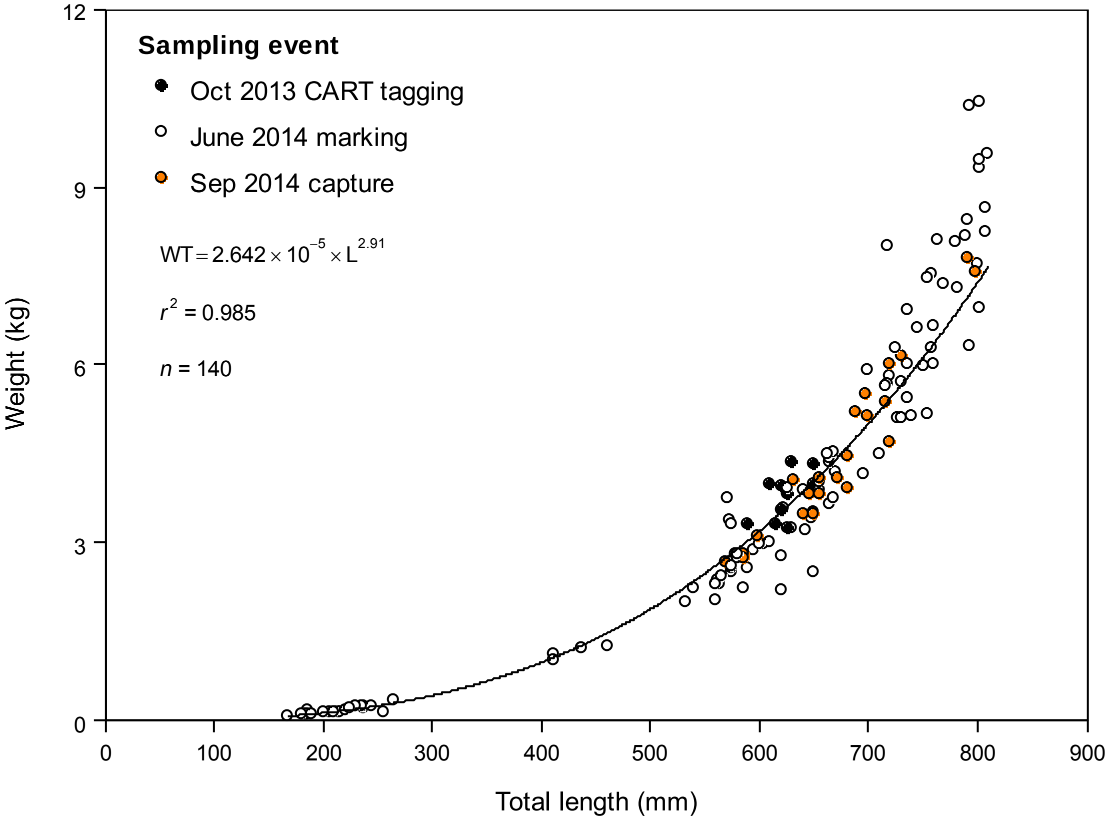

Figure 3-14. Carp Weight-Total Length Relationship, 2013-2014 Study Period

Notes:

The regression line is shown, together with r^2 value and number of fish.

In October 2013, the scale used had a maximum capacity of 5 kg, so carp weighing > 5 kg were recorded as “> 5000 g” and were omitted from this graph.

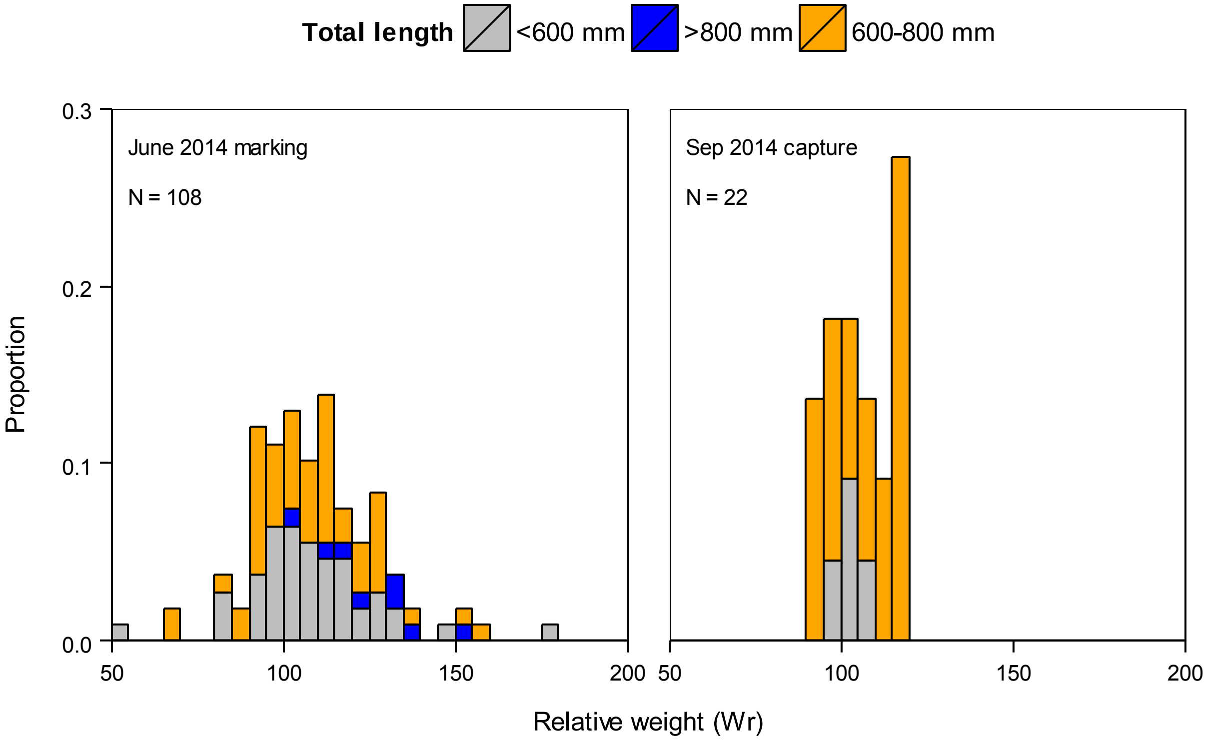

Figure 3-15. Histograms of Relative Weights, Estimated for June and September 2014 Sampling Periods by Total-Length Categories

Note:

> Separate panels are provided for carp captured in June and September of 2014, and the number of carp used for each sampling period is provided.

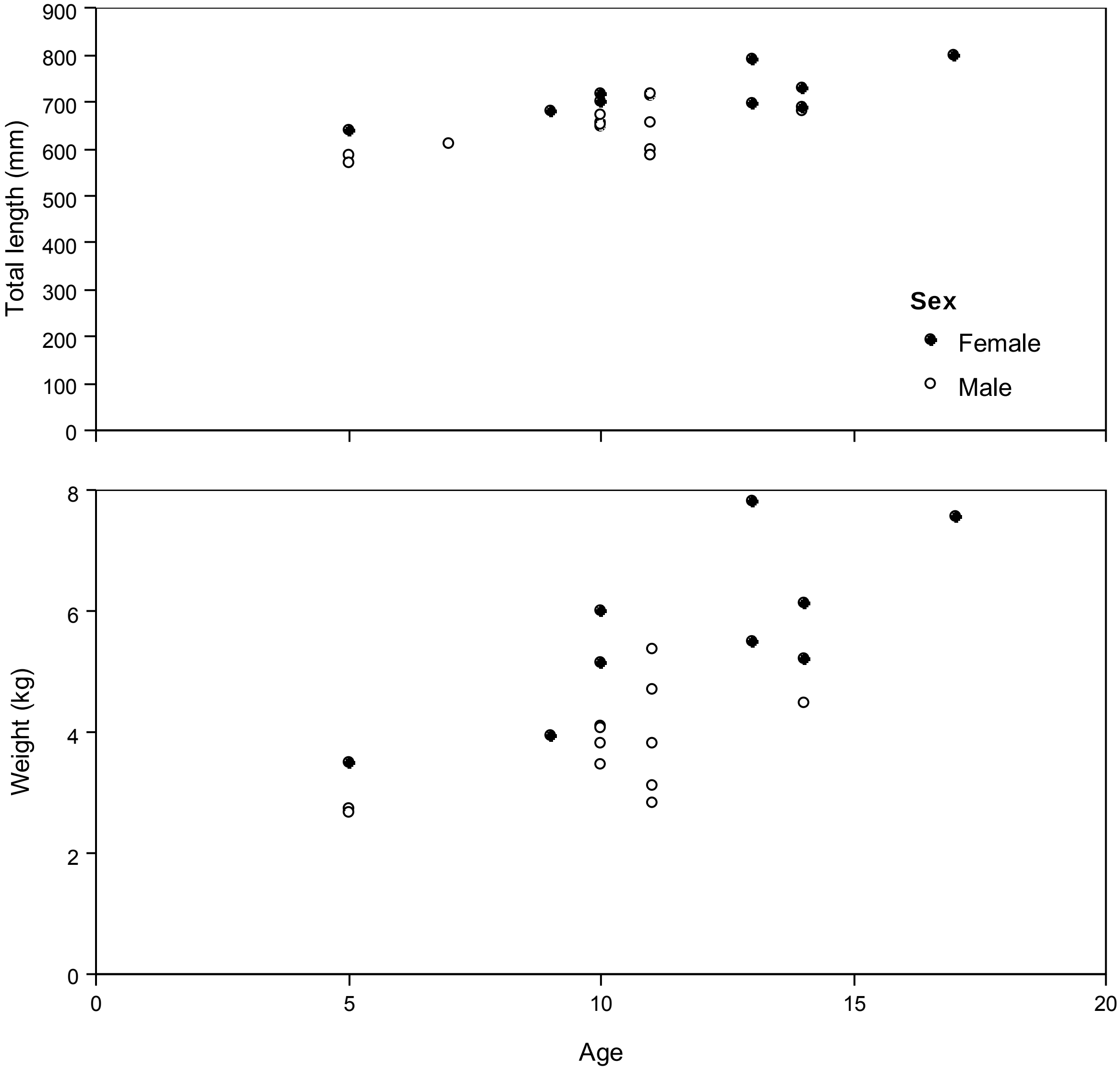

Figure 3-16. Carp Length-at-Age (top) and Carp Weight-at-Age (bottom)

Notes:

Age of carp is based on dorsal spine samples collected in September 2014.

ATTACHMENT A

SUMMARY OF CART TAG DETECTIONS

Table A-1. Summary of CART tag detections, by Tracking Session

# of Sessions Detected	% of Sessions Detected	RMK Min	RKM Max	Tag Code	Fork Length (mm)	10/30/13	11/6/13	11/13/13	11/21/13	12/3/13	12/16/13	12/30/13	1/14/14	2/4/14	2/20/14	3/12/2014	3/22/2014	4/5/2014	4/11/2014	4/15/2014	4/29/2014	5/15/2014	5/23/2014	5/28/2014	6/3/2014	6/9/2014	6/20/2014	7/12/2014	7/21/2014	8/6/2014	8/20/2014	9/10/2014	9/23/2014	9/30/2014	10/9/2014	10/17/2014	10/24/2014	10/31/2014	11/3/2014
31	91%	79.1	87.5	**11**	625	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
33	97%	79.4	87.0	**12**	565	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
30	88%	78.4	83.3	**13**	595	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	Yes	Yes	Yes	Yes	Yes
23	68%	79.4	87.5	**14**	560	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	No	No
33	97%	79.4	85.1	**15**	580	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
31	91%	77.4	80.0	**16**	565	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Yes
32	94%	72.5	79.9	**17**	570	No	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
31	91%	77.7	80.8	**18**	585	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
18	53%	77.7	80.0	**19**	705	No	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No	No	No	No	Yes	No	Yes	Yes	No	No	Yes	Yes	Yes	No	Yes	No	No	Yes	No	No
20	59%	77.8	80.0	**20**	680	No	No	No	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	Yes	Yes	No	Yes	No	Yes	No	No	No	No	Yes	Yes	Yes	Yes	No	Yes
28	82%	77.9	81.7	**21**	700	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
30	88%	79.3	85.1	**22**	600	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No
34	100%	79.1	81.7	**23**	560	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
34	100%	79.3	83.4	**24**	650	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
33	97%	79.2	81.1	**25**	590	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
33	97%	79.4	81.5	**26**	630	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
33	97%	79.4	83.2	**27**	615	Yes	Yes.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
33	97%	78.8	83.1	**28**	545	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
31	91%	79.4	80.9	**29**	595	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Yes	No	Yes	Yes	Yes
22	65%	78.7	83.7	**30**	640	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	No	No	No	No	No
																				Sup.			Sup.		Sup.			Sup.					Sup.						
593	**N/A**			**Total # Detected**	**N/A**	**15**	**18**	**16**	**19**	**19**	**20**	**17**	**19**	**20**	**20**	**20**	**20**	**17**	**19**	**17**	**18**	**18**	**16**	**20**	**17**	**19**	**20**	**17**	**17**	**18**	**17**	**15**	**13**	**16**	**17**	**16**	**16**	**14**	**14**
N/A	87%			**% Detected**	**N/A**	**75%**	**90%**	**80%**	**95%**	**95%**	**100%**	**85%**	**95%**	**100%**	**100%**	**100%**	**100%**	**85%**	**95%**	**85%**	**90%**	**90%**	**80%**	**100%**	**85%**	**95%**	**100%**	**85%**	**85%**	**90%**	**85%**	**75%**	**65%**	**80%**	**85%**	**80%**	**80%**	**70%**	**70%**
				Warning Level	**N/A**	Y	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	Y	Y	G	G	G	G	Y	Y
				RKM Min	77.6	78.3	74.5	72.5	79.2	79.3	79.4	79.1	74.0	79.4	73.6	73.6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
				RKM Max	87.5	79.8	81.5	81.4	79.6	85.1	82.3	85.1	84.1	83.4	84.2	83.9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Notes:

1. Red highlighted cells indicate latitude or longitude within 23 meters of previous detected locatior
2. Sup. Indicates supplemental tracking conducted solely by Avista
3. Fork length measured on October 17, 2013.

Table A-2. Summary of depth to Bottom for CART tag detections, by Tracking Session

# of Sessions Measured	% of Sessions Measured	Tag Code	Fork Length (mm)	10/30/13	11/06/13	11/13/13	11/21/13	12/03/13	12/16/13	12/30/13	01/14/14	2/4/2014	2/20/2014	3/12/2014	3/22/2014	4/5/2014	4/11/2014	4/15/2014	4/29/2014	5/15/2014	5/23/2014	5/28/2014	6/3/2014	6/9/2014	6/20/2014	7/12/2014	7/21/2014	8/6/2014	8/20/2014	9/10/2014	9/23/2014	9/30/2014	10/9/2014	10/17/2014	10/24/2014	10/31/2014	11/3/2014
20	77%	**11**	625	N/A	11.6	N/A	N/A	9.6	14	8	7.6	12.2	N/A	N/A	3.9	7	4.7	N/A	4.8	4.2	4.63	4.9	2.74	2.5	2	5.15	6.1	4.3	3.7	5.79	N/A	4	2.2	1.3	5.9	4.6	7.7
23	88%	**12**	565	9	N/A	9.2	9.4	9.6	12	2.7	7	12.2	7.0	2.4	N/A	8.0	6.5	3.6	5.7	4.5	2.7	1.6	N/A	0.5	1.0	4.1	0.7	1.4	2.1	1.8	5.5	1.1	1.2	1.5	4.4	4.6	7.7
24	92%	**13**	595	N/A	7	6.9	9.4	8.1	15	8.6	5.6	12.2	N/A	4.9	4.0	7.5	9.1	9.8	4.8	4.4	6.7	11.5	2.4	1.8	6.0	3.9	4.7	4.3	2.4	N/A	N/A	N/A	2.7	2.4	2.7	4.3	7.7
20	77%	**14**	560	7.5	8	N/A	9.4	9.6	12	N/A	7	9.1	N/A	2.4	N/A	5.4	6.6	5.4	2.5	3.5	3.2	1.1	N/A	0.7	1.5	2.7	2.3	2.6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
22	85%	**15**	580	N/A	8	9.2	9.4	N/A	9.9	7	2.1	12.2	N/A	3.0	3.9	6.7	7.3	N/A	5.0	5.3	1.5	0.8	2.7	0.5	0.5	1.6	1.8	1.3	5.9	2.1	3.4	3.5	6.2	1.7	6.5	N/A	10.4
21	81%	**16**	565	N/A	N/A	9.2	9.4	9.6	12	14.9	5.7	12.2	N/A	N/A	2.0	6.2	9.1	N/A	3.8	7.9	16.2	2.6	2.2	8.3	0.5	1.5	3.6	2.3	0.8	3.4	4.3	1.1	2.0	1.2	N/A	N/A	10.4
22	85%	**17**	570	N/A	8	9	9.4	10.5	13.7	N/A	8.5	12.2	N/A	3.4	N/A	6.2	6.6	4.7	7.4	7.9	12.8	15.7	2.2	1.3	0.8	10.0	0.8	1.3	2.3	3.7	3.0	2.5	7.5	2.3	5.3	4.7	21.0
22	85%	**18**	585	3	N/A	8.2	N/A	5.2	12	14.9	4	12.2	N/A	3.0	3.9	1.2	4.7	4.4	0.9	14.4	N/A	7.4	2.7	0.6	1.7	3.9	6.1	3.2	2.5	6.4	2.4	4.6	1.2	3.2	2.2	1.5	N/A
14	54%	**19**	705	N/A	6	N/A	N/A	9.8	12	12.6	12	12.2	4.9	3.0	3.9	N/A	N/A	N/A	N/A	N/A	N/A	17.8	N/A	3.7	4.0	N/A	N/A	3.2	2.2	4.3	N/A	2.6	N/A	N/A	N/A	N/A	N/A
11	42%	**20**	680	N/A	N/A	N/A	9.5	9.6	12	14.9	N/A	12.2	N/A	N/A	4.9	N/A	N/A	7.3	N/A	N/A	N/A	15.1	2.8	N/A	2.6	N/A	12.1	N/A	N/A	N/A	N/A	20.7	5.0	7.0	6.6	N/A	10.4
18	69%	**21**	700	N/A	N/A	10	9.4	N/A	12	9.2	8.8	12.2	N/A	3.4	2.4	N/A	N/A	N/A	9.7	12.5	N/A	2.6	2.2	0.6	4.1	1.8	3.8	3.7	3.1	N/A	3.0	7.2	4.2	2.3	3.5	4.2	14.0
23	88%	**22**	600	7.3	6	N/A	9.4	7.6	9.9	7	4.6	12.2	3.7	N/A	5.5	5.1	4.4	4.5	8.1	4.0	1.4	3.4	2.7	0.7	1.0	4.3	N/A	1.4	4.2	6.1	2.4	4.7	4.4	N/A	N/A	6.8	N/A
22	85%	**23**	560	N/A	N/A	N/A	9.4	10.5	15	9.2	7	12.2	N/A	3.4	3.9	6.7	7.5	4.8	8.4	6.2	2.6	2.8	1.5	1.0	1.5	4.7	4.8	4.2	1.7	5.2	4.0	2.9	2.4	6.7	3.4	4.6	14.0
23	88%	**24**	650	N/A	6	8	9.4	8.2	15	9	5	12.2	N/A	2.4	3.9	9.1	4.8	N/A	7.1	4.5	6.2	5.0	2.7	4.9	3.7	4.5	1.2	3.7	3.3	5.8	4.3	3.0	4.4	2.7	5.6	4.7	7.7
23	88%	**25**	590	N/A	8	9.2	9.4	10.5	12	14.9	4	12.2	N/A	3.0	4.5	N/A	10.2	5.5	8.4	4.1	2.7	0.9	1.5	3.7	0.9	3.9	13.2	16.2	5.0	6.4	3.0	3.6	1.2	20.0	2.2	4.6	7.7
21	81%	**26**	630	N/A	N/A	N/A	9.4	14	9.7	N/A	7	12.2	N/A	3.0	2.0	8.7	6.9	8.2	7.3	2.4	4.6	8.6	4.9	10.1	4.1	6.6	1.0	8.6	5.1	5.5	3.0	3.1	1.2	3.4	8.4	9.2	14.0
24	92%	**27**	615	N/A	N/A	7.2	9.4	9	12	8.4	6.6	12.2	4.0	6.4	3.9	3.8	8.6	5.2	8.6	10.0	5.0	4.2	2.7	0.9	2.5	4.7	8.1	2.7	7.8	6.4	2.7	1.2	3.6	2.1	4.0	4.4	7.7
25	96%	**28**	545	N/A	6	8	10	9.6	12	14.9	12	12.2	4.0	3.4	3.6	1.2	5.3	4.7	4.2	4.6	6.7	4.4	2.7	0.8	1.2	2.2	1.1	0.7	1.2	1.8	2.4	1.6	1.6	0.9	1.4	1.1	N/A
24	92%	**29**	595	N/A	8	7.2	9.4	9.6	12	8	4	12.2	N/A	3.4	3.9	4.6	5.4	5.5	0.9	3.3	5.2	7.6	2.7	1.8	2.4	3.4	5.2	2.9	2.9	3.0	N/A	N/A	N/A	N/A	8.2	8.4	9.8
21	81%	**30**	640	N/A	6	8.2	9.4	9.6	12	14.9	4.6	12.2	7.0	3.7	4.1	5.5	7.7	8.4	0.9	4.1	3.0	4.3	2.7	1.1	6.6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
																		Sup.			Sup.		Sup.	Sup.		Sup.					Sup.						
		Total # Measured	N/A	4	12	13	17	18	20	17	19	20	6.0	16	17	16	17	14	18	18	16	20	17	19	20	17	17	18	17	15	13	16	16	15	15	14	14
		Min	N/A	3.0	6.0	6.9	9.4	5.2	9.7	2.7	2.1	9.1	3.7	2.4	2.0	1.2	4.4	3.6	0.9	2.4	1.4	0.8	1.5	0.5	0.5	1.5	0.7	0.7	0.8	1.8	2.4	1.1	1.2	0.9	1.4	1.1	7.7
		25%	N/A	4.1	6.0	7.6	9.4	8.8	12.0	8.0	4.6	12.2	3.9	3.0	3.8	4.7	5.1	4.7	3.5	4.1	2.7	2.6	2.2	0.7	1.0	2.5	1.2	1.4	2.2	3.0	2.6	1.8	1.3	1.5	2.7	4.3	7.7
		50%	N/A	7.4	7.5	8.2	9.4	9.6	12.0	9.2	6.6	12.2	4.4	3.2	3.9	6.2	6.6	5.3	5.4	4.5	4.6	4.4	2.7	1.1	1.9	3.9	3.8	3.1	2.9	5.2	3.0	3.1	2.6	2.3	4.4	4.6	10.1
		75%	N/A	8.6	8.0	9.2	9.4	10.0	13.3	14.9	7.6	12.2	7.0	3.4	4.1	7.4	8.2	7.5	8.2	7.9	6.6	8.4	2.7	3.7	3.9	4.7	6.1	4.2	4.6	6.1	4.1	4.5	4.4	3.4	6.5	5.2	14.0
		Max	N/A	9.0	11.6	10.0	10.0	14.0	15.0	14.9	12.0	12.2	7.0	6.4	5.5	9.1	10.2	9.8	9.7	14.4	16.2	17.8	4.9	10.1	6.6	10.0	13.2	16.2	7.8	6.4	5.5	20.7	7.5	20.0	8.4	9.2	21.0

Notes:

1. Sup. Indicates supplemental tracking conducted solely by Avista.
2. Fork length measured on October 17, 2013.

APPENDIX C

Phase II Analysis Carp Harvest Potential in Lake Spokane (Horner 2015)

Phase II Analysis
Carp Harvest Potential in Lake Spokane

Prepared for

Avista

Prepared by

Ned Horner, LLC

January 2015

1.0 OVERVIEW

This report includes a Phase II Analysis which evaluates the feasibility of carp harvesting methods and provides the technical and economical practicality for each removal method, along with the expected reduction in phosphorus mass. The results of the evaluation and recommendations for a carp removal method(s) to implement in Lake Spokane are also included.

2.0 EVALUATION OF CARP HARVESTING METHODS

Chemical, biological and mechanical methods have been used with varying success to reduce carp densities to improve water quality and fisheries. Chemical methods would include attractants and the use of piscicides. Additionally, bait has been used to attract carp for angling, or to areas where traps or piscicides can be utilized to catch or kill carp. A variety of baits attract carp including vitalin (a type of dog food), cat food, chicken feed or other bird seed mixes, barley, chick peas, maize, groats, hemp, bread or bread crumbs and corn. Sweet corn or deer corn is one of the most effective, readily available and inexpensive attractant baits used. At Malheur Lake, corn is used to bait carp into trap net locations by placing the corn in a feed sack and staking the sack to the bottom with a fence post (personal communication, Linda Beck, USFWS). Attempts to infuse carp bait with rotenone to kill feeding carp directly once the fish have become accustom to the bait has not worked (Bonneau and Scarnecchia 2001).

2.1 Chemical Methods

The most common chemical or piscicide used since the 1940s to manage nuisance fish species is rotenone (O’Donnell 1943; Weier and Starr 1950). Rotenone has been use to treat entire bodies of water where replacement of one fish assemblage by another is the goal. Selective treatment of coves and spawning tributaries has been used to eliminate high densities of carp with minimal impact to desirable species (Bonneau et al. 1995). Rotenone kills fish by blocking the uptake of oxygen in the gills, so non-target fish species within the area of application are also affected. Rotenone is typically applied as a 5% liquid formulation at a rate of 0.33 to 0.66 gallon/acre foot to effectively kill carp (Whetstone et al. 2001), but high biological activity associated with dense aquatic vegetation can require higher concentrations. The cost of liquid rotenone for fish management agencies was $62/gallon in 2013 (personal communication, Jim Fredericks, Regional Fishery Manager, IDFG). Assuming a typical Lake Spokane carp spawning area was 50+ acres and up to 2 meters (m) deep (equates to about 350 acre foot) treated at the higher rate of 0.66 gallon/acre foot, the cost for the rotenone alone would be about $14,000 for a 50 acre site. The use of rotenone in Washington waters requires obtainment of a National Pollutant Discharge Elimination System (NPDES) permit through the Washington Department of Ecology (Ecology) and adherence to a lengthy checklist to comply with Washington Department of Fish and Wildlife (WDFW) requirements (personal communication, Randal Osborne, Fisheries Biologist, WDFW). Fish killed by rotenone often sink and are not recoverable. The use of rotenone to remove carp from Lake Spokane will not be considered as a tool for phosphorus reduction due to the potentially high cost, non-target mortality of desirable fish species and undesirable effect of nutrient release from carp that could not be recovered.

2.2 Biological Methods

Biological methods of carp reduction focus on disrupting carp recruitment. Water level manipulation (drawdown after carp have spawned) (Summerfelt 1999) and exclosures to limit access to spawning habitat (Lougheed and Chow-Fraser 2001) have been used in some areas to reduce spawning success. Lake Spokane is typically drawn down during the winter months (January and February), but this drawdown occurs too early in the year to disrupt carp spawning that occurs in the spring. Carp spawning in Lake Spokane in 2014 started in mid-May, peaked in June and was essentially over by mid July. Spawning occurred in many diverse locations throughout the upper half of the reservoir (**Figure 1**), primarily associated with depths less than 2 m and dense aquatic macrophytes beds (primarily yellow floating heart). Warmwater game fish species like large and smallmouth bass, crappie and pumpkinseed sunfish could also be spawning during the carp spawning time frame. Drawdown during the spring spawning period, or exclosures to prevent carp from spawning in shallow aquatic vegetation would likely have negative impacts on game fish species. A spring drawdown would also require FERC approval.

Biological carp control can occur through predation of carp at both the egg stage and as juveniles. Sampling of carp in Lake Spokane in 2014 captured primarily large fish with very few small carp. Dominant carp year classes can result from winter hypoxia conditions that kill off populations of cyprinids (typically bluegill and other sunfish) that are very effective predators on carp eggs (Bajer et al. 2012). However, ages from the Lake Spokane carp ranged from age 5 to age 17 indicating successful spawning over multiple years rather than one or two dominant year classes. However, the small number of fish aged is too small to draw meaningful conclusions about the dynamics of this population. The high reproductive potential of carp (10,000 eggs per pound) and the lack of a diverse cyprinid population in Lake Spokane likely mean that carp recruitment will be successful even if the adult segment of the population were reduced.

The success of predation as a control agent on juvenile carp depends on predators consuming carp as a major part of their diet (Paukert et al. 2003; Ward et al. 2008), the biomass of the predator population, and predator and prey body size (Skov and Nilsson 2007). Rapid growth of juvenile carp and the ability of carp to reach large sizes minimizes their vulnerability to predation (Carlander 1969; Crivelli 1983). Pumpkinseed sunfish, largemouth bass, smallmouth bass, northern pike and walleye are present in Lake Spokane, but not likely at densities to limit carp recruitment through predation on carp eggs or juveniles. The use of existing or new fish predators to reduce carp numbers in Lake Spokane would not achieve Avista’s goal of phosphorus removal.

2.3 Mechanical Methods

Mechanical methods such as seines, gill nets, trap nets, trawling, electrofishing and angling provide the greatest chance of achieving the objective of removing carp from Lake Spokane with minimal impacts to non-target species. Commercial fisheries are frequently utilized to manage carp populations (Fritz 1987), but the low price for carp and lack of markets limits harvest (Wydoski and Wiley 1999). Commercial fishermen from the Midwest utilize primarily large seines (up to over a km long) to target winter aggregations of common carp. One of the most ambitious carp reduction projects currently underway is in Utah Lake, Utah, as part of a June sucker recovery program (USFWS 2010). The goal is to remove 5 million pounds of carp over a 6 year period with commercial gear, primarily large seines. Commercial fishermen (Loy Fisheries) have been contracted to seine carp 120 days a year, utilizing both boats and under ice techniques. The seines are several hundred meters long, approximately 6 m tall and require two to three boats with a four person crew to set, retrieve and handle fish. Under ice seining is accomplished with the use of a submarine to pull haul ropes between holes cut in the ice to set the net and winches to haul and bag the seine in a larger opening in the ice. Captured carp are removed with a tractor mounted dip net and hauled away in trailers. Netting contractors are paid 20 cents per pound for carp removed. Limited numbers of carp have been used for compost and mink food, while the majority have been hauled to the landfill.

2.3.1 Active Mechanical Methods

Trawling

Trawling for carp is an active mechanical method primarily used as a research tool to assess recruitment and age class composition. Catch per unit effort (CPUE) is typically low for trawls and this method would not be recommended for carp harvest on Lake Spokane.

Electrofishing

Electrofishing is an active mechanical method that can be very effective at collecting carp during the spring spawning period when carp are shallow and aggregated. However, electrofishing catch rates are typically highly variable (personal communication, Dr. Mike Quist, Assistant Coop Unit Leader, University of Idaho, Moscow) and ranged from 0 to 146 carp/hr on Lake Spokane (Golder 2015). The capture range of the electrofishing boat is typically restricted to within a meter or so of the electrical field and is greatly influenced by water conductivity. Electrofishing boats are commonly used by state and federal fishery management or research agencies, Tribes, consulting firms and utilities conducting research, but this is not a gear type typically used by commercial fishermen. An electrofishing crew consist of a minimum of four persons; two netters up front, one person to drive the boat and operate the electronics (generator and VVP unit), and an assistant to help transfer fish from the netters to a tank. A new Smith Root electrofishing boat equipped to fish would cost in the range of $60,000 to over $90,000 (http://www.smith-root.com/electrofishers/boats/). Due to the inherent danger of utilizing high voltage equipment in and around water, good equipment, maintenance and proper training are essential to reduce the risk of injury to both people and fish.

Angling

Angling (rod and reel, archery and spearing) is another active mechanical method currently occurring on Lake Spokane and is used to harvest nuisance species, but not typically at a level that would affect population abundance. A bounty of $15/fish was required to entice anglers to harvest lake trout from Lake Pend Oreille. Contract gill and trap netting that specifically targeted both adult and juvenile lake trout was required in addition to angler harvest to increase exploitation to achieve population reduction. Carp are notoriously difficult to catch on rod and reel. Carp are most vulnerable to archers and spear fishermen during the spring spawning period, but the number of archers and the effectiveness of that technique is unlikely to result in any meaningful population reduction without a significant monetary incentive.

2.3.2 Passive Mechanical Methods

Passive gear types can be set and fished without constant attention by personnel. Gill nets and trammel nets (a type of gill net) have been used by state agencies for research (index netting) and commercial fishermen to harvest common carp in both large rivers and lakes. The length, height, mesh size and twine type (monofilament versus other fabrics) and thickness can be tailored to the site specific conditions (water depth, clarity, size of fish, etc.) to maximize capture of carp while minimizing bycatch and mortality of non-target fish species. Trammel nets are constructed in a way that captures a wide variety of fish sizes and reduces gilling mortality. Essentially, a trammel net is three layers of netting tied together on a common floatline and common leadline. The two outer layers of netting (known as walls or brails) are constructed out of large mesh netting (30.5 to 46 centimeters [cm] square) with a twine size of #9 multifilament nylon or .81 to .90 millimeter (mm) monofilament. The light-weight or fine netting sandwiched between the two walls is usually small mesh multifilament or monofilament gill netting. Trammel nets have a large amount of lightweight gill netting hung in the nets, and fish will be caught by tangling in the excess netting. These efficient nets can be fished floating or sinking, and stationary or drifting (http://www.millernets.com/trammelnets.html). Although trammel nets reduce gilling loss of target and non-target species, the barbed dorsal and anal spines on carp tangle easily in the trammel nets making removal of carp difficult.

WDFW currently allows the use of trammel nets on Lake Spokane to harvest carp with specific conditions to reduce non-target bycatch mortality (mesh restrictions, constant surveillance and 2 hour maximum soak time). The WDFW approved trammel nets have much smaller net mesh sizes (outside panels of 12 inch [in], or 30.5 cm stretch mesh (about a 6 in or 15 cm square mesh) and a 5.5 in (14 cm) stretch mesh for the inside panel (about 2.5 in or 6.4 cm square mesh) than described by Miller Net Company.

Trap nets, hoop nets and fyke nets are a type of live capture gear that can be set, fished and emptied at intervals. The success of trap nets for harvesting carp would depend on tailoring the type (floating versus sinking), size and location of the trap net to intercept migrating carp. Mortality and bycatch of non-target species is typically very low, with an occasional gilling of small fish in the leads or trap mesh material. A typical trap net consists of underwater fences (leads and wings) constructed of thick, small mesh material that acts as a visual barrier to guide migrating fish into a series of funnels that trap the fish. The hoop or trap portion is lifted and emptied of fish and then reset in the same location. The height of the wings and leads and diameter of the funnel hoops (typically 1-2 m) are tailored to the depth of the water fished, the behavior of the fish, and the number of fish to be trapped.

One limitation of passive gear (gill, trammel and trap nets) is that carp appear to learn quickly to avoid passive gear once they have been exposed to it. Clear water can also limit the effectiveness of passive gear as it is easier to detect and avoid when seen by fish. Baiting to attract carp to the site where gear is fished and driving or herding carp into the nets with noise can increase catch rates of passive gear.

3.0 LAKE SPOKANE SPECIFIC HARVEST OPTIONS

This section will discuss carp harvest methods most suitable to Lake Spokane based on the data collected for the Phase I Analysis, the technical and economic practicality for each removal method, and the expected reduction in phosphorus mass.

3.1 Winter Seining

Carp have been documented to aggregate in deeper offshore areas during the winter (Penne and Peirce 2012; Otis and Weber 1982; Garcı´a-Berthou 2001). Winter temperatures of below 8°C were correlated with carp aggregations in Lake Mendota, Wisconsin (Johnson and Hasler 1977) and Clear Lake, Iowa (Penne and Peirce 2012). The preferred time for commercial seining of carp is during the winter under the ice when carp are highly aggregated and vulnerable to harvest (personal communication, Jeff Riedemann, JR Commercial Fish).

The carp telemetry data for Lake Spokane indicate that carp aggregate during the winter months (November through March) when water temperatures recorded by Ecology at their Spokane River at Nine Mile Bridge Station (54A090) ranged from 8.4°C to 3.7°C in an area of the reservoir adjacent to Sportsman's Paradise (River Kilometer [RKM] 79 to 81.5). Depth of where carp were aggregating during the winter months is not known precisely, but water depths recorded for the presumed location of the tagged carp indicate fish may be aggregating at depths from about 1.5 m (5 feet [ft]) to over 12 m (40 ft). No attempts were made to locate tagged carp more precisely with acoustic gear and large aggregations of carp associated with tagged fish were not observed on the bottom with sonar (fish finder) or with an underwater camera.

The preference of carp to be associated with the Sportsman's Paradise area of Lake Spokane was pronounced during all times of the year, but especially strong during the winter months. The majority of tagged carp (16 of 20, 19 of 20 and 18 of 20) were located near Sportsman's Paradise during the November 6, November 21 and December 16, 2013 tracking events, respectively, in water depths that were typically 3 m to over 12 m deep (**Figure 2**). Carp were more widely dispersed during the January 14, 2014 tracking event when only five of 19 carp tags were detected near Sportsman's Paradise. Nineteen of 20 tagged carp were again tightly aggregated in one location off Sportsman's Paradise in approximately 29 feet of water on February 4, 2014. However, on February 20, 2014, carp had again dispersed both up and downstream and only nine fish were associated with Sportsman's Paradise. During March, 13 and 19 of the tagged fish were located near Sportsman's Paradise on March 12 and 22, respectively.

It appears that winter drawdown of Lake Spokane results in carp moving both up and downstream as water levels change, but that the Sportsman's Paradise area is a preferred winter aggregation area so long as water levels are relatively stable regardless of the winter pool elevation. In 2014, winter drawdown occurred between January 4 and March 13, with a maximum drawdown of 4.1 m (13.4 ft) reached on January 29 and 30. The largest aggregations of tagged carp occurred during tracking dates of 11/6, 11/21, 12/16, 2/4 and 3/22 when water levels were cold and stable. Tagged carp were more dispersed when the water elevation was decreasing (1/14) or increasing (2/21 and 3/12).

Winter aggregations of carp in Lake Spokane may provide an opportunity to harvest large numbers of carp in a relatively short amount of time with commercial seining gear. However, this effort should be guided by good telemetry data and a site visit from a commercial fisherman to determine both the feasibility and logistics of the effort. Seining operations have been conducted on Lake Lowell, Idaho and Malheur Lake, Oregon. The Lake Lowell effort (conducted by Jeff Riedemann of J R Commercial Fish) resulted in an initial capture of an estimated 400,000+ pounds of carp, but a snag tore the net during the retrieval process and few fish were ultimately captured. The Malheur Lake effort (conducted by Jeff Riedemann and USFWS) included two weeks of experimental seining in May of 2014. For this effort six areas totaling 235 hectares (ha) (580 arcres [ac]) were seined, and 6,797 carp were captured with an estimated weight of 54,596 lbs. One 34 ha (85 ac) site resulted in the capture of 4,782 carp. The cost of the Malheur Lake operation was $27,000 (personal communication, Jeff Riedemann, J R Commercial Fish).

For these efforts, large seines over a km long in length with depths of 12 m or more were used to target carp aggregations under the ice or with large (24-33 ft) flat bottom boats. Many nets can be strung together to tailor the seine to the specific site. Lake Spokane is unlikely to get thick enough ice for long enough, so boat seining will be required. Boats are equipped with hydraulic winches to pull the nets and the seines can be bagged either from operating off the shore, or from anchored boats. Typical seine hauls from Midwest lakes can result in hundreds of thousands of pounds of fish, so efficient transferring of fish from the net to trucks is essential. Shoreline access for removing carp from the seine with a tractor mounted dip net and transferring carp to trucks with a conveyor belt is desired, but not essential. The biggest limitation to an efficient commercial seining operation is identifying the presence of aggregated carp and ensuring a snag free bottom. Telemetry studies can be used to identify likely aggregation areas and a boat mounted sonar unit to locate carp aggregations prior to setting nets. Snags can be identified with a good side scanning sonar unit. A typical seining operation would take two large boats and a minimum crew of 5-6 experienced people.

The number of carp captured in a short duration, high intensity commercial seining operation could be substantial. Carp from the spring sampling effort in 2014 averaged 4 kg. If 10,000 carp could be captured in a seining operation (typical seining efforts on known aggregations of carp yield catches of 200,000+ fish), 40,000 kg of carp could be removed in one effort.

Bycatch of non-target species in large seines is unknown, but would be greatly influenced by the mesh size of the seine. Larger mesh sizes would allow smaller fish than the target carp size to avoid capture. Live release of non-target species is the norm as carp are transferred from the bagged seine. Commercial carp fishermen from the Midwest typically target relatively large carp, 2.25 kg (5 lb), to meet buyer’s needs. Largescale suckers were the most common bycatch during carp sampling efforts in Lake Spokane, although warmwater game fish were also captured.

3.2 Spring Electrofishing

Carp are also well documented to utilize shallow vegetated areas before and during the spring spawning period (Penne and Peirce 2012; Otis and Weber 1982; Garcı´a-Berthou 2001). We documented carp spawning at eight locations associated with shallow (depths of 2 m or less), vegetated flats in Lake Spokane primarily during the month of June (Figure 2-9). Spawning activity appeared to correspond with a decrease in discharge and a corresponding increase in water temperature to about 15-16°C.

Carp were vulnerable to electrofishing during spring spawning, but catch rates were highly variable (Golder 2015). During the spring carp marking event in Lake Spokane, the mean catch rate for carp was 44 carp/hr (CPUE range of 3 carp/hr to146 carp/hr). Larger diameter dip nets and focusing efforts on carp concentrations will improve catch rates, as compared to the 2014 marking event. Assuming that a four person crew could achieve an average CPUE of 50 carp/hr and a fishing time of 8 hr/day, a minimum of 400 carp could be captured daily. If the electrofishing crew fished during the peak two weeks of the spawning season (middle two weeks in June), an estimate 4,000 to 5,000 carp, or 16,000-20,000 kg of carp could be removed with one four person crew.

The bycatch of game fish species was relatively low during the June electrofishing marking event. A few largemouth bass, smallmouth bass, walleye, black crappie, yellow perch and black bullhead were captured, but all were released alive. The shallow, turbid, weedy areas where carp prefer to spawn do not appear to be preferred habitat for game fish species. Spring electrofishing would be a good selective removal technique with minimal effects on game fish species.

Bycatch of adult largescale suckers was high, with numbers of suckers captured equal to or greater than the capture of carp. Adult tench were also encountered while electrofishing, but in far fewer numbers than carp or suckers. If WDFW approved removing adult largescale suckers and tench encountered during spring electrofishing for carp, the total biomass of fish removed for phosphorus reduction would increase significantly. If approved, suckers and tench would be analyzed for phosphorus content to determine the overall benefit in P removal.

3.3 Passive Netting

It appears that the majority of tagged carp locations were between RKM 77 and 84 regardless of the season and within that area, the Sportsman’s Paradise area of Lake Spokane (about RKM 79 to 82) was the most frequently utilized area of the reservoir (**Figure 1**). This area is characterized by a deep (12-18 m or 40-60 ft) thalwag that represents the old river channel and a large (approximately 2 km long by 0.5 km wide) shallower floodplain flat with depths of 3-5 m at full pool. When carp were dispersed from Sportsman’s Paradise, they were observed adjacent to other flooded flats like Willow Bay (RKM 74), Felton Slough (RKM 78-79), and the flats on both south and north banks around the Suncrest community (RKM 82-85). Telemetry locations were not precise enough to determine if the carp were using the flats or deeper areas adjacent to the flats. We also observed carp feeding on the surface film throughout the reservoir at different times of the year. Carp are very opportunistic feeders and surface feeding is not uncommon (personal communication, Dr. Mike Quist, Assistant Coop Unit Leader, University of Idaho, Moscow). Depths for setting passive gear should be guided by sonar locations of fish concentrations associated with known telemetry “hot spots”. WDFW would need to approve the specific gear type and conditions under which passive netting gear would be allowed.

The most efficient use of passive netting may be to fish strategically placed gill nets or trammel in shallow spawning areas while simultaneously electrofishing. Carp are notorious for avoiding passive gear once they have encountered it. CPUE could be enhanced due to the relatively turbid water where carp are actively spawning, constantly moving carp, and the effect of electrofishing activity driving carp into the nets. The same electrofishing crew could periodically check the nets reducing personnel needs. Gill or trammel nets could also be set in likely spawning areas prior to active spawning (starting in May) when weed beds are not as dense. Carp are known to stage in shallow weedy areas well prior to spawning (Swee and McCrimmon 1966; Horvath 1985). Due to the tangling issue of carp dorsal and anal spines in the fine mesh portion of trammel nets and the increased effort it would take to remove carp, gill nets of the correct mesh size and monofilament diameter would be preferred over trammel nets.

4.0 ECONOMIC PRACTICALITY

There are markets for fresh caught carp and carp roe in the East and Midwest, but landing prices for carp are typically around $.20-$.25/lb. Carp eggs can range from 7-12% of the total landed weight (the percentage increases the closer carp come to the spawning season) and the value of eggs can be $4-$5/lb. Many times the value of carp fish flesh is about equal to the cost of a seining operation, so profit is made from the roe. Carp roe is most valuable while water temperatures are still cold and the skanes are fully developed, but not loose.

There is also a market for sucker (Catastomous species) meat back East and internationally. Suckers are usually marketed as “mullet” in fresh and frozen forms. Suckers make an excellent smoked product and can be turned into flavorful fish sausages, due to the whiteness, flavor, and texture of the meat. The value of sucker meat is often $.40-$.50/lb live weight and the bycatch of suckers can also provide the profit for a commercial carp seining operation. There would be much greater interest in carp for the fresh food market from Lake Spokane if suckers comprise 25%-30% of the total catch.

Currently, all processing plants for utilizing carp in the fresh food market are located in the Midwest and back East. Schafer Fisheries, Inc., (PO Box 399, Thomson, Illinois 61285, Phone: 800-291-3474) is the Midwest’s largest processor and wholesale/retail distributor of fresh fish and frozen seafood. They are located in North Western Illinois and have a 30,000 square foot processing facility located in Thompson, Illinois, with collection facilities in Southeastern Iowa, Wisconsin and Kentucky. They own and operate their own fleet of trucks. Mike Schafer came out to Lake Lowell to haul carp captured during that effort, however it didn’t work out due to a poor catch (the nets snagged up and most of the haul was lost).

Jeff Riedemann of J R Commercial Fish is working with his shipper to build a processing plant out west (American Falls, Idaho) to take advantage of supplies of common carp out west (Lake Lowell, American Falls Reservoir, Snake River reservoirs, Malheur Lake, etc.) and Lake Spokane would be within “striking distance”.

In 2002, Schafer Fisheries, Inc. began production of Schafer’s Liquid Fish (now known as SF Organics) as a type of plant fertilizer created from fish offal. In addition to reducing the production facility’s waste product, SF Organics is 100% environmentally friendly. Carpe carpum (http://www.carpecarpum.com/, Carp Solutions LLC, P.O. Box 1722, Boise, ID, 83702, 208-340-6323, CarpFertilizer@gmail.com) is another company that makes organic fish fertilizer out of common carp. I spoke to Tom Lansing of Carpe Carpum and they were interested in the fish, currently do not have the equipment or facilities to handle large catches of carp in a short amount of time. They are expanding in 2015, so this may be a good option for disposing of fish in the future if there is no fresh fish market.

5.0 ESTIMATED PHOSPHORUS REMOVAL

Based upon the work completed during 2013 to 2014, we know electrofishing during the spawning period can achieve catch rates of around 50 carp/hr. CPUE for spring electrofishing could be improved with larger diameter dip nets, concentrating where carp are most aggregated, and simultaneously fishing gill nets in areas that are being actively electrofished. A minimum of 4,000-5,000 carp could likely be captured during a two week electrofishing effort, with up to double that if simultaneous netting is effective. Winter seining of presumed aggregations of carp associated with the Sportsman's Paradise area could yield catches of 10,000 or more carp if the tagged carp aggregations seen during the fall, winter and early spring of 2013-2014 are indicative of the carp population as a whole. Passive netting (trap nets and gill or trammel nets) in areas of the reservoir used by migrating carp (RKM 77-85) would likely result in highly variable catch rates and the lowest CPUE of any harvest method evaluated. The number of carp harvested would be associated with the effectiveness of different gear types and the amount of effort expended.

Based on data obtained in 2014, the average carp weighed 4 kg/fish with about 5 grams of TP/kg of wet weight of carp. If 10,000 to 20,000 carp were harvested (40,000 to 80,000 kg of carp flesh), that equates to a range of 200 to 400 kg of TP. If largescale suckers can be added to the total biomass of fish flesh removed, the amount of TP would increase. Removal of carp would also reduce bioturbation and resuspension of TP in sediments.

6.0 LITERATURE CITED

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Figures

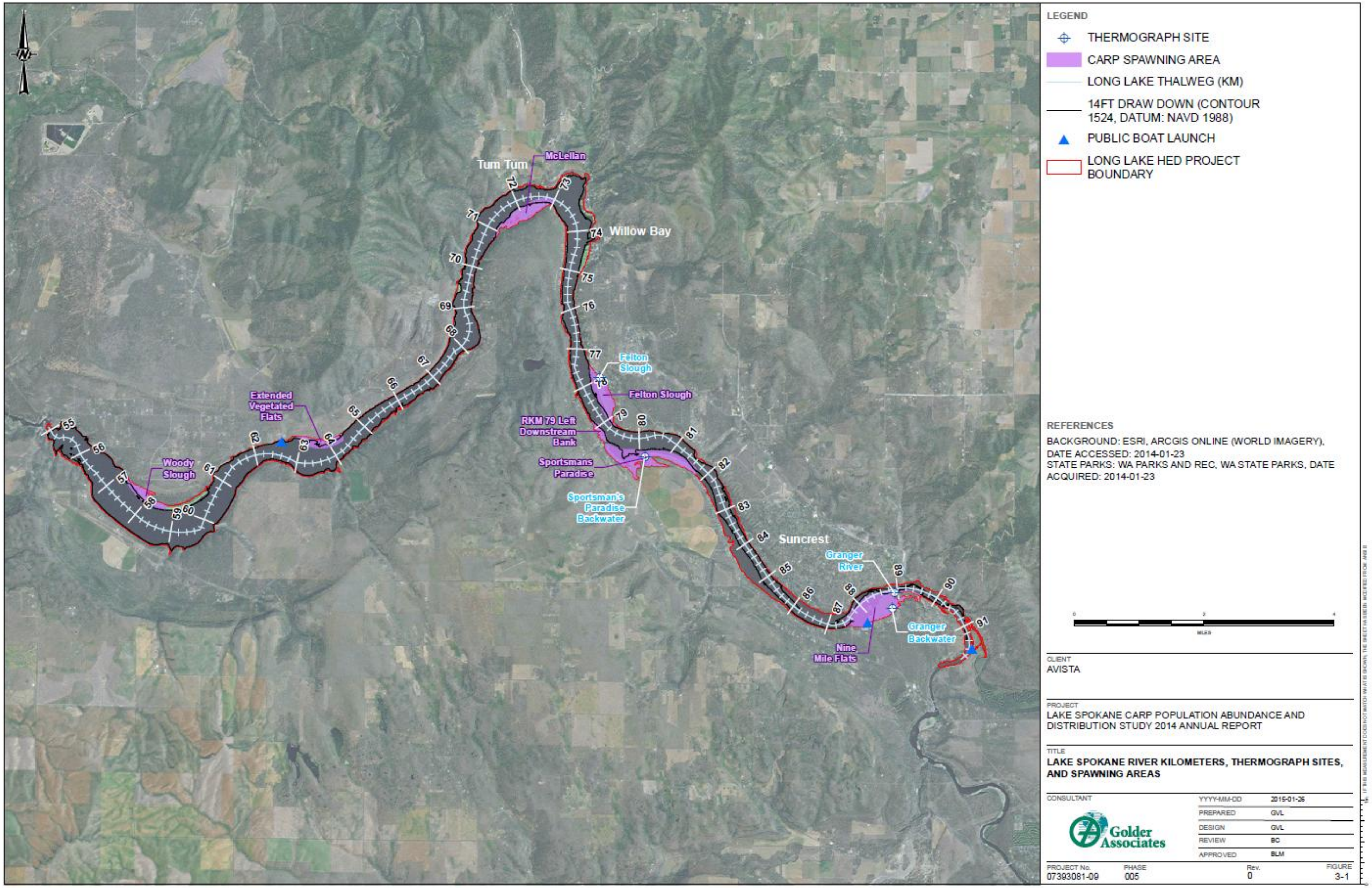


Figure 1. Lake Spokane River Kilometers and Carp Spawning Areas

Map Source: Lake Spokane Carp Population Abundance and Distribution Study 2014 Annual Report Phase I (Golder 2015, Figure 3-1)

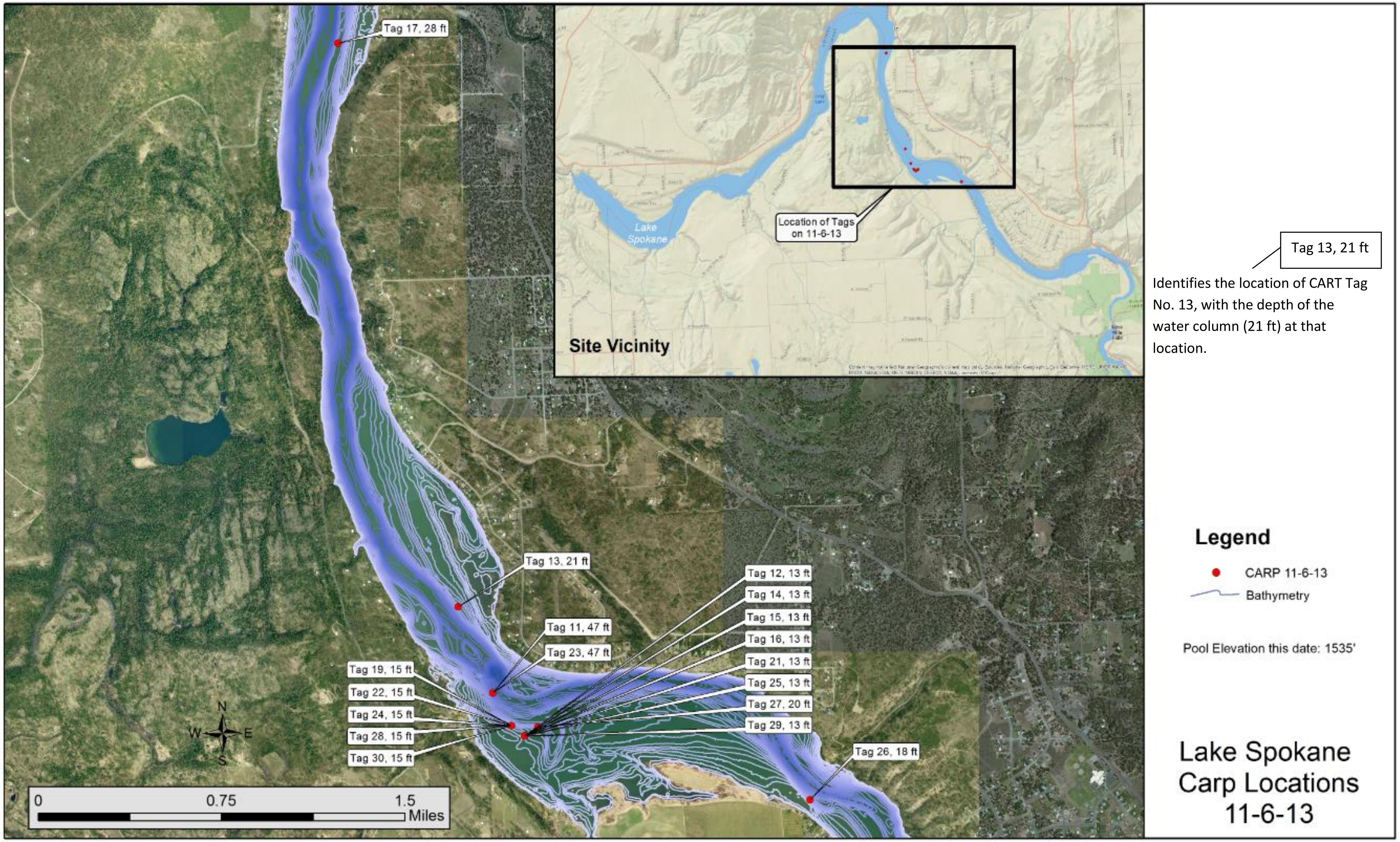
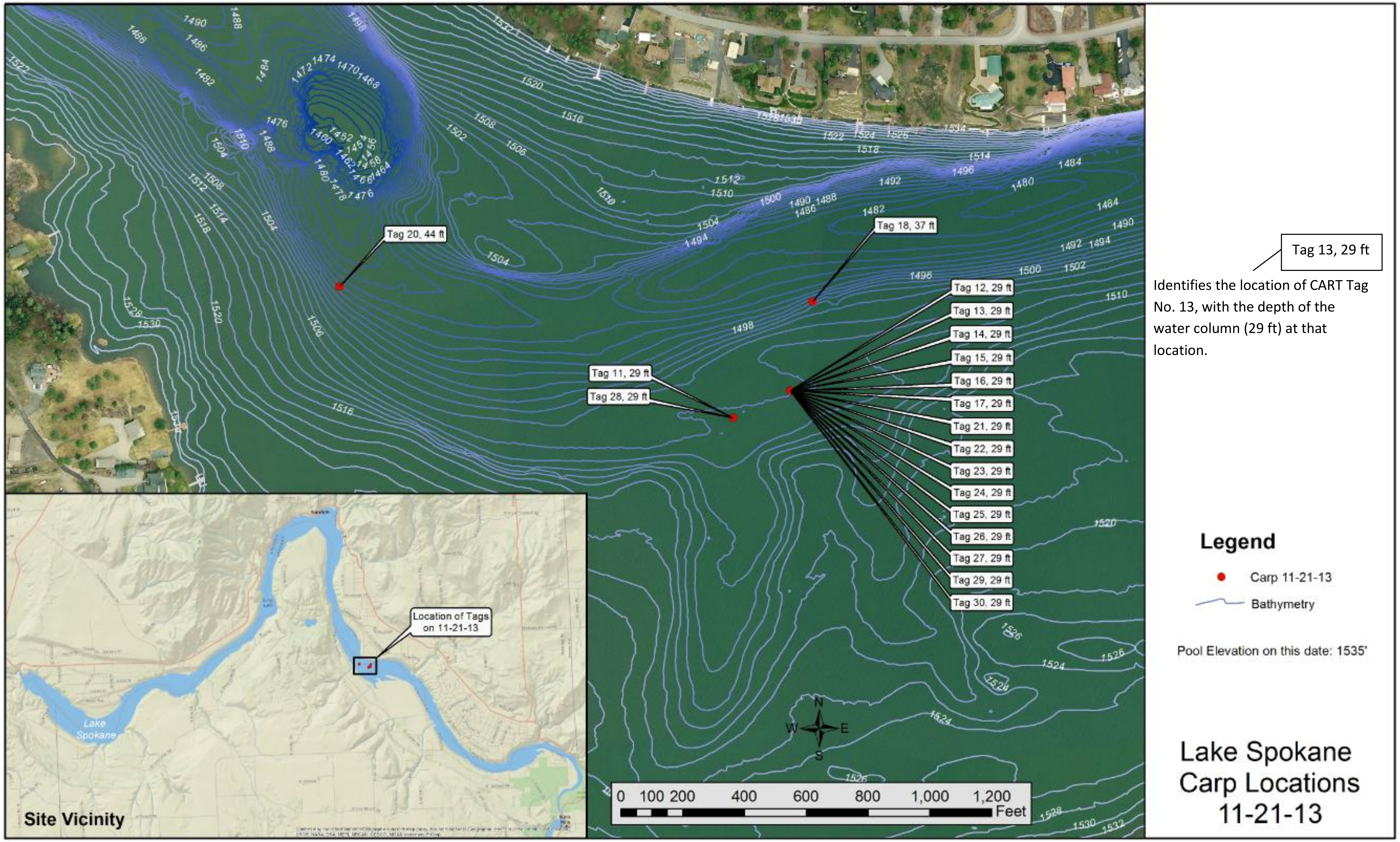


Figure 2. Locations of CART Tagged Carp in Lake Spokane on November 6, 2013



Identifies the location of CART Tag No. 13, with the depth of the water column (29 ft) at that location.

Figure 3. Locations of CART Tagged Carp in Lake Spokane on November 21, 2013

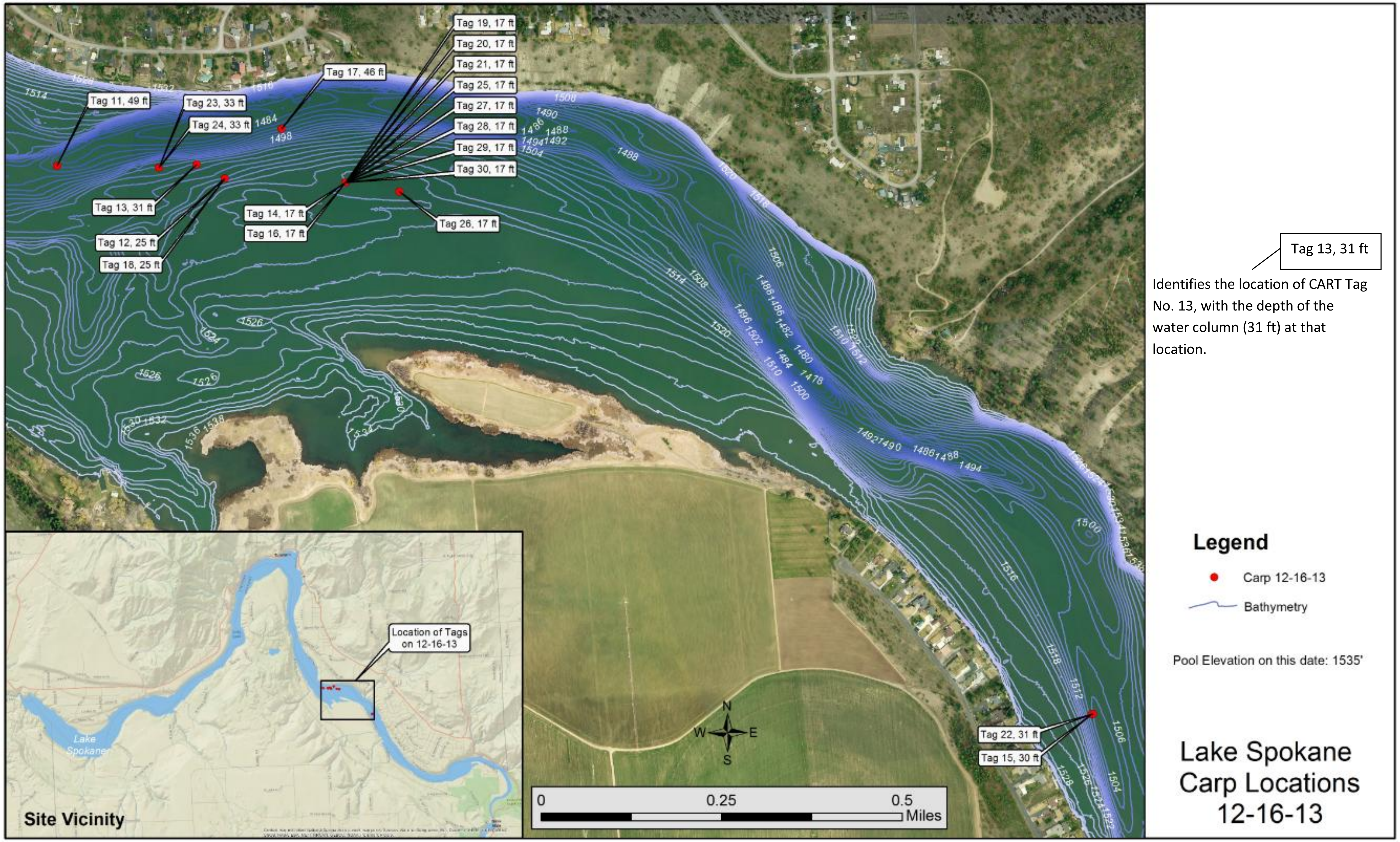
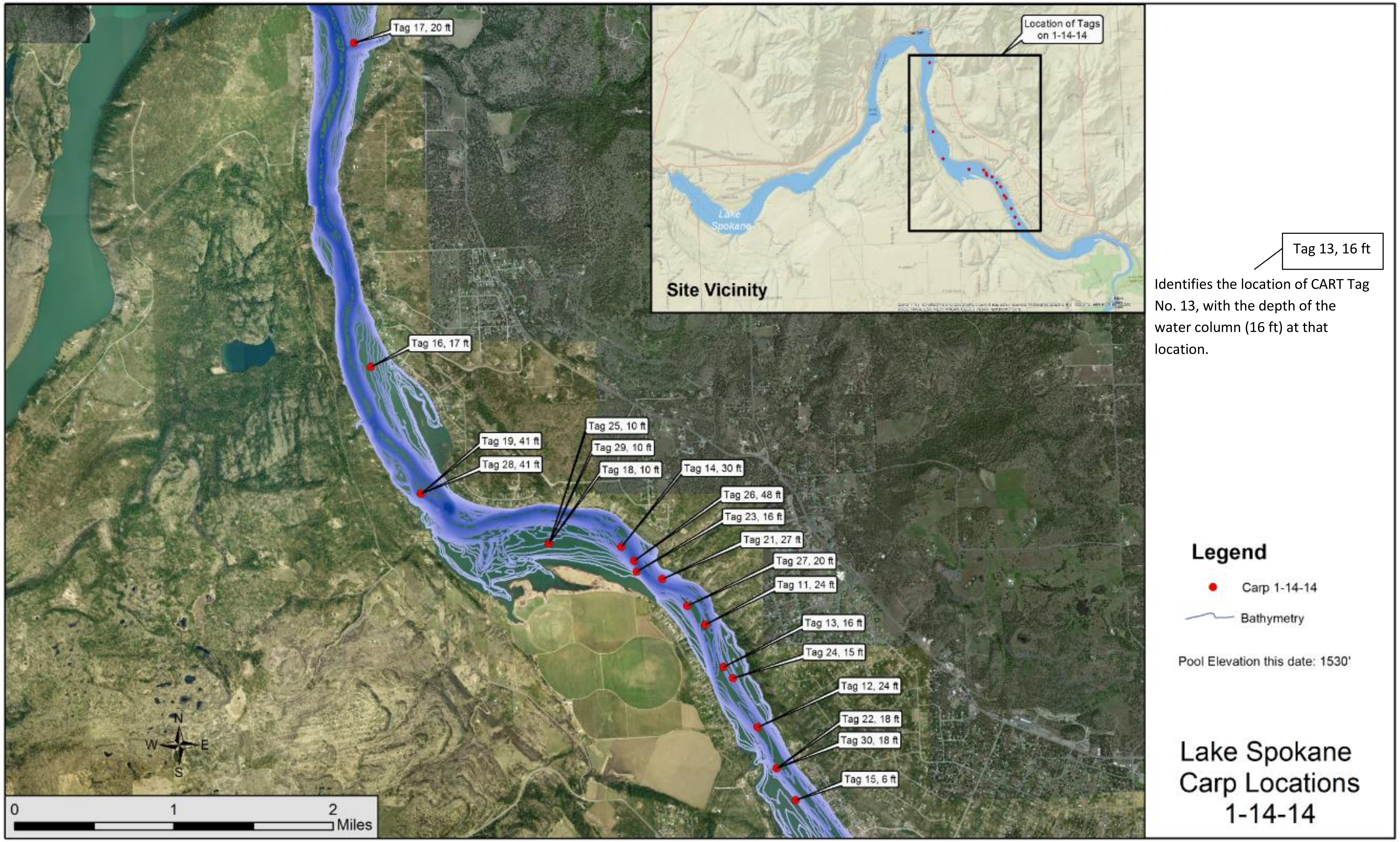


Figure 4. Locations of CART Tagged Carp in Lake Spokane on December 16, 2013

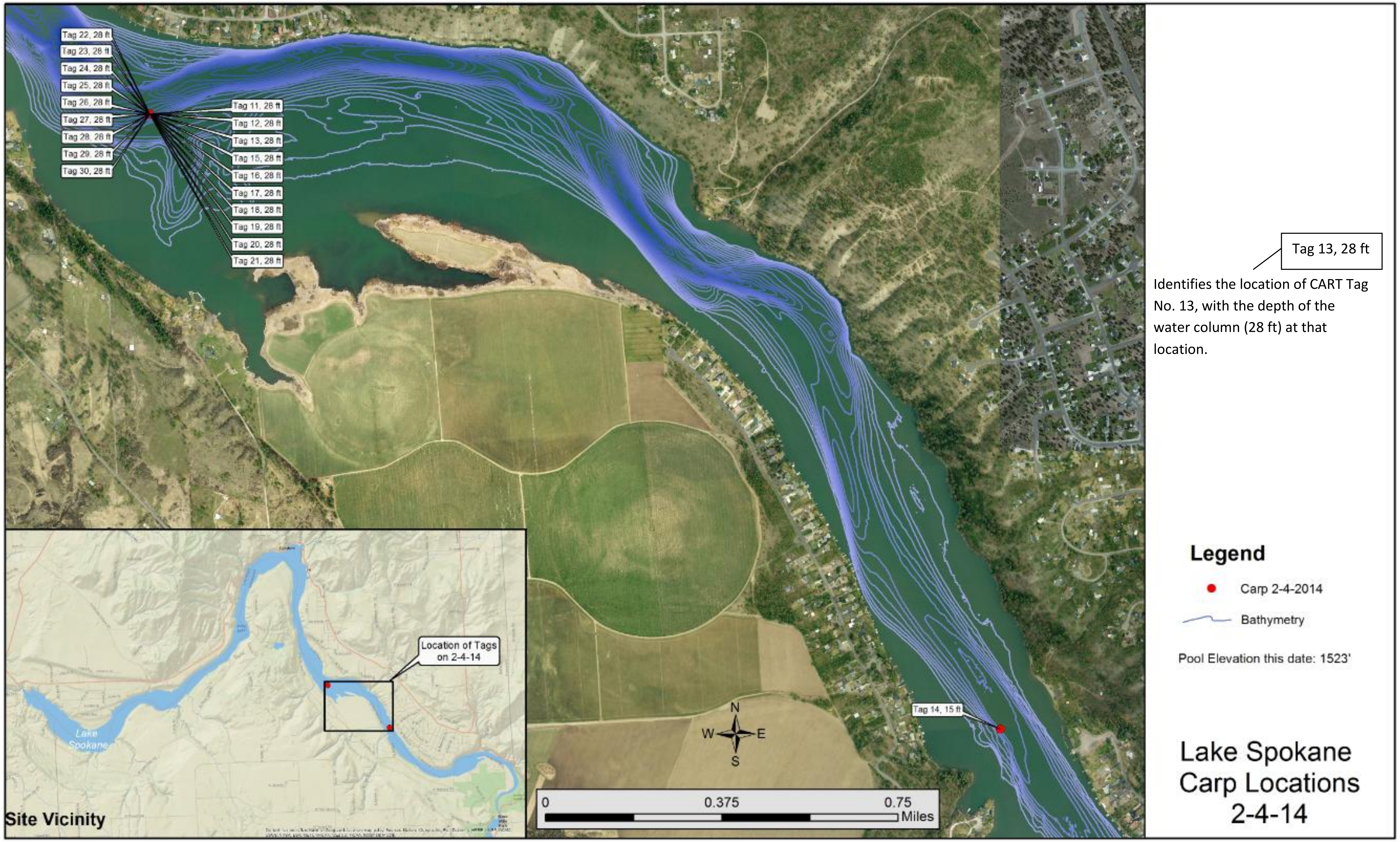


Identifies the location of CART Tag No. 13, with the depth of the water column (16 ft) at that location.

Pool Elevation this date: 1530'

Lake Spokane Carp Locations 1-14-14

Figure 5. Locations of CART Tagged Carp in Lake Spokane on January 14, 2014



Identifies the location of CART Tag No. 13, with the depth of the water column (28 ft) at that location.

Pool Elevation this date: 1523'

Lake Spokane
Carp Locations
2-4-14

Figure 6. Locations of CART Tagged Carp in Lake Spokane on February 4, 2014

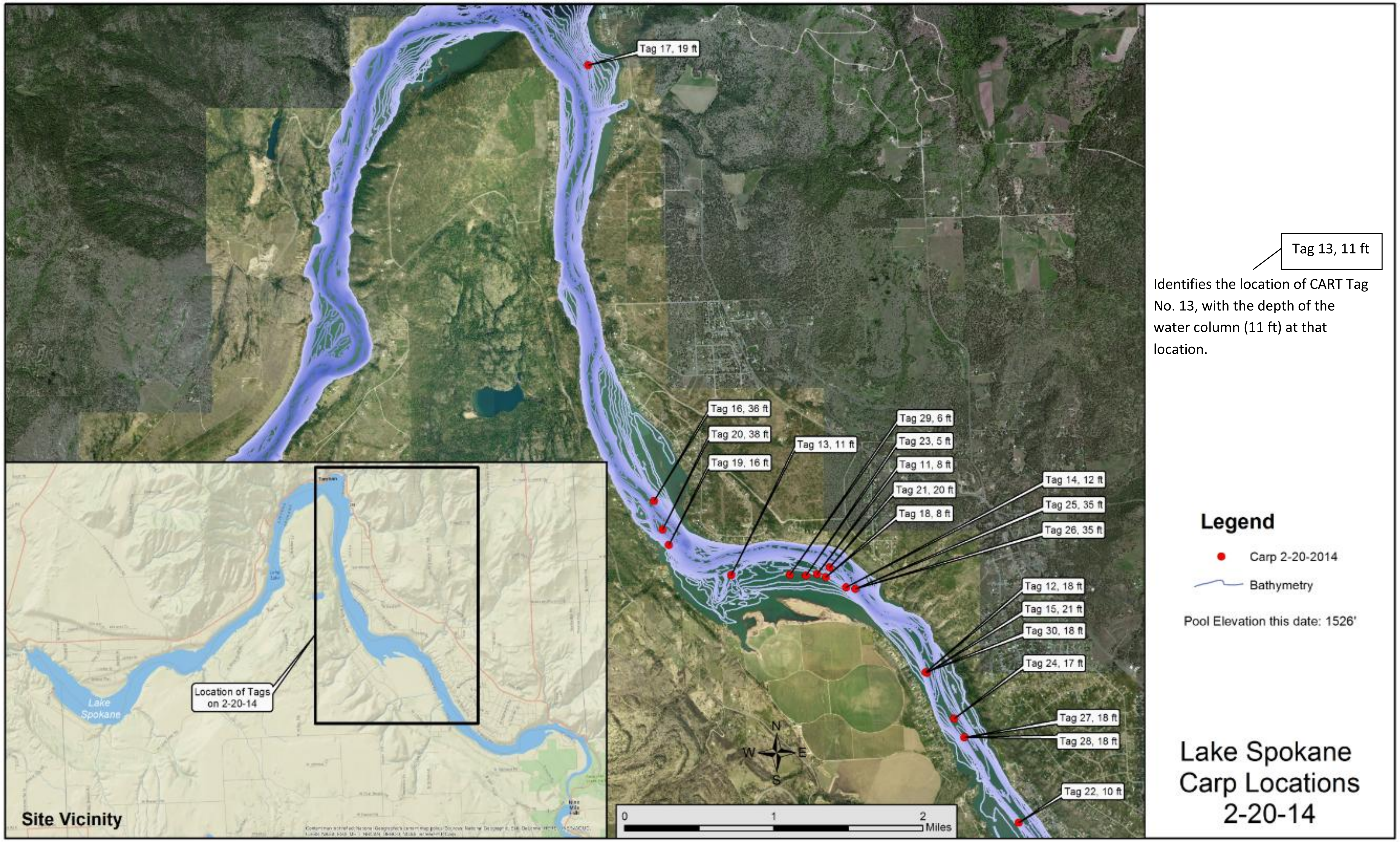
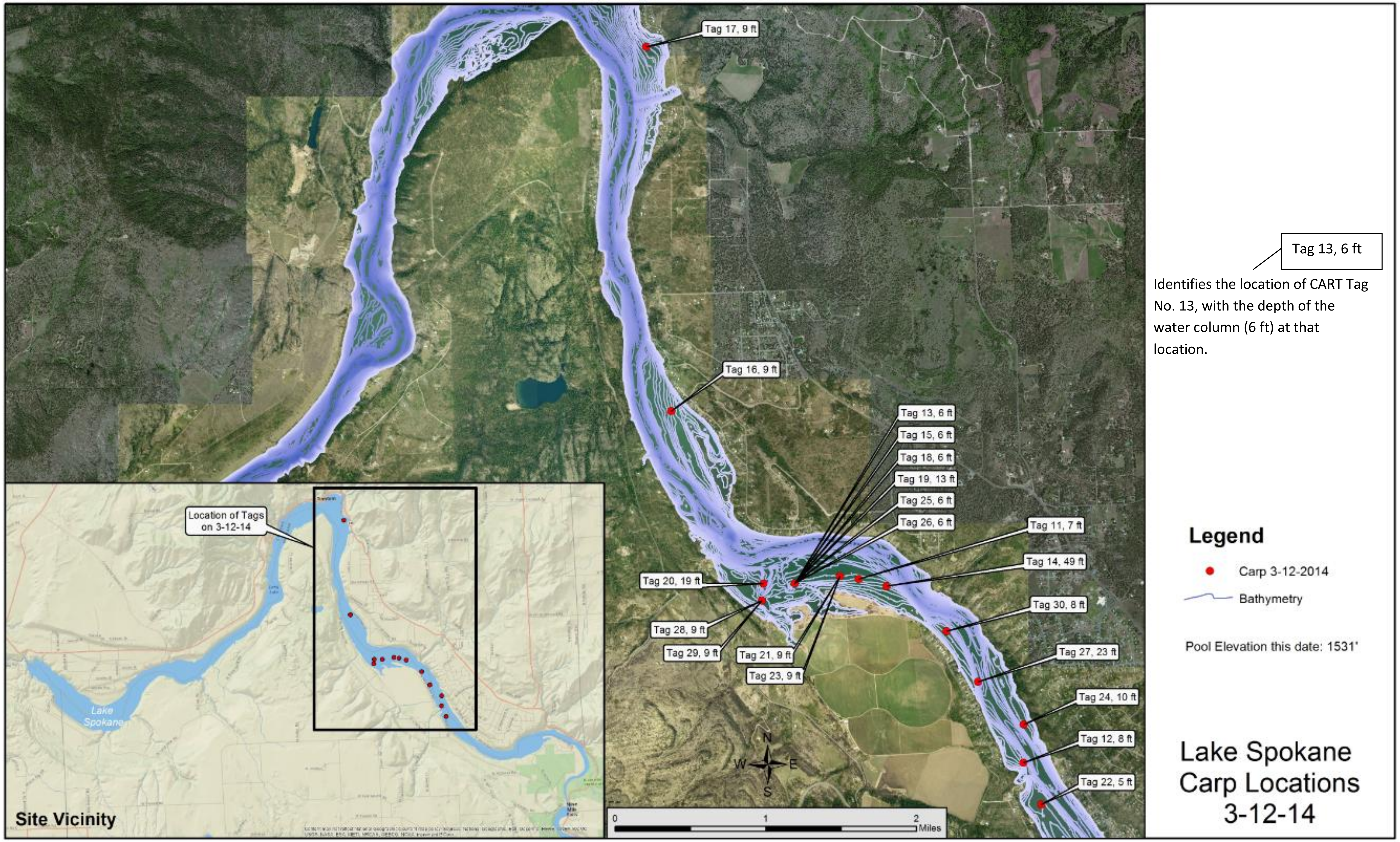
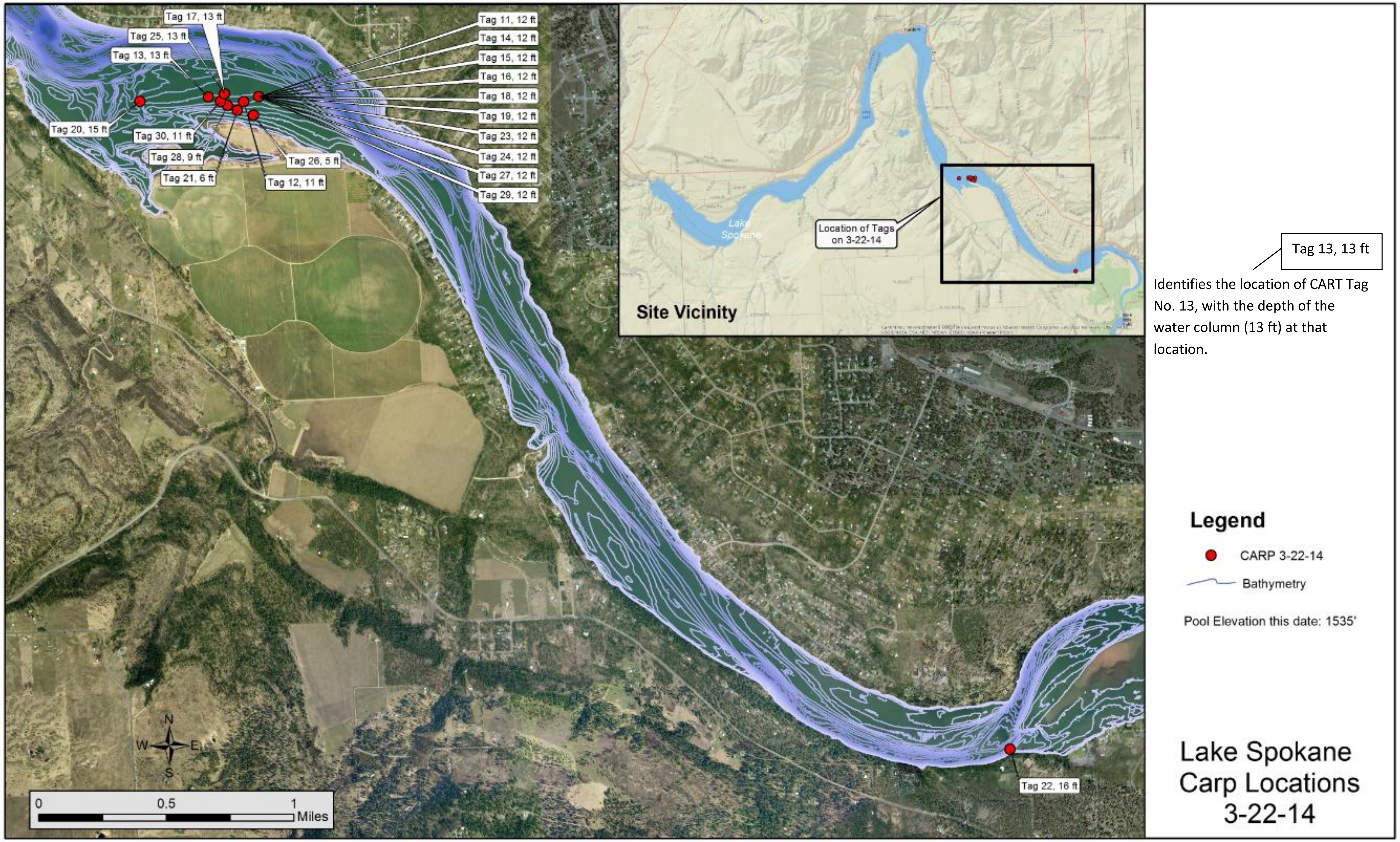


Figure 7. Locations of CART Tagged Carp in Lake Spokane on February 20, 2014



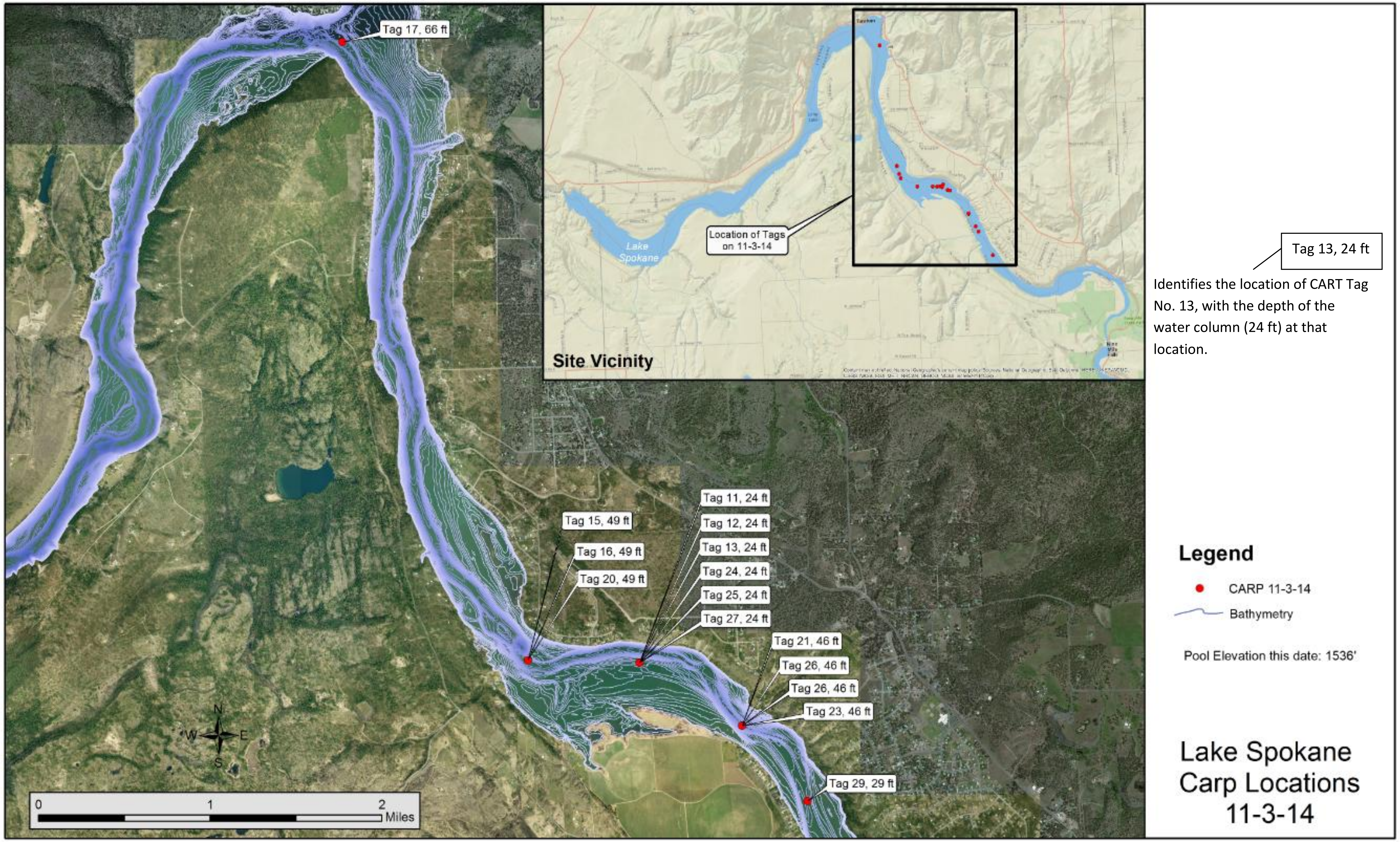
Identifies the location of CART Tag No. 13, with the depth of the water column (6 ft) at that location.

Figure 8. Locations of CART Tagged Carp in Lake Spokane on March 12, 2014



Identifies the location of CART Tag No. 13, with the depth of the water column (13 ft) at that location.

Figure 9. Locations of CART Tagged Carp in Lake Spokane on March 22, 2014



Identifies the location of CART Tag No. 13, with the depth of the water column (24 ft) at that location.

Figure 10. Locations of CART Tagged Carp in Lake Spokane on November 3, 2014

APPENDIX D

Total Phosphorus Lab Analysis – Lake Spokane Carp

ALS Environmental
ALS Group USA, Corp
1317 South 13th Avenue
Kelso, WA 98626
T: 1-360-577-7222
F: 1-360-636-1068
www.alsglobal.com

November 14, 2014

Analytical Report for Service Request No: K1411051

Brian Mattax
Golder Associates, Incorporated
18300 NE Union Hill Road, Suite 200
Redmond, WA 98052

RE: Lake Spokane Carp/0739308109

Dear Brian:

Enclosed are the results of the samples submitted to our laboratory on October 8, 2014. For your reference, these analyses have been assigned our service request number **K1411051**.

Analyses were performed according to our laboratory's NELAP-approved quality assurance program. The test results meet requirements of the current NELAP standards, where applicable, and except as noted in the laboratory case narrative provided. For a specific list of NELAP-accredited analytes, refer to the certifications section at www.alsglobal.com. All results are intended to be considered in their entirety, and ALS Environmental is not responsible for use of less than the complete report. Results apply only to the items submitted to the laboratory for analysis and individual items (samples) analyzed, as listed in the report.

Please contact me if you have any questions. My extension is 3275. You may also contact me via email at Chris.Leaf@ALSGlobal.com.

Respectfully submitted,

ALS Group USA Corp. dba ALS Environmental

C. Leaf

Chris Leaf
Project Manager

CL

Acronyms

ASTM	American Society for Testing and Materials
A2LA	American Association for Laboratory Accreditation
CARB	California Air Resources Board
CAS Number	Chemical Abstract Service registry Number
CFC	Chlorofluorocarbon
CFU	Colony-Forming Unit
DEC	Department of Environmental Conservation
DEQ	Department of Environmental Quality
DHS	Department of Health Services
DOE	Department of Ecology
DOH	Department of Health
EPA	U. S. Environmental Protection Agency
ELAP	Environmental Laboratory Accreditation Program
GC	Gas Chromatography
GC/MS	Gas Chromatography/Mass Spectrometry
LOD	Limit of Detection
LOQ	Limit of Quantitation
LUFT	Leaking Underground Fuel Tank
M	Modified
MCL	Maximum Contaminant Level is the highest permissible concentration of a substance allowed in drinking water as established by the USEPA.
MDL	Method Detection Limit
MPN	Most Probable Number
MRL	Method Reporting Limit
NA	Not Applicable
NC	Not Calculated
NCASI	National Council of the Paper Industry for Air and Stream Improvement
ND	Not Detected
NIOSH	National Institute for Occupational Safety and Health
PQL	Practical Quantitation Limit
RCRA	Resource Conservation and Recovery Act
SIM	Selected Ion Monitoring
TPH	Total Petroleum Hydrocarbons
tr	Trace level is the concentration of an analyte that is less than the PQL but greater than or equal to the MDL.

Inorganic Data Qualifiers

*	The result is an outlier. See case narrative.
#	The control limit criteria is not applicable. See case narrative.
B	The analyte was found in the associated method blank at a level that is significant relative to the sample result as defined by the DOD or NELAC standards.
E	The result is an estimate amount because the value exceeded the instrument calibration range.
J	The result is an estimated value.
U	The analyte was analyzed for, but was not detected ("Non-detect") at or above the MRL/MDL. *DOD-QSM 4.2 definition* : Analyte was not detected and is reported as less than the LOD or as defined by the project. The detection limit is adjusted for dilution.
i	The MRL/MDL or LOQ/LOD is elevated due to a matrix interference.
X	See case narrative.
Q	See case narrative. One or more quality control criteria was outside the limits.
H	The holding time for this test is immediately following sample collection. The samples were analyzed as soon as possible after receipt by the laboratory.

Metals Data Qualifiers

#	The control limit criteria is not applicable. See case narrative.
J	The result is an estimated value.
E	The percent difference for the serial dilution was greater than 10%, indicating a possible matrix interference in the sample.
M	The duplicate injection precision was not met.
N	The Matrix Spike sample recovery is not within control limits. See case narrative.
S	The reported value was determined by the Method of Standard Additions (MSA).
U	The analyte was analyzed for, but was not detected ("Non-detect") at or above the MRL/MDL. *DOD-QSM 4.2 definition* : Analyte was not detected and is reported as less than the LOD or as defined by the project. The detection limit is adjusted for dilution.
W	The post-digestion spike for furnace AA analysis is out of control limits, while sample absorbance is less than 50% of spike absorbance.
i	The MRL/MDL or LOQ/LOD is elevated due to a matrix interference.
X	See case narrative.
+	The correlation coefficient for the MSA is less than 0.995.
Q	See case narrative. One or more quality control criteria was outside the limits.

Organic Data Qualifiers

*	The result is an outlier. See case narrative.
#	The control limit criteria is not applicable. See case narrative.
A	A tentatively identified compound, a suspected aldol-condensation product.
B	The analyte was found in the associated method blank at a level that is significant relative to the sample result as defined by the DOD or NELAC standards.
C	The analyte was qualitatively confirmed using GC/MS techniques, pattern recognition, or by comparing to historical data.
D	The reported result is from a dilution.
E	The result is an estimated value.
J	The result is an estimated value.
N	The result is presumptive. The analyte was tentatively identified, but a confirmation analysis was not performed.
P	The GC or HPLC confirmation criteria was exceeded. The relative percent difference is greater than 40% between the two analytical results.
U	The analyte was analyzed for, but was not detected ("Non-detect") at or above the MRL/MDL. *DOD-QSM 4.2 definition* : Analyte was not detected and is reported as less than the LOD or as defined by the project. The detection limit is adjusted for dilution.
i	The MRL/MDL or LOQ/LOD is elevated due to a chromatographic interference.
X	See case narrative.
Q	See case narrative. One or more quality control criteria was outside the limits.

Additional Petroleum Hydrocarbon Specific Qualifiers

F	The chromatographic fingerprint of the sample matches the elution pattern of the calibration standard.
L	The chromatographic fingerprint of the sample resembles a petroleum product, but the elution pattern indicates the presence of a greater amount of lighter molecular weight constituents than the calibration standard.
H	The chromatographic fingerprint of the sample resembles a petroleum product, but the elution pattern indicates the presence of a greater amount of heavier molecular weight constituents than the calibration standard.
O	The chromatographic fingerprint of the sample resembles an oil, but does not match the calibration standard.
Y	The chromatographic fingerprint of the sample resembles a petroleum product eluting in approximately the correct carbon range, but the elution pattern does not match the calibration standard.
Z	The chromatographic fingerprint does not resemble a petroleum product.

ALS Group USA Corp. dba ALS Environmental (ALS) - Kelso
State Certifications, Accreditations, and Licenses

Agency	Web Site	Number
Alaska DEC UST	http://dec.alaska.gov/applications/eh/ehllabreports/USTLabs.aspx	UST-040
Arizona DHS	http://www.azdhs.gov/lab/license/env.htm	AZ0339
Arkansas - DEQ	http://www.adeq.state.ar.us/techsvs/labcert.htm	88-0637
California DHS (ELAP)	http://www.cdph.ca.gov/certlic/labs/Pages/ELAP.aspx	2795
DOD ELAP	http://www.denix.osd.mil/edqw/Accreditation/AccreditedLabs.cfm	L14-51
Florida DOH	http://www.doh.state.fl.us/lab/EnvLabCert/WaterCert.htm	E87412
Hawaii DOH	Not available	-
Idaho DHW	http://www.healthandwelfare.idaho.gov/Health/Labs/CertificationDrinkingWaterLabs/tabid/1833/Default.aspx	-
ISO 17025	http://www.pjlabs.com/	L14-50
Louisiana DEQ	http://www.deq.louisiana.gov/portal/DIVISIONS/PublicParticipationandPermitSupport/LouisianaLaboratoryAccreditationProgram.aspx	03016
Maine DHS	Not available	WA01276
Michigan DEQ	http://www.michigan.gov/deq/0,1607,7-135-3307_4131_4156---,00.html	9949
Minnesota DOH	http://www.health.state.mn.us/accreditation	053-999-457
Montana DPHHS	http://www.dphhs.mt.gov/publichealth/	CERT0047
Nevada DEP	http://ndep.nv.gov/bsdw/labservice.htm	WA01276
New Jersey DEP	http://www.nj.gov/dep/oqa/	WA005
North Carolina DWQ	http://www.dwqlab.org/	605
Oklahoma DEQ	http://www.deq.state.ok.us/CSDnew/labcert.htm	9801
Oregon – DEQ (NELAP)	http://public.health.oregon.gov/LaboratoryServices/EnvironmentalLaboratoryAccreditation/Pages/index.aspx	WA100010
South Carolina DHEC	http://www.scdhec.gov/environment/envserv/	61002
Texas CEQ	http://www.tceq.texas.gov/field/qa/env_lab_accreditation.html	T104704427
Washington DOE	http://www.ecy.wa.gov/programs/eap/labs/lab-accreditation.html	C544
Wisconsin DNR	http://dnr.wi.gov/	998386840
Wyoming (EPA Region 8)	http://www.epa.gov/region8/water/dwhome/wyomingdi.html	-
Kelso Laboratory Website	www.alsglobal.com	NA

Analyses were performed according to our laboratory’s NELAP-approved quality assurance program. A complete listing of specific NELAP-certified analytes, can be found in the certification section at www.ALSGlobal.com or at the accreditation bodies web site.
Please refer to the certification and/or accreditation body's web site if samples are submitted for compliance purposes. The states highlighted above, require the analysis be listed on the state certification if used for compliance purposes and if the method/anlayte is offered by that state.

ALS ENVIRONMENTAL

Client:	Golder Associates, Incorporated	**Service Request No.:**	K1411051
Project:	Lake Spokane Carp/0739308109	**Date Received:**	10/8/2014
Sample Matrix:	Animal Tissue		

Case Narrative

All analyses were performed consistent with the quality assurance program of ALS Environmental. This report contains analytical results for samples designated for Tier II data deliverables. When appropriate to the method, method blank results have been reported with each analytical test. Additional quality control analyses reported herein include: Matrix Spike (MS), Matrix/Duplicate Matrix Spike (MS/DMS), Laboratory Control Sample (LCS), and Laboratory/Duplicate Laboratory Control Sample (LCS/DLCS).

Sample Receipt

Three whole body carp samples were received for analysis at ALS Environmental on 10/8/2014. The samples were received in good condition and consistent with the accompanying chain of custody form. The samples were stored frozen at –20ºC upon receipt at the laboratory. The individual whole body species were homogenized and composited to create three individual animal tissue samples for analysis per the chain of custody.

Total Metals

Matrix Spike Recovery Exceptions:
The control criteria for matrix spike recovery of Phosphorus for sample fish ID 658 site 055 were not applicable. The analyte concentration in the sample was significantly higher than the added spike concentration, preventing accurate evaluation of the spike recovery.

No other anomalies associated with the analysis of these samples were observed.

Approved by____

ALS Environmental

CHAIN OF CUSTODY
53088

001

1317 South 13th Ave, Kelso, WA 98626 Phone (360) 577-7222 / 800-695-7222 / FAX (360) 636-1068
www.alsglobal.com

SR# K1411051
COC Set 2 of 2
COC#________

Page 1 of 1

Project Name: Lake Spokane Carp
Project Number: 0739308109
Project Manager: Brian Mattax
Company: Golder associates
Address: 18300 NE Union Hill Road Suite 200
Phone #: 1-425-883-0777
email: bmattax@golder.com
Sampler Signature: Jason S Wilmoth
Sampler Printed Name: Jason S Wilmoth

CLIENT SAMPLE ID	LABID	SAMPLING Date	SAMPLING Time	Matrix	NUMBER OF CONTAINERS	180D 6010C / Metals T	999D Frz Dry / Frz Dry	Homogen / Homogen	1	2	3	4	5	Remarks
1. Fish ID 658														
2. Site 055														
3.														
4. Fish ID 656														
5. Site 055														
6.														
7.														
8.														
9.														
10.														

Cooler Contents:
2 Carp

Report Requirements

___ I. Routine Report: Method Blank, Surrogate, as required
___ II. Report Dup., MS, MSD as required
___ III. CLP Like Summary (no raw data)
___ IV. Data Validation Report
___ V. EDD

Invoice Information

P.O.#________
Bill To:________

Turnaround Requirements

____ 24 hr. ____ 48 hr.
____ 5 Day
____ Standard

Requested Report Date

Circle which metals are to be analyzed

Total Metals: Al As Sb Ba Be B Ca Cd Co Cr Cu Fe Pb Mg Mn Mo Ni K Ag Na Se Sr Tl Sn V Zn Hg

Dissolved Metals: Al As Sb Ba Be B Ca Cd Co Cr Cu Fe Pb Mg Mn Mo Ni K Ag Na Se Sr Tl Sn V Zn Hg

Special Instructions/Comments:

*Indicate State Hydrocarbon Procedure: AK CA WI Northwest Other_____(Circle One)

Relinquished By:	Received By:	Relinquished By:	Received By:	Relinquished By:	Received By:
Signature: Jason S Wilmoth	Signature:	Signature	Signature	Signature	Signature
Printed Name: Jason Wilmoth	Printed Name: A Ryan	Printed Name	Printed Name	Printed Name	Printed Name
Firm: Golder Assoc	Firm: ALS	Firm	Firm	Firm	Firm
Date/Time: 10/7/2014 1500	Date/Time: 10/8/14 0940	Date/Time	Date/Time	Date/Time	Date/Time

ALS Environmental

CHAIN OF CUSTODY
53088

001

SR# K1411091
COC Set 1 of 2
COC#__________
Page 1 of 1

1317 South 13th Ave, Kelso, WA 98626 Phone (360) 577-7222 / 800-695-7222 / FAX (360) 636-1068
www.alsglobal.com

Project Name: Lake Spokane Comp
Project Number: 073930809
Project Manager: Brian Mattax
Company: Golder associates
Address: 18300 NE Union Hill Road Suite 200 Redmond WA
Phone # 1-425-883-0777
email: bmattax@golder.com
Sampler Signature: Jason S Wilmoth
Sampler Printed Name: Jason Wilmoth

CLIENT SAMPLE ID	LABID	SAMPLING Date	SAMPLING Time	Matrix	NUMBER OF CONTAINERS	180D 6010C / Metals T	999D Frz Dry / Frz Dry	Homogen / Homogen	1	2	3	4	5	Remarks
1. Fish ID 659														
2. Site 055														
3.														
4.														
5.														
6.														
7.														
8.														
9.														
10.														

Report Requirements

___ I. Routine Report: Method Blank, Surrogate, as required
___ II. Report Dup., MS, MSD as required
___ III. CLP Like Summary (no raw data)
___ IV. Data Validation Report
___ V. EDD

Invoice Information

P.O.#__________
Bill To:__________

Turnaround Requirements

____ 24 hr. ____ 48 hr.
____ 5 Day
____ Standard

Requested Report Date

Circle which metals are to be analyzed

Total Metals: Al As Sb Ba Be B Ca Cd Co Cr Cu Fe Pb Mg Mn Mo Ni K Ag Na Se Sr Tl Sn V Zn Hg

Dissolved Metals: Al As Sb Ba Be B Ca Cd Co Cr Cu Fe Pb Mg Mn Mo Ni K Ag Na Se Sr Tl Sn V Zn Hg

Special Instructions/Comments:

*Indicate State Hydrocarbon Procedure: AK CA WI Northwest Other_____(Circle One)

Relinquished By:	Received By:	Relinquished By:	Received By:	Relinquished By:	Received By:
Jason S Wilmoth					
Signature	Signature	Signature	Signature	Signature	Signature
Jason Wilmoth	A Lynn				
Printed Name	Printed Name	Printed Name	Printed Name	Printed Name	Printed Name
Golder Assoc	ALS				
Firm	Firm	Firm	Firm	Firm	Firm
10/7/14 1500	10/8/14 0940				
Date/Time	Date/Time	Date/Time	Date/Time	Date/Time	Date/Time

PC CV

Cooler Receipt and Preservation Form

Client / Project: Golder Service Request K14 11051

Received: 10/8/14 Opened: 10/8/14 By: Unloaded: 10/8/14 By:

1. Samples were received via? *Mail* [✓ *Fed Ex*] *UPS* *DHL* *PDX* *Courier* *Hand Delivered*
2. Samples were received in: (circle) [✓ *Cooler*] *Box* *Envelope* *Other*______ *NA*
3. Were custody seals on coolers? NA [✓ Y] ~~N~~ AM If yes, how many and where? 2 SIDE

   If present, were custody seals intact? Y N If present, were they signed and dated? Y N

Raw Cooler Temp	Corrected. Cooler Temp	Raw Temp Blank	Corrected Temp Blank	Corr. Factor	Thermometer ID	Cooler/COC ID NA	Tracking Number NA	Filed
-2.1	-2.3	FROZEN		-0.2	342		780146327988	
0.7	0.8	FROZEN		0.1	316		780146327977	

4. Packing material: *Inserts* *Baggies* *Bubble Wrap* [✓ *Gel Packs*] *Wet Ice* *Dry Ice* *Sleeves* ______ FA
5. Were custody papers properly filled out (ink, signed, etc.)? NA ~~Y~~ [✓ N]
6. Did all bottles arrive in good condition (unbroken)? *Indicate in the table below.* NA [✓ Y] N
7. Were all sample labels complete (i.e analysis, preservation, etc.)? NA [✓ Y] N
8. Did all sample labels and tags agree with custody papers? *Indicate major discrepancies in the table on page 2.* NA [✓ Y] N
9. Were appropriate bottles/containers and volumes received for the tests indicated? NA [✓ Y] N
10. Were the pH-preserved bottles (*see SMO GEN SOP*) received at the appropriate pH? *Indicate in the table below* [✓ NA] Y N
11. Were VOA vials received without headspace? *Indicate in the table below.* [✓ NA] Y N
12. Was C12/Res negative? [✓ NA] Y N

Sample ID on Bottle	Sample ID on COC	Identified by:

Sample ID	Bottle Count Bottle Type	Out of Temp	Head-space	Broke	pH	Reagent	Volume added	Reagent Lot Number	Initials	Time

Notes, Discrepancies, & Resolutions: Analyses not marked on COC

Page _____ ***of*** _____

Analytical Report

Client:	Golder Associates, Incorporated	**Service Request:**	K1411051
Project:	Lake Spokane Carp/0739308109	**Date Collected:**	NA
Sample Matrix:	Animal Tissue	**Date Received:**	10/8/14
Analysis Method:	Freeze Dry	**Units:**	Percent
Prep Method:	None	**Basis:**	Wet

Total Solids

Sample Name	Lab Code	Result	MRL	Dil.	Date Analyzed	Q
fish ID 658 site 055	K1411051-001	**25.5**	-	1	10/23/14 13:15	
fish ID 656 site 055	K1411051-002	**27.0**	-	1	10/23/14 13:15	
fish ID 659 site 055	K1411051-003	**31.5**	-	1	10/23/14 13:15	

ALS Group USA, Corp.
dba ALS Environmental

QA/QC Report

Client:	Golder Associates, Incorporated	**Service Request:**	K1411051
Project	Lake Spokane Carp/0739308109	**Date Collected:**	NA
Sample Matrix:	Animal Tissue	**Date Received:**	10/08/14
		Date Analyzed:	10/23/14

Replicate Sample Summary
Inorganic Parameters

Sample Name:	fish ID 658 site 055	**Units:**	Percent
Lab Code:	K1411051-001	**Basis:**	Wet

Analyte Name	Analysis Method	MRL	Sample Result	Duplicate Sample K1411051-001DUP Result	Average	RPD	RPD Limit
Total Solids	Freeze Dry	-	25.5	25.4	25.5	<1	20

Results flagged with an asterisk (*) indicate values outside control criteria.

Results flagged with a pound (#) indicate the control criteria is not applicable.

Percent recoveries and relative percent differences (RPD) are determined by the software using values in the calculation which have not been rounded.

ALS Group USA, Corp.
dba ALS Enviromental

Analytical Report

Client :	Golder Associates, Incorporated	**Service Request :**	K1411051
Project Name :	Lake Spokane Carp	**Date Collected :**	NA
Project No. :	0739308109	**Date Received :**	10/08/14
Matrix :	Tissue	**Date Extracted :**	11/03/14

Total Metals

Sample Name :	fish ID 658 site 055	**Units :**	mg/Kg (ppm)
Lab Code :	K1411051-001	**Basis :**	As Received

Analyte	**Analysis Method**	**MRL**	**Date Analyzed**	**Sample Result**	**Result Notes**
Phosphorus	6010C	20	11/05/14	4520	

Comments:

ALS Group USA, Corp.
dba ALS Enviromental

Analytical Report

Client :	Golder Associates, Incorporated	**Service Request :**	K1411051
Project Name :	Lake Spokane Carp	**Date Collected :**	NA
Project No. :	0739308109	**Date Received :**	10/08/14
Matrix :	Tissue	**Date Extracted :**	11/03/14

Total Metals

Sample Name :	fish ID 656 site 055	**Units :**	mg/Kg (ppm)
Lab Code :	K1411051-002	**Basis :**	As Received

Analyte	Analysis Method	MRL	Date Analyzed	Sample Result	Result Notes
Phosphorus	6010C	20	11/05/14	10300	

Comments:

ALS Group USA, Corp.
dba ALS Enviromental

Analytical Report

Client :	Golder Associates, Incorporated	**Service Request :**	K1411051
Project Name :	Lake Spokane Carp	**Date Collected :**	NA
Project No. :	0739308109	**Date Received :**	10/08/14
Matrix :	Tissue	**Date Extracted :**	11/03/14

Total Metals

Sample Name :	fish ID 659 site 055	**Units :**	mg/Kg (ppm)
Lab Code :	K1411051-003	**Basis :**	As Received

Analyte	Analysis Method	MRL	Date Analyzed	Sample Result	Result Notes
Phosphorus	6010C	20	11/05/14	3940	

Comments:

ALS Group USA, Corp.
dba ALS Enviromental

Analytical Report

Client :	Golder Associates, Incorporated	**Service Request :**	K1411051
Project Name :	Lake Spokane Carp	**Date Collected :**	NA
Project No. :	0739308109	**Date Received :**	NA
Matrix :	Tissue	**Date Extracted :**	11/03/14

Total Metals

Sample Name :	Method Blank	**Units :**	mg/Kg (ppm)
Lab Code :	K1411051-MB	**Basis :**	As Received

Analyte	**Analysis Method**	**MRL**	**Date Analyzed**	**Sample Result**	**Result Notes**
Phosphorus	6010C	2.0	11/05/14	ND	

Comments:

ALS Group USA, Corp.
dba ALS Enviromental

QA/QC Report

Client :	Golder Associates, Incorporated	**Service Request :**	K1411051
Project Name :	Lake Spokane Carp	**Date Collected :**	NA
Project No. :	0739308109	**Date Received :**	10/08/14
Matrix :	Tissue	**Date Extracted :**	11/03/14
		Date Analyzed :	11/05/14

Duplicate Summary
Total Metals

Sample Name :	fish ID 658 site 055	**Units :**	mg/Kg (ppm)
Lab Code :	K1411051-001D	**Basis :**	As Received

Analyte	Analysis Method	MRL	Sample Result	Duplicate Sample Result	Average	Relative Percent Difference	Result Notes
Phosphorus	6010C	20	4520	5910	5210	27	

Comments:

ALS Group USA, Corp.
dba ALS Enviromental

QA/QC Report

Client :	Golder Associates, Incorporated	**Service Request :**	K1411051
Project Name :	Lake Spokane Carp	**Date Collected :**	NA
Project No. :	0739308109	**Date Received :**	10/08/14
Matrix :	Tissue	**Date Extracted :**	11/03/14
		Date Analyzed :	11/05/14

Matrix Spike Summary
Total Metals

Sample Name :	fish ID 658 site 055	**Units :**	mg/Kg (ppm)
Lab Code :	K1411051-001S	**Basis :**	As Received

Analyte	MRL	Spike Level	Sample Result	Spiked Sample Result	Percent Recovery	ALS Percent Recovery Acceptance Limits	Result Notes
Phosphorus	20	248	4520	6290	NA	75-125	

Comments:

ALS Group USA, Corp.
dba ALS Enviromental

QA/QC Report

Client :	Golder Associates, Incorporated	**Service Request :**	K1411051
Project Name :	Lake Spokane Carp	**Date Collected :**	NA
Project No. :	0739308109	**Date Received :**	NA
Matrix :	Water	**Date Extracted :**	11/03/14
		Date Analyzed :	11/05/14

Laboratory Control Sample Summary
Total Metals

Sample Name :	Laboratory Control Sample	**Units :**	mg/L (ppm)
Lab Code :	K1411051-LCS	**Basis :**	NA

Analyte	Analysis Method	True Value	Result	Percent	ALS Percent Recovery Acceptance Limits	Result Notes
Phosphorus	200.7	10.0	9.73	97	80-120	

Comments:

APPENDIX E

Technical Memorandum, Literature Review of Phosphorus Loading from Carp Excretion and Bioturbation & Phosphorus Loading Estimates for Lake Spokane Carp (TetraTech 2015b)

TECHNICAL MEMORANDUM

Literature Review of Phosphorus Loading from Carp Excretion and Bioturbation & Phosphorus Loading Estimates for Lake Spokane Carp

Prepared for

AVISTA

SPOKANE, WASHINGTON

PREPARED BY:

Tetra Tech, Inc.

316 W. Boone Avenue, Suite 363
Spokane, WA 99201

January 2015

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Tetra Tech completed a literature review to determine a range of total phosphorus loadings from carp nutrient-pump excretions and bioturbation. A summary of the literature review, as well as an estimate of the potential total phosphorus loading in Lake Spokane due to carp excretions and bioturbation based on estimated carp density and area are provided below.

Phosphorus loading from carp can be a significant source to lakes. Excretion was studied by Shapiro et al. (1975) and Morgan and Hicks (2013), and their work provides some rates that may apply to Lake Spokane. If carp excrete phosphorus from food consumed in the water column, that is simply recycling what was already in the water, albeit in a soluble form readily available to algae, rather than supplying a new source of phosphorus to the water column. However, if consumed from the bottom as detritus, carp excretion would be a new source of phosphorus to the overlying water column. Since carp do feed extensively on the bottom, these excretion estimates for Lake Spokane assume primarily bottom feeding as worst case for new phosphorus.

Excretion rates decrease with carp size; largely because growth rate decreases with size and feeding habits and diets shift. Carp size in Shapiro's experiments were relatively small (≤ 1 kilogram [kg]). Assuming carp are located in the upper portion of Lake Spokane, which equates to 1,024 hectares (ha) (2,530 acres), excretion rates would be between 8 and 30 kg/day of phosphorus (Table 1) based on those experiments. For perspective, external loading (flow x concentration) during June – October, the period of algal growth and abundance, was about 100 kg/day in 2014, which is about 13% of average loading (750 kg/day) before wastewater phosphorus reduction in 1978 (assuming 2014 flows and the average inflow total phosphorus (TP) concentration prior to phosphorus reduction of 86 micrograms per liter (µg/L) (Patmont 1987)). Also, a nominal sediment release rate of 10 milligrams per meter squared (mg/m^2) per day in the transition and riverine zones would also amount to about 100 kg/day for the same area in upper Lake Spokane. That nominal rate is based on average sediment core release rates of 7 (oxic) and 20 (anoxic) mg/m^2 per day (Owens and Cornwell 2009). So both phosphorus sources (external loading and sediment release within the transition and riverine zones) would yield nearly 7 times that of the highest carp excretion rate. Moreover, carp density is likely closer to 60 kg/ha (8 kg/day), rather than 250 kg/ha (30 kg/day).

Bioturbation, on the other hand, is a result of disturbance to the sediment that suspends particulate sediment phosphorus so that it may be released as soluble phosphorus to the overlying water column. Such release is, however, not likely if sediment phosphorus is bound with iron under aerobic conditions. Rates reported here assumed phosphorus resuspended due to bioturbation was not bound with iron, i.e., bioturbed sediment phosphorus is available for algae in the water column as new phosphorus. Carp, at a density of 180 kg/ha, mixed bottom sediment to a depth 2.5 times greater, to 13 centimeters (cm), in a 30 ha Minnesota lake, compared to a carp-excluded area (Huser et al. 2015).

Bioturbation could be slightly more significant than excretion; 42 to 147 kg/day (Table 2), especially given the average size of carp in Lake Spokane (4 kg). However, given the carp density in Lake Spokane is likely closer to 60 kg/ha, the loading from bioturbation is likely closer to the 42 kg/day. Also, it should be noted, the availability of phosphorus attached to particulate matter resuspended into an oxygenated water column depends on whether the phosphorus is complexed with iron. Nevertheless, the expected rate from a carp density around 60 kg/ha is relatively small. This relatively small contribution from carp, based on comparison with whole summer average loading from other sources, may be underestimated if a smaller area is considered, specifically between stations LL4 to LL5 where algal blooms occur during late summer with low flow, and longer water residence times. Also, phosphorus concentration is more important than loading. Inflow concentration from external loading averaged only 11.5 µg/L in 2014, while sediment released phosphorus from carp bioturbation and/or diffusion flux in shallow water would likely result in higher water column concentrations and produce denser algal blooms than the whole area estimate presented here.

Table 1. Estimated TP Loading in Lake Spokane due to carp excretion based on carp density, area and experimental results elsewhere (assuming the area of the upper reservoir where carp are located is 1,024 ha).

Carp Density	TP Loading Rate by Excretion from Literature	Estimated TP Loading to Lake Spokane (kg/day)	Literature Source
60 kg/ha	0.75 mg/m^2/day	7.7	Shapiro et al. 1975; See Figure 1 below
100 kg/ha	1.2 mg/m^2/day	12.3	Shapiro et al. 1975; See Figure 1 below
250 kg/ha	2.9 mg/m^2/day	29.7	Shapiro et al. 1975; See Figure 1 below
300 kg/ha	0.4 mg P/m^2/day	4.1	Bajer and Sorensen 2014
Unknown; for a benthivorus fish assemblage	1.0 mg P/m^2/day	10.2	Vanni 2002

Table 2. Estimated potential TP loading in Lake Spokane due to carp bioturbation based on estimated carp density and area (assuming area of the upper reservoir where carp are located is 1,024 ha). Rates based on experimental conditions of sediment TP concentration of 2052 mg/kg and a sediment disturbance rate by carp of 33 kg/ha/day and 100 kg carp/ha.

Carp Density	Potential TP Loading Rate from Literature	Estimated Potential TP Loading in Lake Spokane (assuming similar sediment conditions) (kg/day)	Literature Source
60 kg/ha	24.7 kg TP/ha/yr per 100 kg carp/ha	41.6	Akhurst et al. 2012
100 kg/ha	24.7 kg TP/ha/yr per 100 kg carp/ha	69.3	
250 kg/ha	24.7 kg TP/ha/yr per 100 kg carp/ha	173.2	

Table 3. Summary of literature reviewed on carp excretion, bioturbation, and its effect on nutrient concentrations.

Literature Source	TP Loading by Excretion	TP Loading by Bioturbation	Other Findings/Notes	Waterbody Characteristics
Bajer and Sorensen 2014; Effects of common carp on phosphorus concentrations, water clarity, vegetation density; a whole system experiment in a thermally stratified lake	Carp removal had little or no effect on P concentrations indicating role of carp in P budget may be minor compared to abiotic internal loading. Excretion did not play a significant role in P budget Use theoretical calcs to support conclusion; estimated daily carp excretion rate of ~ 0.4 mg P/m2/day or 0.2 µg P/L/d assuming 2-m average depth (only a relatively small fraction of the mid-summer increase of 1.5 ug TP/L/d)	Carp removal had little or no effect on P concentrations indicating role of carp in P budget may be minor compared to abiotic internal loading. Bioturbation did not play a significant role in P budget	Carp removal had positive effect on water clarity, especially in spring and TSS. Increased aquatic vegetation after carp removal Carp biomass in excess of 300 kg/ha is damaging to aquatic vegetation but little damage occurs in lakes with biomass less than 100 kg/ha	Lake Susan, MN Small (35.1 ha) Hyper-eutrophic Max depth 5.1 m Stratifies DO < 0.1 mg/L covers 50% of bottom during July and August Carp occupy the littoral zone Carp biomass before removal = 307.1 kg/ha; mean length = 598 mm After removal carp biomass ranged from 40.8 to 64.5 kg/ha; length ranged from 587 to 677 mm
Huser et al. 2015 (draft publication to Hydrobiologia); Effects of common carp (*Cyprinus carpio*) on sediment mixing depth and potential phosphorus availability in a shallow lake		P release due to bioturbation especially difficult to estimate because they are influenced by many factors including sediment properties, chemical milieu, available of mobile-P, water column mixing	Increased sediment mixing depth caused by carp may reduce the longevity of treatment Al dose added to the lake was based on mass of mobile P in the upper 6 cm of sediment; adequate if no carp Apparent increase in the short-term binding effectiveness between Al and P in the presence of carp; Ratio of Al added to Al:P	Kohlman Lake, MN Small (30 ha) Eutrophic Residence time = 30 days Max depth 2.7 m Mean depth 1.2 m Weakly stratifies Sediment P release rates up to 9.7 mg/m2/d, 25-30% of P load during growing season Carp 50

Literature Source	TP Loading by Excretion	TP Loading by Bioturbation	Other Findings/Notes	Waterbody Characteristics
		and carp burrowing depth Study clearly shows free-ranging adult carp can dig deeply in lake sediments Clear increase in sediment active layer caused by carp (from 5 to between 13.5 and 16 cm); was at least 2.5 times greater in areas with carp Applied the increase in mixing depth caused by carp to the mass of mobile P the amount of P potentially available for release increased by 55% (shallower areas) to 92% (deeper areas) However the release rate might not change sustainably; P loading rate from sediment may not be affected by an increase in mixing depth Carp bioturbation has	formed was 30 whereas in nearby lake with similar dose ratio was 87	individuals/ha and 180 kg/ha Experiment following alum treatment

Literature Source	TP Loading by Excretion	TP Loading by Bioturbation	Other Findings/Notes	Waterbody Characteristics
		the potential to increase the total amount available for release from both sediment P forms (inorganic and organic) but more research is needed on organic matter release		
Akhurst et al. 2012; Effects of carp, gambusia, and Australian bass on water quality in a subtropical freshwater reservoir	TP concentrations increased in carp enclosures and continually increased throughout the experimental period; final concentrations were significantly higher than control enclosures	TP concentrations increased in carp enclosures and continually increased throughout the experimental period; final concentrations were significantly higher than control enclosures If carp manipulated ECD sediments at rates calculated during enclosure experiments (33 kg/ha/d/100 kg carp/ha) then carp would potentially resuspend 24.7 kg TP/ha/yr/100 kg carp/ha Carp may redistribute a continuous supply of bioavailable	Turbidity, TSS, and TN increased significantly in carp enclosures Chl concentration were always significantly greater in the carp enclosures than control Enclosures with carp developed significantly different physicochemical parameters within 3 days; all of which attributed to carp-induced sediment resuspension Carp removal from an aquatic system should increase zooplankton grazing top-down as well as reduce nutrient availability in the water column bottom-up	Emigrant Creek Dam Freshwater Reservoir in subtropical New South Wales, Australia Eutrophic SA = 0.27 km2 Mean depth = 3 m Study used impermeable enclosures; initial fish biomass of 1875 kg/ha Carp in this study were goldfish size (10 cm)

Literature Source	TP Loading by Excretion	TP Loading by Bioturbation	Other Findings/Notes	Waterbody Characteristics
		nutrients to the overlying water column must faster than would occur through pore water diffusion		
Driver, Closs and Koen 2005; The effects of size and density of carp (*Cyprinus carpio* L.) on water quality in an experimental pond	There is a negative correlation between the release rate of P from carp excretion (ug P/g fish/hr) and the wet weight of small carp. Such changes in excretion rates with fish size are associated with ontogenetic diet shifts, and are a consequence of altered concentrations of nutrients in fish tissues and mass-specific ingestion rates Enclosures with carp had higher TP concentrations Small carp contribute P through excretion	Enclosures with carp had higher TP concentrations Enclosures with higher biomass densities had more TP than lower density at end of experiment Large carp enclosures were associated with more P than small carp Larger carp have lower mass-specific P excretion rates but the larger carp in experiment mobilize more P per unit weight compared to smaller; indicating primarily through resuspension (supported by close relationship between turbidity and P)	Carp enclosures were more turbid, had higher concentrations of N and P and lower pH compared to controls Large carp at high density caused the highest turbidities Significance in bioturbation and excretion differed between different size classes of common carp Large and small common carp tended to influence nutrient dynamics and phytoplankton biomass by means of differently mechanism through bioturbation and excretion, respectively	100 m long, 30 m wide pond Depth 1-2 m 20 m from Broken River, north-east Victoria, Australia Experimental enclosures with small carp, low density; small carp, high density; large carp low density; and large carp high density; control, and a mix of large and carp at intermediate density
Matsuzaki et al. 2007; Effects of common carp on	TP did not differ among treatments but TN	TP did not differ among treatments but	Carp influenced water quality and nutrient dynamics, altered phytoplankton	Experimental ponds connected to Lake

Literature Source	TP Loading by Excretion	TP Loading by Bioturbation	Other Findings/Notes	Waterbody Characteristics
nutrient dynamics and littoral community composition: roles of excretion and bioturbation	increased in carp enclosures with a significant carp effect Excretion by carp may have directly stimulated nutrient dynamics and changed phytoplankton biomass and composition resulting in a cyanobacteria bloom In contrast to earlier studies, TN but not TP increased in carp enclosures. Probably owing to difference in limited nutrient concentrations in water column. Study system was probably N limited thus TN excretion by carp resulted in relatively great increase in chl PO4-P decreased significantly in the carp treatments probably due to rapid uptake through cyanobacteria bloom Because the carp used in study were small effects of nutrient excretion were more pronounced	TN increased in carp enclosures with a significant carp effect	biomass and composition and decreased submerged macrophyte biomass independently of sediment access; indicating that nutrient excretion was the primary mechanism for the carp effects Secchi depth decreased while the concentrations of SS increased when carp access to sediments was allowed suggestion bioturbation effects Submerged macrophtye biomass decreased significantly in both carp-net and carp+net Chl concentration was higher in the carp+net relative to the carp-net treatments Cryptophyte was dominant phyto in fishless enclosures while Cyanobacteria were most abundant in carp enclosures	Kasumigaura (shallow eutrophic lake) Each pond 65 m x 45 m Submerged macrophytes abundant Plants were removed and re-planted with equal numbers Net was placed in some enclosures to prevent carp access to sediment Each carp treatment was stocked with one small common carp (wet mass = 148 ±13 g resulting in total of 369 ±32 kg/ha

Literature Source	TP Loading by Excretion	TP Loading by Bioturbation	Other Findings/Notes	Waterbody Characteristics
	than that of bioturbation			
Morgan and Hicks 2013; A metabolic theory of ecology applied to temperature and mass dependence of N and P excretion by common carp	**<u>Table of measured excretion rates</u>** Greater excretion rates in summer (mean temp = 24.2C) than winter (mean temp = 9.2C) Mass specific excretion rates decreased with increasing fish size Study directly measured short-term nutrient excretion rates by carp with range of body size Whole body excretion rates generally increased as body mass increased particularly for N but weaker for P Whole body Excretion rates for most nutrient species were affected by season with lower rates in winter (strongest for N). Rates for PO4 differed significantly between summer and winter but relationship between body mass and PO4			Nutrient excretion experiments done on two occasions over the austral summer and once during winter near main outlet of Lake Waikare, Waikato, New Zealand 3,442 ha shallow hypereutrophic lake in upper North Island For each experiment, 10 to 11 carp captured immediately transferred to tanks holding 40 L of dechlorinated tap water

Literature Source	TP Loading by Excretion	TP Loading by Bioturbation	Other Findings/Notes	Waterbody Characteristics
	excretion was not significant in winter. TP excretion rates were also generally lower during winter than summer but there was a high degree of variability within each season Smaller fish generally excreted more nutrient per gram of body mass compared to larger fish. However was marginally insignificant for PO4 excretion in the summer. Most of the N excreted was in the form NH4 while a high proportion of P was in particulate form. Large fish excreted a higher proportion of total nutrients as dissolved forms than smaller fish although this was only significant for N during the summer. A lower proportion of P excretion was in the dissolved form but PO4 was still an important component of TP especially for larger fish			

Literature Source	TP Loading by Excretion	TP Loading by Bioturbation	Other Findings/Notes	Waterbody Characteristics
	Excretion rates of P by carp were considerably lower than N and in some instances the measured concentrations of P was close to the detection limits of the discrete analyzer			
Shapiro et al. 1975; Biomanipulation: An Ecosystem Approach to Lake Restoration	Increases in P and chl in the enclosures were caused by excretion by carp; Carp are nutrient pumps Carp were captured from various lakes and imprisoned in plastic bags where they released significant quantities of phosphorus Paper includes several figures showing excretion data with individual fish and the relationships of excretion to fish size and density; can use this data to calculate the rate of P return from sediments by a given number of carp of a given size distribution which results in a	Increased P was not caused by simple stirring of sediments was confirmed by the periodic mechanical stirring of the sediment in the small enclosures and no P was released and no algae grew	When carp had access to the sediments phosphorus concentrations, chl levels increased in the enclosures	Experimental enclosures 3 m in diameter added to a variety of lakes and ponds; experiments verified in a 1 ha pond divided into four with plastic sheets; Lamarra 1975

Literature Source	TP Loading by Excretion	TP Loading by Bioturbation	Other Findings/Notes	Waterbody Characteristics
	significant figure From Figure 5: P Loading in mg/m2/day by density of carp kg/ha From Figure 6: P release rates in ug/g-hr based on wet weight of carp			
Vanni et al. 2013; When are fish sources vs. sinks of nutrients in lake ecosystems?			At the ecosystem scale the removal of P via harvesting of fish may be offset by increased anthropogenic P loading from runoff; harvesting may be an important nutrient loss in many systems but the net effect in the context of whole-ecosystem nutrient budgets is difficult to evaluate given the lack of information on flux rates Removal of benthivorous fish takes nutrients from the ecosystem and may reduce nutrient flux from the benthos to water by reducing fish-mediated bioturbation and/or excretion of benthic-derived nutrients 60% of fish carcass P was lost in 109 days in the summer but only 20% was lost in the winter over 20 days Bones and scales contain the most fish P and decompose more slowing than other tissue the fate of this P is critical Paper assumed a 50% mineralization rate for fish	Conceptual modeling

Literature Source	TP Loading by Excretion	TP Loading by Bioturbation	Other Findings/Notes	Waterbody Characteristics
			carcasses which was a reasonable lower bound for an annual period	
Vanni 2002; Nutrient Cycling by Animals in Freshwater Ecosystems	Includes an excretion rates for a benthivorous fish assemblage of 1.0 mg P/m2/day			
Weber and Brown 2009; Effects of Common Carp on Aquatic Ecosystems 80 years after "Carp as a Dominant": Ecological Insights for Fisheries Management (a review for Fisheries Science)	At least 50% of the P excreted by common carp may be readily available for phytoplankton production; However effect on water column nutrients is likely to vary as a result of diet and habitat variability Excretion is likely major driver behind elevated nutrients in water column in ecosystems with hard substrate	Carp may not mobilize nutrients in ecosystems with hard substrate types that do not facilitate benthic foraging behaviors Large carp can effectively penetrate up to 12 cm into the substrate while searching for food	Common carp increased water column nutrients in 75% of the surveyed literature whereas 4% found a decrease in nutrients Carp may directly and indirectly increase water column P, N and ammonia as a result of benthic foraging activities, excretion, or destruction/decomposition of macrophtyes Increases in nutrient loading, turbidity and carp biomass may induce an indirect shift in phyto community from one dominated by green algae to noxious and often toxic cyanobacteria Phytoplankton production increase in 80% and chla increased in 73% of the surveyed literature in the presence of carp Aquatic macrophyte diversity and abundance may be reduced or eliminated when carp biomass approaches 200 kg/ha; submergent species may be more susceptible than emergent species because they generally have weaker root systems and are more influenced by turbidity Carp removal may be more successful in less productive	**Remedial Measures** Carp removal may be one reclamations strategy necessary to decrease internal nutrient cycling, increase transparency, re-establish macrophytes and return shallow lakes to a clear water state Studies have noted a carp biomass threshold of 250-450 kg/ha where carp populations influence biotic and abiotic ecosystem properties More than 70% of carp biomass may have to be removed to realize improvements **Removal/Control** techniques include chemical and physical removal, destruction of spawning habitat, water level manipulation, fish barriers, and

Literature Source	TP Loading by Excretion	TP Loading by Bioturbation	Other Findings/Notes	Waterbody Characteristics
			systems resulting in improved water quality and native fish abundance Inorganic turbidity will be reduced by reducing bioturbation	predator introduction; Chemical removal is popular but non-target species are vulnerable; spot treatments may be an option of carp aggregations Physical removal includes seining, electrofishing, gill netting, and traps; effectiveness and implementation is often dictated by habitat type; more successful in large systems than chemical treatments Drawdowns during spawning may reduce spawning habitat and recruitment; successfully implemented in Australia; also barriers prevent adult carp access to spawning area may reduce recruitment Physical agitation of water in shallow spawning may damage eggs but may also impact native fish
Parkos III et al 2003; Effects of		In this study large amount of	TP concentrations elevated in the presence of carp	Four enclosures in four 0.4hg clay-

Literature Source	TP Loading by Excretion	TP Loading by Bioturbation	Other Findings/Notes	Waterbody Characteristics
adult common carp (Cyprinus carpio) on multiple trophic levels in shallow mesocosms		inorganic suspended particles and the adsorption of P to clay particle suggest that the high turbidity and a large portion of the TP increase was primarily due to carp disturbance of sediments	especially at high carp biomass (476 kg/ha) At both low and high biomass carp had strong effects on turbidity Strongest effect on turbidity and nutrients at a high biomass; however both low and high biomass altered turbidity, SS, zooplankton biomass, macroinvertebrate and vegetation cover	bottom ponds Carp collected from Fox River, IL.
Roozen et al 2007; Resuspension of algal cells by benthivorous fish boosts phytoplankton biomass and alters community structure in shallow lakes			Hypothesis that resuspension of settled planktonic algae by carp is important mechanism that enhance algal biomass and changes community structure No major differences in nutrients in water from the different enclosures and the lake were found except for ammonium which showed an initial increase Phyto community composition significantly different among enclosures. Density of diatoms higher in enclosures where carp had access to sediments, no difference in cyanobacteria, cryptophyta, or chrysophyta but green algae were close to significant more abundance in enclosures where carp had access to sediments Survey and experiment provide support for the idea that fish-induced resuspension of algae cells not only boots overall phyto biomass but alters community structure	Multi-lake survey Dutch part of the River Rhine August 1999; all floodplain lakes shallow (mean depth 0.08 and 5.40 m) and 90% of them smaller than 10 ha Enclosure experiment lake south bank of river Waal mean depth 1 m

Literature Source	TP Loading by Excretion	TP Loading by Bioturbation	Other Findings/Notes	Waterbody Characteristics
			Study found no significant difference in nutrient concentrations in the different enclosures which was not expected. TP did not change when fish stirred up the sediment in the enclosures. The lake was a young lake though with a sandy sediment bottom and only a small layer of silt, detritus and algae Conclude that besides fish-mediated nutrient release and possible cascading trophic interactions, the fish-induced resuspension of algal cells from the sediment may be considered an important proximate mechanism affecting phyto biomass and community structure in shallow lakes	
Weber and Brown 2013; Continuous, pulsed, and disrupted nutrient subsidy effects on ecosystem productivity, stability, and energy flow	Common carp increase nutrient availability and ecosystem instability in shallow lake ecosystems through benthic foraging behaviors and excretion that transfer nutrients from sediments to pelagic habitats	SRP and TP concentrations generally increased for the first three to four weeks before declining and were greatest in the pulsed, intermediate in continuous and lowest in the disrupted and control systems Pulsed systems had up to 10 times higher SRP values compared to other treatments,	This study compared the effects of common carp bioturbation (continuous), decomposition (pulse) and removal (disrupted) on aquatic food webs and ecosystem productivity Pulsed and continuous both had decreases in water clarity. Turbidity was up to 30 times higher in the continuous, 15 times higher in the pulsed system, and lowest in the disrupted and control systems Phyto chla peaked during week 4 and was highest in the pulsed and continuous, intermediate in disrupted and lowest in the control system. After week 4 phyto	16 opaque 4,543 liter mesocosms (2.4 m dia, 1.3 m high) containing 5 cm homogenized lake sediment and filled with groundwater; seeded with macrophytes, zoops and invertebrates Carp placed in 12 random mesocosms at 1000 kg/ha; allowed to develop for 14 days then treatments were applied

Literature Source	TP Loading by Excretion	TP Loading by Bioturbation	Other Findings/Notes	Waterbody Characteristics
		continuous had intermediate SRP values following week 6, and disrupted and control systems had similar low levels of SRP throughout the experiment TP concentrations increased the first four weeks and remained up to 45 times greater in pulsed compared to other treatments Despite ability of carp to increase nutrient availability and phyto as a result of bioturbation, the magnitude of nutrient availability and primary and secondary production was typically greater in pulsed than continuous treatments	production declined in pulsed systems but was more stable in continuous, disrupted and control system Daphnia spp and total zoop densities were greater than 10 times higher in pulsed treatments on week 6 than other treatments with differences among pulsed, control, and disrupted treatment persisting through week 9 Decomposing carp provided an important nutrient pulse that stimulated algal production which competed with macrophytes and shifted energy flow from benthic to pelagic pathways Nutrient availability in pulsed systems peaked 2-3 weeks post-mortem and was initially 3-5 fold greater than those in continuous systems Enriched nitrogen 15 signatures of biological material in pulsed systems provided evidence that carp derived nitrogen was assimilated at multiple trophic levels resulting In the observed increased productivity Regardless of nutrient source (excretions, bioturbation, decomposition) nutrients released by carp were derived from benthic food sources and were translocated to pelagic providing a “new” source for primary production. Shift from benthic to pelagic pathways can affect	

Literature Source	TP Loading by Excretion	TP Loading by Bioturbation	Other Findings/Notes	Waterbody Characteristics
			community structure, stability of pelagic food webs and energy pathways in ecosystem	

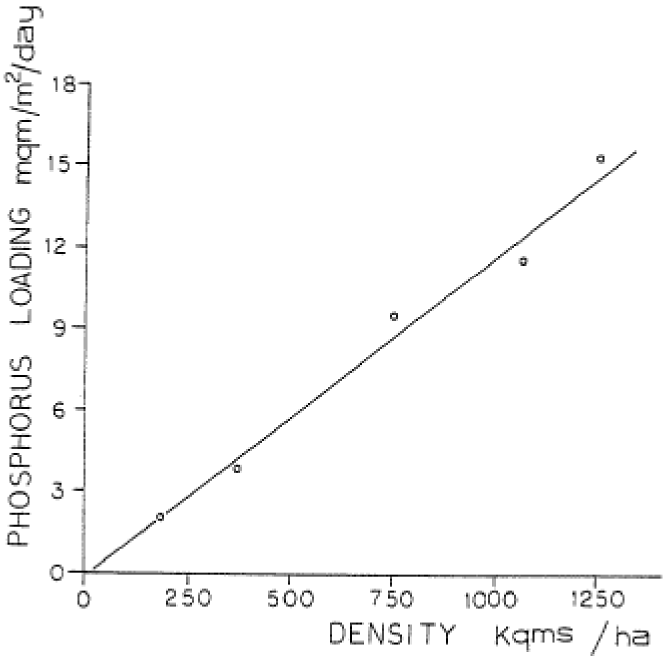

Fig. 5. Relation between fish density and phosphorus release. Data from days 7 to 14, Fig. 4A.

Figure 1. Relationship between fish density and phosphorus release, (Source: Shapiro et al 1975, Figure 5).

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APPENDIX F

Agency Consultation

AVISTA

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

January 29, 2015

Patrick McGuire, 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, 2014 Annual Summary Report**

Dear Mr. McGuire:

I have enclosed the Lake Spokane Dissolved Oxygen Water Quality Attainment Plan 2014 Annual Summary Report (Annual Report) for your review and approval. The Annual Report was completed in accordance with the Lake Spokane Dissolved Oxygen Water Quality Attainment Plan, required by the Spokane River Hydroelectric Project License (License) Appendix B, Section 5.6.C of the Washington Department of Ecology Section 401 Water Quality Certification.

As we discussed in our January 21, 2015 meeting, the Annual Report provides a summary of the 2014 baseline monitoring, implementation activities, effectiveness of the implementation activities, and proposed actions of the upcoming year. The Annual Report also includes a recommendation to implement a pilot study utilizing a combination of mechanical methods (including spring electrofishing, passive netting, and winter seining), to identify which is the most effective method to remove carp from Lake Spokane. Should Ecology agree with this recommendation, Avista will work with Ecology and WDFW on the pilot study and will obtain all required permits prior to implementation.

In addition to the above, we discussed the possibility of revising the overall compliance schedule to better sync it with the compliance schedule of the upstream dischargers. Avista agrees with this and plans to work with Ecology this year to reassess our compliance schedule and to revise it accordingly.

Finally, Avista is required to upload the nutrient monitoring data to Ecology's Environmental Information Management (EIM) database no later than December 31st. While we uploaded the 2014 data in early December, due to a vacancy in Ecology's EIM Coordinator Unit the data could not be reviewed and posted into the EIM database. Our correspondence with Ms. Susan Braley of Ecology's Headquarters Office pertaining to this will be included in the consultation section of the Annual Report.

We request your review of the Annual Report by **March 9, 2015**. This will allow us time to incorporate your comments and recommendations as appropriate, and submit it to the Federal Energy Regulatory Commission by **April 1, 2015**.

Please feel free to call me at (509) 495-4643 if you have any questions about the Annual Report.

Sincerely,

Meghan Lunney

Meghan Lunney
Aquatic Resource Specialist

Enclosure

cc: Dave Knight, Ecology
Chad Brown, Ecology
Speed Fitzhugh, Avista

Lunney, Meghan

From: McGuire, Patrick D. (ECY) [PMCG461@ECY.WA.GOV]
Sent: Friday, February 27, 2015 10:53 AM
To: Lunney, Meghan
Cc: Fitzhugh, Speed (Elvin); Knight, David T. (ECY); Baldwin, Karin K. (ECY)
Subject: Ecology Request for Time Extension to Complete Review of DO WQ Attainment Plan

Hi Meghan –

Ecology requests an extension of our review due date from March 9 to March 31st. The reasons for the request:

- We have a number of people here in Spokane and in Olympia that will need to do reviews, including a qualified modeler;
- The Lake Spokane Dissolved Oxygen Water Quality Attainment Plan 2014 is a complex and detailed report;
- Ecology will need to compile all of our review comments into a response;
- We would then like to meet with Avista soon after we have submitted our comments.

Please let me know if this will work for Avista. If you have any questions please e-mail or call me. Thanks.

Patrick McGuire
Hydropower Compliance Specialist
Water Quality Program
Eastern Regional Office
(509) 329-3567
e-mail: pmcg461@ecy.wa.gov

AVISTA

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

March 9, 2015

Ms. Kimberly D. Bose, Secretary
Federal Energy Regulatory Commission
888 First Street, N.E.
Washington, D.C. 20426

RE: Spokane River Hydroelectric Project, FERC Project No. 2545
Request for a 60-day Extension of Time to File the Lake Spokane Dissolved Oxygen Water Quality Attainment Plan 2014 Annual Summary Report

Dear Secretary Bose:

Ordering Paragraph E of the Federal Energy Regulatory Commission (FERC) Spokane River Hydroelectric Project (FERC Project No. 2545) License incorporated the Washington Department of Ecology (Ecology) Certification Conditions under Section 401 of the Federal Clean Water Act Water Quality Certification (Certification) as Appendix B of the License. In accordance with Appendix B, Section 5.6.C of the License, Avista developed the Lake Spokane Dissolved Oxygen Water Quality Attainment Plan (DO WQAP). The DO WQAP was approved by Ecology on September 27, 2012 and by FERC in its December 19, 2012 Order.

As required by the DO WQAP, Avista met with Ecology on January 21, 2015 to discuss the contents of the Lake Spokane Dissolved Oxygen Water Quality Attainment Plan 2014 Annual Summary Report (Annual Report). The Annual Report provides a summary of the 2014 baseline monitoring, implementation activities, effectiveness of the implementation activities, and proposed actions for the upcoming year. The Annual Report also includes a recommendation to implement a carp removal 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.

Avista submitted the Annual Report to Ecology for a 30-day review period on January 29, 2015, and on February 27 Ecology requested additional time to review the report. We have enclosed Ecology's request for your reference.

With this letter, we are requesting a 60-day extension, from April 1 to June 1, 2015. This will allow us time to address Ecology's comments and/or recommendations prior to submitting the Annual Report to FERC. Please feel free to contact either me at (509) 495-4998 or Meghan Lunney at (509) 495-4643 if you have any questions or wish to discuss this extension request. Thank you for your consideration.

Sincerely,

Speed Fitzhugh

Elvin "Speed" Fitzhugh
Spokane River License Manager

Enclosure (1)

cc: Heather Campbell, FERC-DHAC
Steve Hocking, FERC-DHAC
T.J. LoVullo, FERC-DHAC
Patrick McGuire, WA Department of Ecology
Meghan Lunney, Avista

150 FERC ¶ 62,211
UNITED STATES OF AMERICA
FEDERAL ENERGY REGULATORY COMMISSION

Avista Corporation Project No. 2545-158

ORDER GRANTING EXTENSION OF TIME UNDER ORDER MODIFYING AND APPROVING WATER QUALITY ATTAINMENT PLAN

(Issued March 27, 2015)

1. On March 9, 2015, Avista Corporation filed with the Federal Energy Regulatory Commission (Commission) a request for a 60 day extension of time to file its annual report pursuant to Order Modifying and Approving Water Quality Attainment Plan (Order).[1] The project is located on the Spokane River in Spokane, Lincoln, and Stevens counties, Washington, and in Kootenai and Benewah counties, Idaho.

LICENSE REQUIREMENTS AND BACKGROUND

2. License[2] Appendix (B) contains Washington Department of Ecology's (Ecology) 401 Clean Water Certificate. Section 5.6(C) of the project's water quality certification requires the licensee to develop a Dissolved Oxygen Water Quality Attainment Plan.

3. The licensee filed the Dissolved Oxygen Water Quality Attainment Plan (WQAP) with the Commission on October 8, 2012. The Commission approved the licensee's plan in the Order issued December 19, 2012. The licensee proposed in the plan to demonstrate ongoing compliance with the WQAP by documenting activities described in the WQAP, including a summary of each year's baseline monitoring, implementation activities, effectiveness of the implementation activities, proposed actions for the upcoming year (including new mitigation measures), and ongoing habitat evaluation results (using collected data and the habitat module of the CE-QUAL-W2 model). The licensee states that its annual reports will embody an adaptive management approach by assessing (as appropriate) newly-available information, new technologies, and factors impacting the schedule, in addition to other relevant items. The licensee states that it will consult with Ecology and seek its approval on potential actions proposed for the

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[1] 141 FERC ¶ 62,205 (issued December 19, 2012).

[2] 127 FERC ¶ 61,265 (issued June 18, 2009).

upcoming year, and will have final reports available for Ecology's approval by February 1 each year, starting in 2014.

4. Ordering Paragraph (B) of the December 19, 2012, Order requires the licensee to file the annual report with the Commission by April 1, beginning in 2014, including any comments or recommendations received from the agencies, and the licensee's response to the comments. The Commission also reserves the right to modify the plan or project operations and facilities based on the results of the reports to ensure compliance with license requirements.

LICENSEE'S REQUEST

5. The licensee is requesting a 60 day extension of time to file its Dissolved Oxygen Water Quality Attainment Report pursuant to the Order issued December 19, 2012. The licensee states that the report was submitted to Ecology for a 30 day review on January 29, 2015, and that Ecology requested additional time to review the report on February 27, 2015. The additional time will allow Ecology enough time to complete their review of the report as well as allow the licensee an opportunity to respond to the comments prior to filing the report with the Commission.

DISCUSSION

6. The licensee's request for a 60 day extension of time to file the Dissolved Oxygen Water Quality Attainment Report will accommodate Ecology's request for additional time to review the report as well as allow the licensee adequate time to respond to the comments. The licensee's request is reasonable and is supported by the state water quality certification conditioning agency, and should be approved.

<u>The Director orders</u>:

(A) Avista Corporation's request, filed with the Federal Energy Regulatory Commission on March 9, 2015, for the Spokane River Project No. 2545, to extend the due date for the Dissolved Oxygen Water Quality Attainment Annual Report, pursuant to the Order Modifying and Approving Water Quality Attainment Plan issued December 19, 2012, is approved. The annual report is due June 1, 2015.

(B) This order constitutes final agency action. Any party may file a request for rehearing of this order within 30 days from the date of its issuance, as provided in section 313(a) of the Federal Power Act, 16 U.S.C. § 825*l* (2012), and the Commission's regulations at 18 CFR § 385.713 (2014). The filing of a request for hearing does not operate as a stay of the effective date of this order, or of any other date specified in this order. The licensee’s failure to file a request for rehearing shall constitute acceptance of this order.

Thomas J. LoVullo
Chief, Aquatic Resources Branch
Division of Hydropower Administration
and Compliance

1889

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

March 12, 2015

Ms. Meghan Lunney
Avista Utilities
PO Box 3727
Spokane, WA 99220-3727

Re: Lake Spokane Dissolved Oxygen Water Quality Attainment Plan, 2014 Annual Summary Report

Dear Ms. Lunney:

Thank you for the opportunity and additional time to complete our review of the 2014 Annual Summary Report. The 2013 and 2014 reports offer good historical perspective while providing vital information about Avista's activities to reduce phosphorus in Lake Spokane.

Five years have passed since the Environmental Protection Agency approved the Spokane River and Lake Spokane Dissolved Oxygen Water Quality Improvement Plan (TMDL), and people are eager for quantified information on the progress made towards achieving the water quality standards. We wanted to better understand how information in Avista's report compares with the TMDL, so we asked our engineers and modelers to perform a comprehensive review. Based on this review, we believe that at this point in time, Avista's annual reports should focus more on summarizing annual data and forego more in-depth analysis.

Yearly data summaries would capture incremental improvements in water quality, which will provide valuable information during the ten-year assessment as outlined in the TMDL. The ten-year assessment will evaluate the complex interactions between the river, tributaries, and the lake after improvements are completed at permitted facilities and as nonpoint source implementation activities are completed on the Spokane River, its tributaries and Lake Spokane.

Enclosed are in-depth comments for your review. We look forward to meeting with you to discuss our comments.

Best Regards,

David Knight
Watershed Unit Supervisor
Water Quality Program, Eastern Regional Office

Enclosure
cc: Speed Fitzhugh, Avista Utilities
Pat McGuire, Ecology
Chad Brown, Ecology

March 5, 2015

To: Dave Knight, WQP, ERO

From: Paul Pickett, EAP, EOS

Subject: Ecology technical comments on Avista's "Lake Spokane Dissolved Oxygen Water Quality Attainment Plan 2014 Annual Summary Report"

I have reviewed this report and reviewed the comments made by Bob Cusimano and Tony Whiley from their review of this report. Our detailed comments are provided as attachments to this memo. I would like to highlight the major themes that came from our review.

Major Comments

1. Overall, the information provided in the report is valuable, reflecting the complexity of the reservoir's physical, chemical, and ecosystem characteristics. Determining the extent of improvements in Lake Spokane and the success of the TMDL will require an extensive and detailed analysis of data for the entire Spokane River DO TMDL study area, and the information in this report will support that future assessment.

2. We concur that data demonstrate a significant reduction in total phosphorus (TP) entering Lake Spokane. The evidence from the report supports a conclusion that these lower TP levels are resulting in higher levels of dissolved oxygen (DO) in the reservoir.

3. The report provides no quality assurance (QA) results. Avista should be including all QA information (e.g., replicates, splits, blanks, field equipment calibration results) in their annual reports.

4. Several of the report's references – specifically Cooke et al., 2011, and Thornton et al., 1990 – do not support statements made in the report citing those references. In Appendix A:
    - On page 19, although in Section 3.2.2 about conductivity, there is broad generalization regarding DO. One sentence generalizes from just one journal article (Cooke et al., 2011) which is about a particular reservoir in Oklahoma. This discussion also makes statements that misquote or directly contradict the cited article.
    - On page 23 in Section 3.2.3 (Dissolved Oxygen), a statement is made that cites Thornton et al., 1990, but nothing in the cited book actually supports that statement.

- On page 89, the report cites Thornton et al., 1990 again to support an interpretation of data, but the cited book both partially supports and partially contradicts the report's interpretation.

5. In general, although Appendix A provides a detailed analysis that illuminates a variety of environmental process, it is flawed by many statements made from the selective interpretation of data and citations and by opinions made without adequate evidence to support them.

6. Specifically, the discussion in Section 4 of Appendix A makes speculative assertions that the reservoir has "reached potential" for dissolved oxygen improvements from external loading. The authors base these assertions on a limited analysis that provides insufficient evidence to support their conclusions. These assertions are premature and are beyond the scope of the purpose of the annual report.

7. The report should provide specific information on compliance with state water quality standards (WQS) consistent with the Spokane River DO total maximum daily load (TMDL). Although this was partially done, many aspects of the analysis deviated from or contradicted the approach used in the TMDL to determine compliance with WQS.

8. We have concerns about the seasonal averaging periods used in Appendix A. Significant differences exist in the reservoir between the spring freshet period (May-June) and late summer low-flow period (August-September). Averaging across these periods will mask significant conditions at a shorter time scale. The critical seasons defined in the TMDL should be the guidelines for selecting averaging periods (March-May, June, and July-Oct).

9. We have concerns about the areas of spatial analysis applied. The reservoir has several distinct zones caused by the morphology and hydraulics of the reservoir: the riverine zone, the epilimnion, the metalimnion-interflow zone, and the hypolimnion. These zones were described in many of the previous studies and simulated in the reservoir by CE-QUAL-W2 modeling. The data in the report confirms the continued existence of the zones. Averaging across these spatial zones can mask significant conditions within these zones. The analysis of data and compliance with standards should focus on each of these zones. Sensitivity to external loading may differ in each of the zones. This is due to their unique characteristics, such as the dynamics of settling and re-release in the riverine zone or transport and separation of epilimnion from hypolimnion in the interflow zone.

10. Appendix A makes statements about flow conditions that appear to misstate 2014 conditions in the context of historical and projected future flows. Analysis of the flow record shows several important points:
    - Low-flow conditions for the river upstream of the reservoir in 2014 were around median conditions for the record.
    - Inflow conditions for 2010 through 2014 were near or above average.
    - Inflow conditions for 2001 through 2007 included several of the lowest flow years on record.
    - Trends in annual minimum flows show declining flows in the Spokane River. Although this trend is likely to be somewhat offset by the minimum flows set for the Spokane River below Post Falls, it may also be affected by long-term trends in climate and aquifer withdrawals.
    - Even taking the increased minimum flows into account, low flows in the future are likely to be 20-30% lower than flows in 2010-2014.

11. Although the relationship of DO conditions to flow is well-documented, the requirements for the TMDL are to regulate pollutants in the context of expected flow conditions. Therefore, the relationship of declining flow to lower DO levels only increases the concern for ensuring pollutant discharges meet TMDL allocation targets. This is especially true if flow is not the direct cause of lower DO levels, but rather causes the physical conditions that make the reservoir more sensitive to pollutants.

12. We recognize that retention time is controlled by dam outflows. Outflow rates and residence time are clearly strong drivers of reservoir conditions. Given the importance of the different zones described, and given the very different hydraulic characteristics of the zones, the analysis should look at the effect of the different residence times of the different zones.

13. Section 4.1 has an extended discussion of minimum DO. However, it is not clear how minimum DO was calculated and whether it was the absolute minimum or some average of minima. As discussed above, minimum DO should be evaluated separately for different reservoir zones and for different seasonal periods.

14. The method for calculating volume-weighted DO should be stated clearly. However, these calculations should be based on the zones and seasons mentioned above, and they should be consistent with the approach used to determine compliance with standards in the final TMDL.

15. pH results that exceed water quality criteria are reported. The report should highlight these data. Appendix A refers to "high levels" of pH as greater than 9.0. It's not clear why that

value was selected. It would be more appropriate to report on pH levels above the water quality criterion of 8.5.

16. TP loading is a central part of the Spokane DO TMDL. However, in the narrative of the report, loading is only mentioned in two locations, and the values are not consistent. Specific calculations for the reservoir should be provided separately and clearly.

17. The report makes statements suggesting that internal loading is at a similar level to external loading, or that internal loading is the principal driver of phytoplankton production. However, these statements are not supported by the reported data or analysis. Internal loading is certainly a factor that contributes to phytoplankton growth and should be analyzed and evaluated. Nonetheless, any comparison between loading sources should use comparable metrics, and should recognize that a detailed modeling analysis of the reservoir ecosystem is required to evaluate the differing effects of the two sources.

18. The analysis of DO and temperature conditions, and their relationship to fish habitat, are interesting but are based on interpretations of just a few literature sources. As such, they are speculative. The issue of site-specific water quality limitations on fish habitat is highly complex and would require a detailed analysis far beyond the scope of this report.

19. Adjustment of the monitoring schedule should be considered to increase the number of samples in late August and early September.

cc: Karin Baldwin, Tony Whiley, Bob Cusimano, Pat McGuire, Jim Ross, Tom Mackie, Will Kendra

From: Lunney, Meghan
To: Knight, David T. (ECY)
Cc: Pat McGuire (Pmcg461@ecy.wa.gov); Karin Baldwin (kbal461@ecy.wa.gov); Ross, James D. (ECY); Fitzhugh, Speed (Elvin)
Subject: Revised Lake Spokane DO WQAP 2014 Annual Summary Report
Date: Tuesday, May 19, 2015 4:54:00 PM
Attachments: Avista_Lake Spokane DOWQAP_2014 AnnualSummaryRpt_Revised 5-19-15_TRACK CHANGES.pdf
Avista Response to Ecology Comments_DO_5-19-15.pdf
Importance: High

Hi Dave,

We have revised the Lake Spokane Dissolved Oxygen Water Quality Attainment Plan 2014 Annual Summary Report (2014 Annual Summary Report) to address the comments you provided on March 12th, as well as to reflect our discussion in the March 17th meeting. The revisions include modifications to the main body of the report and to Appendix A (2014 Baseline Water Quality Monitoring Results). To help expedite your review, I have included the red-lined revisions of the report and Appendix A as well as our response to Ecology's comments.

Because the revised 2014 Annual Summary Report is 19 MB in size I have provided a FTP link for your review.
ftp://198.181.21.179/Usr/mll6521a/Avista_Lake Spokane DOWQAP_2014 AnnualSummaryRpt_Revised 5-19-15.pdf

With this, we would greatly appreciate your expedited review of the 2014 Annual Summary Report by **May 28th** in order to meet the FERC submittal date of **June 1**. Upon your approval, we will submit the report to FERC and continue pursuing the carp removal pilot study, as well as the other implementation activities outlined in the report.

Please feel free to give me a call with any questions at 509-495-4643, and I'd be more than happy to answer them.

Thanks!!

-Meghan.

Meghan Lunney
Aquatic Resource Specialist

AVISTA

1411 E Mission MSC-1
Spokane, WA 99202
P 509.495.4643
C 509.842.6133
meghan.lunney@avistacorp.com
http://www.avistautilities.com/environment/spokaneriver/resources/Pages/default.aspx

-----Original Message-----

From: Knight, David T. (ECY) [mailto:dkni461@ECY.WA.GOV]
Sent: Thursday, March 12, 2015 10:35 AM
To: Lunney, Meghan
Cc: Fitzpatrick, Kevin (ECY); Baldwin, Karin K. (ECY); McGuire, Patrick D. (ECY)
Subject: Comments on the Draft DO WQ Attainment Plan Annual Summary

Good morning Meghan. Here are our comments on the Draft DO WQ Attainment Plan Annual Summary. I put a hardcopy in the mail this morning, but wanted to get this into your hands as soon as possible. We look forward to meeting with you next week....................Dave

Dave Knight
Watershed Unit Supervisor
WA State Dept. of Ecology
Eastern Regional Office
4601 N. Monroe
Spokane WA 99205
(509) 329-3590

ECOLOGY COMMENTS AND AVISTA RESPONSES

On March 12, 2015, Ecology provided comments on the Lake Spokane Dissolved Oxygen Water Quality Attainment Plan 2014 Annual Summary Report, dated January 29, 2015. Avista met with Ecology to discuss these comments on March 17, 2015. As discussed in the March 17th meeting, Ecology's "Major Comments" (pages 1-4) are provided here, with Avista's responses to them, are provided as follows. Ecology provided the comments on pages 5-20 of their March 12, 2015 letter to provide context for the major comments.

Ecology Comment 1:
Overall, the information provided in the report is valuable, reflecting the complexity of the reservoir's physical, chemical, and ecosystem characteristics. Determining the extent of improvements in Lake Spokane and the success of the TMDL will require an extensive and detailed analysis of data for the entire Spokane River DO TMDL study area, and the information in this report will support that future assessment.

Avista Response
Thank you, we appreciate your comment and look forward to working with Ecology to support the future assessment.

Ecology Comment 2:
We concur that data demonstrate a significant reduction in total phosphorus (TP) entering Lake Spokane. The evidence from the report supports a conclusion that these lower TP levels are resulting in higher levels of dissolved oxygen (DO) in the reservoir.

Avista Response
Comment noted.

Ecology Comment 3:
The report provides no quality assurance (QA) results. Avista should be including all QA information (e.g., replicates, splits, blanks, field equipment calibration results) in their annual reports.

Avista Response
Appendix A has been modified to provide quality assurance results and we will include this information in subsequent reports. Additionally, the data is uploaded into Ecology's Environmental Information Management (EIM) database where a thorough QA/QC process is completed.

Ecology Comment 4:
Several of the report's references – specifically Cooke et. al., 2011, and Thorton et al., 1990 do not support statements made in the report citing those references. In Appendix A:

- On page 19, although in Section 3.2.2 about conductivity, there is broad generalization regarding DO. One sentence generalizes from just one journal article (Cooke et al., 2011) which is about a particular reservoir in Oklahoma. This discussion also makes statements that misquote or directly contradict the cited article.
- On page 23 in Section 3.2.3 (Dissolved Oxygen), a statement is made that cites Thornton et al., 1990, but nothing in the cited book actually supports that statement.
- On page 89, the report cites Thornton et al., 1990 again to support an interpretation of data, but the cited book both partially supports and partially contradicts the report's interpretation.

Avista Response:
We have removed the referenced statements from Appendix A.

Ecology Comment 5:
In general, although Appendix A provides a detailed analysis that illuminates a variety of environmental process, it is flawed by many statements made from the selective interpretation of data and citations and by opinions made without adequate evidence to support them.

Avista Response
We have removed the referenced statements from Appendix A.

Ecology Comment 6:
Specifically, the discussion in Section 4 of Appendix A makes speculative assertions that the reservoir has "reached potential" for dissolved oxygen improvements from external loading. The authors base these assertions on a limited analysis that provides insufficient evidence to support their conclusions. These assertions are premature and are beyond the scope of the purpose of the annual report.

Avista Response
We have removed the assertions from Appendix A.

Ecology Comment 7:
The report should provide specific information on compliance with state water quality standards (WQS) consistent with the Spokane River DO total maximum daily load (TMDL). Although this was partially done, many aspects of the analysis deviated from or contradicted the approach used in the TMDL to determine compliance with WQS.

Avista Response
Section 1 of Appendix A has been revised to include the DO water quality standard for the Spokane River and Lake Spokane.

Ecology Comment 8:
We have concerns about the seasonal averaging periods used in Appendix A. Significant differences exist in the reservoir between the spring freshet period (May – June) and late summer low-flow period (August – September). Averaging across these periods will mask significant conditions at a shorter time scale. The critical seasons defined in the TMDL should be the guidelines for selecting averaging periods (March-May, June, and July – Oct).

Avista Response
Appendix A has been revised to provide more perspective on the approach used in the DO TMDL to determine compliance with the water quality standard. We have included tables with residence times using the seasonal timeframes identified in the DO TMDL (May, June, July – September, and October). Avista will work with Ecology to more fully incorporate this into future annual summary reports.

ECOLOGY COMMENTS AND AVISTA RESPONSES

Ecology Comment 9:

We have concerns about the areas of special analysis applied. The reservoir has several distinct zones caused by the morphology and hydraulics of the reservoir: the riverine zone, the epilimnion, the metalimnion-interflow zone, and the hypolimnion. These zones were described in many of the previous studies and simulated in the reservoir by CE-QUAL-W2 modeling. The data in the report confirms the continued existence of the zones. Averaging across these spatial zones can mask significant conditions within these zones. The analysis of data and compliance with standards should focus on each of these zones. Sensitivity to external loading may differ in each of the zones. This is due to their unique characteristics, such as the dynamics of settling and re-release in the riverine zone or transport and separation of epilimnion from hypolimnion in the interflow zone.

Avista Response

Comment noted, Avista agrees this is a complex system.

Ecology Comment 11:

Appendix A makes statements about flow conditions that appear to misstate 2014 conditions in the context of historical and projected future flows. Analysis of the flow record shows several important points:

- Low-flow conditions for the river upstream of the reservoir in 2014 were around median conditions for the record.
- Inflow conditions for 2010 through 2014 were near or above average.
- Inflow conditions for 2001 through 2007 included several of the lowest flow years on record.
- Trends in annual minimum flows show declining flows in the Spokane River. Although this trend is likely to be somewhat offset by the minimum flows set for the Spokane River below Post Falls, it may also be affected by long-term trends in climate and aquifer withdrawals.
- Even taking the increased minimum flows into account, low flows in the future are likely to be 20-30% lower than flows in 2010-2014.

Avista Response

Comment noted, Avista recognizes the flows in the Spokane River have varied between 2001 and 2014 as indicated above and that minimum flows from the Post Falls HED will change trends in the downstream river in the future.

Ecology Comment 11:

Although the relationship of DO conditions to flow is well-documented, the requirements for the TMDL are to regulate pollutants in the context of expected flow conditions. Therefore, the relationship of declining flow to lower DO levels only increases the concern for ensuring pollutant discharges meet TMDL allocation targets. This is especially true if flow is not the direct cause of lower DO levels, but rather causes the physical conditions that make the reservoir more sensitive to pollutants.

Avista Response

Comment noted.

Ecology Comment 12:

We recognize that retention time is controlled by dam outflows. Outflow rates and residence time are clearly strong drivers of reservoir conditions. Given the importance of the different zones described, and given the very different hydraulic characteristics of the zones, the analysis should look at the effect of the different residence times of the different zones.

ECOLOGY COMMENTS AND AVISTA RESPONSES

Avista Response

Both inflows and outflows control retention time in the lake. We have revised Appendix A to include residence times, based upon the seasonal timeframes of the DO TMDL for the entire lake, as well as the riverine and transition zones. Residence times for the hypolimnion and lacustrine zones are not available based upon the data currently collected in accordance with the Ecology-approved *Quality Assurance Project Plan for Lake Spokane Baseline Nutrient Monitoring* (QAPP).

Ecology Comment 13:

Section 4.1 has an extended discussion of minimum DO. However, it is not clear how minimum DO was calculated and whether it was the absolute minimum or some average of minima. As discussed above, minimum DO should be evaluated separately for different reservoir zones and for different seasonal periods.

Avista Response

Section 4.1 of Appendix A has been revised to indicate the DO levels being discussed are minimum volume-weighted hypolimnetic DO. Avista will work with Ecology to determine how best to present the data (i.e. different zones and for different seasonal periods).

Ecology Comment 14:

The method for calculating volume-weighted DO should be stated clearly. However, these calculations should be based on the zones and seasons mentioned above, and they should be consistent with the approach used to determine compliance with standards in the final TMDL.

Avista Response

Section 3.2.3 of Appendix A has been revised to provide the method for how the minimum volume-weighted DO values were calculated. Tables 6 and 7 of Appendix A provide these values on a biweekly basis, for each station, over the course of the entire 2014 sampling timeframe. Avista will work with Ecology to determine how best to present the data (i.e. different zones and for different seasonal periods).

Ecology Comment 15:

The pH results that exceed water quality criteria are reported. The report should highlight these data. It would be more appropriate to report on pH levels above the water quality criteria of 8.5.

Avista Response

Appendix A has been revised accordingly.

Ecology Comment 16:

TP loading is a central part of the Spokane DO TMDL. However, in the narrative of the report, loading is only mentioned in two locations, and the values are not consistent. Specific calculations for the reservoir should be provided separately and clearly.

Avista Response

The TP loading discussion has been removed from Appendix A, however Avista will work with Ecology to determine the most appropriate way(s) to calculate and present TP loading.

ECOLOGY COMMENTS AND AVISTA RESPONSES

Ecology Comment 17:

The report makes statements suggesting that internal loading is at a similar level to external loading, or that internal loading is the principal driver of phytoplankton production. However, these statements are not supported by the reported data or analysis. Internal loading is certainly a factor that contributes to phytoplankton growth and should be analyzed and evaluated. Nonetheless, any comparison between loading sources should use comparable metrics, and should recognize that detailed modeling analysis of the reservoir ecosystem is required to evaluate the differing effects of the two sources.

Avista Response

We have removed the referenced statements from Appendix A. Avista will work with Ecology to evaluate how best to calculate and present TP loading.

Ecology Comment 18:

The analysis of DO and temperature conditions, and their relationship to fish habitat, are interesting but are based on interpretations of just a few literature sources. As such, they are speculative. The issue of site-specific water quality limitations on fish habitat is highly complex and would require a detailed analysis far beyond the scope of this report.

Avista Response

We have revised Appendix A recognizing our assessment provides a cursory review of the relationship that temperature and DO have on fish habitat and that a more thorough analysis will need to be completed for the reservoir.

Additionally, as indicated in the 2014 Annual Summary Report, Avista plans to continue stocking 155,000 triploid rainbow trout (approximately six inches in length) in Lake Spokane on an annual basis. Initial responses to the program indicate it is successful and the stocked trout are doing well. This program will assist Avista, Ecology and WDFW in the ongoing effort to evaluate suitable salmonid habitat in Lake Spokane. Avista and WDFW will evaluate the success of the stocking program after ten years of implementation.

Ecology Comment 19:

Adjustment of the monitoring schedule should be considered to increase the number of samples in late August and early September.

Avista Response

Avista and Ecology agreed during our March 17, 2015 meeting that Avista should maintain its current sampling frequency (one a month in May and October and twice a month June through September) as defined in the Ecology-approved QAPP.

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

May 28, 2015

Ms. Meghan Lunney
Aquatic Resource Specialist
Avista Corporation
1411 East Mission Avenue, MSC-1
Spokane, WA 99220-3727

RE: Request for Ecology Review and Approval – *Revised Lake Spokane Dissolved Oxygen Water Quality Attainment Plan, 2014 Annual Summary Report.*
Spokane River Hydroelectric Project, No. P-2545

Dear Ms. Lunney:

The Department of Ecology (Ecology) has reviewed the *Revised Lake Spokane Dissolved Oxygen Water Quality Attainment Plan, 2014 Annual Summary Report* sent to Ecology on May 19, 2015. The Annual Summary Report is a requirement of Section 5.6.C, Appendix B of the 401 Certification.

Ecology APPROVES the *Revised Lake Spokane Dissolved Oxygen Water Quality Attainment Plan, 2014 Annual Summary Report* as submitted.

Please contact me at (509) 329-3567 or pmcg461@ecy.wa.gov if you have any questions.

Sincerely,

Pat McGuire

Patrick McGuire
Eastern Region FERC License Coordinator
Water Quality Program

PDM:jab

cc: Elvin "Speed" Fitzhugh, Avista

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

May 28, 2015

Ms. Meghan Lunney
Aquatic Resource Specialist
Avista Corporation
1411 East Mission Avenue, MSC-1
Spokane, WA 99220-3727

RE: Request for Ecology Approval –*Lake Spokane Dissolved Oxygen Water Quality Attainment Plan, 2014 Annual Summary Report, Carp Removal Pilot Study.*
Spokane River Hydroelectric Project, No. P-2545

Dear Ms. Lunney:

The Department of Ecology (Ecology) has reviewed the recommendation to do a pilot study to determine the most effective methods to remove carp from Lake Spokane. The carp removal project is contained in Section 3.1.1., Carp Population Reduction Program, of the *Lake Spokane Dissolved Oxygen Water Quality Attainment Plan, 2014 Annual Summary Report* sent to Ecology on January 29, 2015.

Ecology APPROVES the Carp Population Reduction Program pilot study recommendation.

Please contact me at (509) 329-3567 or pmcg461@ecy.wa.gov if you have any questions.

Sincerely,

Pat McGuire

Patrick McGuire
Eastern Region FERC License Coordinator
Water Quality Program

PDM:red
cc: Elvin "Speed" Fitzhugh, Avista