Lake Chelan Water Quality Work Plan 2017-2021

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Executive Summary

Lake Chelan provides incredible recreational value to residents and visitors alike. It's clear waters are exceptional and yet water quality monitoring has been done only sporadically over the last 30 years. In 2016 a grant from the Washington State Department of Ecology has enabled initiation of long-term water quality monitoring for the lake. Samples collected in 2016 and early 2017 demonstrate that the total phosphorus values appear to exceed the total maximum daily load (TMDL) of 4.5 ug/l. Thus continuation of nutrient sampling is crucial to assess recovery of the lake's ultraoligtrophic status.

This document lays out the sampling and analysis activities that follow the work perform under the 2016 grant. These activities are funded by local and state government agencies and institutions, but also include significant private support. As a result of these funding commitments and extensive in-kind support, we have the ability to perform monthly sampling for key lake nutrients at three sites for the next 5 years. We also will be conducting key other work that will enable us to interpret the nutrient data. Tasks described in this plan are as follows:

Task 1. Monthly Lake sampling for field parameters and nutrients ***(44%)***
Task 2. Tributary Sampling ***(12%)***
*Task 3. High frequency sampling/monitoring (****17%)***
Task 4. BTEX/gasoline analyses ***(3%)***
Task 5. Mobile Field Parameters (surface and subsurface transects) ***(3%)***
Task 6. Uplake control samples ***(9%)***
Task 7. Weather data ***(0%)***
Task 8. Data Management ***(4%)***
Task 9. Quality Assurance Project Plan (QAAP) ***(6%)***
Task 10. Equipment Procurement ***(6%)***

(**%**'s are the proportion of budget allocated to each task)

Selection of these tasks are based prioritization of stewardship and science opportunities developed by the Lake Chelan Research Institute Board of Directors and have been vetted by the funding agencies and the Lake Chelan Watershed Planning unit. Tasks performed are limited by available funding such that not all data collection and analysis relevant to Lake Chelan water quality could be included in this plan. The plan will be updated annually and expanded as more funding becomes available. Data collection protocols will be described in the QAAP developed in Task 9.

Introduction/background

Lake Chelan is the 3rd deepest lake in the U.S. and its clear waters are key to local tourism. However temporal trends in late water quality are poorly understood due to sporadic and incomplete data. Lake Chelan water quality monitoring has been performed only sporadically since the first water quality study of the lake done in 1986-87 and published as a WA Dept of Ecology document (Patmont et al. 1989). Multi-year gaps in sampling have occurred since that study, including a 9-year gap between 2007 and 2016. Two "Total Maximum Daily Load" (TMDL's) have been promulgated, aimed at maintaining the lake's water quality, one for total phosphorus and one for DDT. Regardless, temporal trends in lake water quality are poorly understood due sporadic and incomplete data (Patmont et al. 1989, Newell and Coffin, 2011 and references therein).

In 2016, the Chelan County Department of Natural Resources received a grant from the WA Dept. of Ecology for ~$160k to initiate a long-term monitoring and model development program for Lake Chelan. The sampling part of that grant (~$100k) was expended in the Spring of 2017 after collection of 4 samples collected approximately quarterly. In November of 2016 the Lake Chelan Research Institute (LCRI) held its first board meeting that included review of results of the first 3 samples. A key recommendation from that meeting was that Lake Chelan needs to be sampled monthly for nutrients, otherwise we will not be able to sort our trends or the impact of singular events on lake water quality. However, monthly sampling could be done on fewer sites (3) instead of the 8 sites sampled under the Washington State Department of Ecology grant.

Given this recommendation, Mike Kaputa (CCDNR) and Phil Long (LCRI) sought funding for the monthly sampling program and related efforts from state and local agencies as well as private sources. Financial commitments obtained to date sum to $79k from seven contributing organizations (see Appendix A). In-kind support is valued at approximately $172k. This work plan describes how the direct financial contributions will be used to conduct key water quality sampling, analysis, and related activities starting in 2017 and continuing through the first half of 2018.

Summary of 2016-2017 results to date

Samples of the upper 20 m of lake water (the epiliminion) were collected at 8 locations in June, August, and October 2016 and in April 2017. The samples were collected and analyzed following the Quality Assurance Project Plan (QAPP; RH2, 2016). The concentrations of field-measured parameters for all four events were generally within historical ranges measured during prior lake water quality monitoring (RH2, 2016). The concentrations of laboratory-analyzed parameters for the June and August 2016 monitoring events were generally within historical ranges

measured during prior lake water quality monitoring (RH2, 2016). Concentrations of total nitrogen, nitrate, total phosphorous and orthophosphate in October 2016 and April were significantly elevated above the previously detected values. For example, total phosphorus measured historically ranged from 2 to 4 micrograms per liter (ug/L), but total phosphorous concentrations were 5 to 6 ug/L in October 2016 and 11 to 12 ug/L in April 2017.

Samples of two tributary streams (Stink Creek, First Creek) at their outlets to Lake Chelan were collected in June, August, and October 2016 and in April 2017. The samples were collected and analyzed following the QAPP (RH2, 2016). The concentrations of field-measured and laboratory-analyzed parameters for all four events were generally within historical ranges measured during prior tributary water quality monitoring (RH2, 2016).

The elevated concentrations detected in October 2016 and April 2017 led to the decision to pursue continuous monthly sampling and supplemental tributary monitoring, largely based on recommendations by the LCRI Board of Directors.

Sampling and analysis Tasks

Task 1. Monthly Lake sampling for field parameters and nutrients—(includes student data collection)

Goals:
Continue to develop and implement a long term monitoring plan of Lake Chelan that will provide consistent monitoring data to assess water quality conditions and trends so that problems can be addressed before they reach levels of concern.
Use the monitoring data and trend analysis to evaluate performance of water and land use practices and to support decisions for land and water management.

Objective:
Conduct monthly samples and measurements at an up-lake (LC-47-8), mid-lake (LC-47-4), and down-lake (LC-47-2) location as well as one blank sample set and one duplicate sample set. Water samples will be analyzed by an accredited laboratory for the following water quality parameters: total phosphorus, orthophosphate, nitrate-nitrite, ammonia, total persulfate nitrogen, total organic carbon, alkalinity and chlorophyll . Other water quality parameters, collected via a multi-parameter probe and secchi disk will include: dissolved oxygen, pH, specific conductance, temperature, and water clarity. A standard sample event will include epilimnion samples only and will occur 8 months per year ; other methods will adhere to the addendum to the QAPP (RH2, 2017). Hypolimnion sampling will be added to the standard sampling protocol ~4 months per year. In addition, every quarter, a profile of 5 samples will be collected at a single site (47-LC-4).

Data application:
The project data will be used to collect high quality data for comparison to TMDL, establish a baseline for future monitoring, and initiate development of the CE-QUAL-W2 model. The model output will be periodically re-calibrated with new monitoring data and the model will be used to evaluate potential effects of land or water management decisions, or changes in environmental conditions, such as wildfire or climate change) on lake water quality.

Funding source:
This activity will be funded by the combined financial resources (Appendix A).

Funding requirements:
The table below describes the costs associated with one monthly sampling event. Annual cost to conduct sampling is calculated below.

Task	Cost epilimnion sampling (8 months/year)	Cost epilimnion + hypolimnion sampling (4 months/year)	Details
boat rental	$250	$250	
mileage	$50	$50	
shipping	$115	$115	
Cascade Analytical lab	$140	$308	(5 samples 8X/year, 11 samples 4X/ year at 28.00/each)
UW Oceanography lab	$516	$908	20 samples 8X/year, 44 samples 4X/year, price ranges from $13.80 - $27.50/each)
CCNRD sampling staff time	$1,191	$1,500	
CCNRD admin	$500	$500	
MONTHLY TOTAL	**$2,762**	**$3,631**	
ANNUAL COST	**$36,620**		

Task 2. Tributary sampling

Goals:

Tributaries to the Wapato Basin contribute directly to water quality status of the Wapato Basin. The goal of tributary sampling is to provide a current snapshot of those contributions.

Objectives:
Collect a set of tributary data on nutrient concentrations entering the lake. These data will be compared to previous sampling events going back to 1987.

Data Applications:
Supplemental funding to the Centennial Grant supported the collection of surface water samples from Stink and First Creeks and from three other creeks (Purtteman, Knapp, Beebe) and from five irrigation return drains, and samples were collected and analyzed following the Addendum to the QAPP (RH2, 2017).
Samples were collected in May and June 2017. The concentrations of field-measured and laboratory-analyzed parameters for both events were generally within historical ranges measured during prior tributary water quality monitoring (RH2, 2016).

Funding source:
Addendum to the QAPP (RH2, 2017), combined financial resources in 2018-2021.

Funding requirements:
Supplemental tributary sampling required approximately $5k in 2017 and $10k in the following years.

Task 3. High frequency sampling/monitoring—osmo samplers, DTS, multiparameter probe, Fluidion total coliform

Goals:
Many of the important processes governing water quality occur on time scales that are much shorter than 1 month. The overall goal of high frequency monitoring is therefore to assess processes that occur on a frequency of hours to days to weeks in the context of the long-term changes in lake water quality. In some cases it is very difficult to interpret data collected on a monthly basis if the shorter term changes are not understood. For example, the internal seiche of the lake is known to bring cold, deep water to the surface during the late summer in the vicinity of site 47-LC-8 up lake from the narrows. The deeper water (hypoliminion) is expected to have different total phosphorus than the epilimnion. Without knowing the status of the internal seiche, which has a 2-day period, we are basically "blind" to the origin of the sampled water. Other features of the lake, like wind-driven re-suspension of sediments are similarly operating on short time frames that may directly impact our monthly sampling results.

Objectives:
Given the above situation, we are therefore initiating collection of relatively high-frequency sampling and monitoring for parameters that can currently be collected in a autonomous or semi-autonomous manner at time scales shorter than a month. High frequency monitoring of selected parameters that are planned or currently under way are as follows:

- Temperature/specific conductivity/depth (methods: Fiber optic distributed temperature sensing—DTS, electrical conductivity, temperature and depth sensors),
- Selected field parameters—T, pH, Specific conductivity, Dissolved oxygen, Turbidity, chlorophyll, Blue-green algae Phycocyanin--BGA-PC (methods: multiparameter probes)
- Orthophosphate/total phosphorus (method: osmo samplers)
- Total Coliform and E. Coli (method: Fluidion sampler)

Identification and location of the monitoring devices are included in Appendix B.

Data applications:
Temperature/specific conductivity/depth (methods: Fiber optic distributed temperature sensing—DTS, electrical conductivity, temperature and depth sensors)

These data will be used to track the world-class internal seiche of Lake Chelan (see discussion above). It is known that the seiche at times pushes cold water into the Chelan River above the dam, an event that will be detected by the instrument at the IID water intake. This information and the T-conductivity data from the multiparameter probes will be compared to the DTS data showing the seiche above and below the sill between the Lucerne and Wapato Basins (the narrows). Results will also be used to assess the likely origin and recent history of the water collected during monthly sampling.

Selected field parameters—T, pH, Specific conductivity, Dissolved oxygen, Turbidity, chlorophyll, Blue-green algae Phycocyanin--BGA-PC (methods: multiparameter probes)

The multiparameter probe data will be used to examine short and long-term changes in water quality on the lake. High frequency data of this type have never been collected on lake Chelan and we foresee long-term (at least 5 years) deployment of these probes followed by assessment the data value. Meanwhile we envision funding and deploying additional probes to see trends along the lake from the Lucerne Basin downlake. Turbidity, chlorophyll, Blue-green algae measurements will be particularly important for tracking daily to weekly nutrient dynamics as well as longer term trends.

Orthophosphate/total phosphorus (method: osmo samplers)

Recent monthly sampling has revealed total phosphorus values that are more than 4 times higher than the TMDL for the lake. While we think deposition of pollen on the lake may be important, we do not yet understand rising total P concentrations during the summer of 2017. In order to connect the observed increases of P with other events on the lake, we need to increase the frequency of phosphorous sampling. One way to do this is to obtain weekly samples using an osmotic pump. Samples are pulled into and stored in a long, small diameter tube. The pump is designed to flow lake water samples into the tube at a rate that yields a sample per week. By this method we will be able, for example, to connect turbidity measurements from the multiparameter probes with P concentrations, something that we are unable to do with monthly samples.

Total Coliform and E. Coli (method: Fluidion sampler)

Fluidion has developed the first ever system to remotely and automatically obtain data on total coliform and E. Coli concentrations in environmental systems. Data from these systems will be compared to total coliform data from the summer of 1987 and then to monitor forward for long-term trends or spikes in lake water bacteria concentrations.

Data collection details and funding sources:

Fiber optic DTS Oregon State University (extensive in kind support, waived most of fiber optic cable and electronics rental, supported by **Center for Transformative Environmental Monitoring Programs** "CTemps"- Oregon State University and National Science Foundation)
WA Department of Ecology ($6k for buoys and related equipment; part of $20k grant amendment).

U. S. Forest Service (in kind support of boat time and pilot for installing cable)

CCDNR (in kind support for permitting the buoys and DNR right of entry)

Pinnacle Surveying—Tim Hollingsworth (in kind support for RTK GPS)

John and Rayetta Browne (in kind support, use of shed and waterfront for bringing fiber cable to shore)

The DTS system will collect temperature data every 15 minutes every 0.5 m along the fiber cable.

Specific conductivity, temperature, and depth sensors ($1k, Isenhart Irrigation District for ES-2 and CDT-10 sensors at IID intake, $2k in-kind support, ITC for CDT-10 sensor at Sunset Marina). Additional Support provided by LCRI from Campbell's Resort and an anonymous donor. Data connection fees of $500/year will be needed.

Selected field parameters—multiparameter probe

- **Sunset Marina** logging every 15 minutes for T, Specific conductivity, Dissolved oxygen, chlorophyll, Blue-green algae Phycocyanin--BGA-PC, and turbidity (to be added later). Key value is detection of leaks from holding tanks in boats in Sunset Marina using the chlorophyll sensor. Data streaming to the internet to be added during August 2017. (In kind support State Parks System (75%)/Sunset Marina (25%) (**SPS/SM**): $12k for YSI EXO3 multiparameter probe that is part of the Sunset Marina sewage pump out system.) Data connection fees of $500/year will be needed.

- **Lookout Marina**. To be installed in August or September 2017. Will use the Manta 2 multiparameter probe purchased under the Centennial Grant for long-term monitoring of Lake Chelan. Will log every 15 minutes for T, pH, Specific conductivity, Dissolved oxygen, Turbidity. Water depth and 3 temperature and specific conductivity depths will be logged. Will have data streaming to internet. (~$1.5k funding for internet streaming and multiple temperature/specific conductivity depths provided by LCRI). Data connection fees of $500/year will be needed.

Note: both probes will be calibrated at least monthly per manufacturer's recommendations.

Orthophosphate/total phosphorus. Osmotic samplers will be built by Evan Solomon of the UW Oceanography Department and deployed at Site 2 (47-LC-2) in order to generate weekly samples over a year's time. We may do a trial run of short duration. Cost $2.4 to cover Evan's build costs. Analytical costs will be on the order of $2.5K or less depending on availability of lab assistants at the time of analysis, likely September 2018. Buoy for deployment is already permitted and available.

Total Coliform and E. Coli. State Parks System is providing two Fluidion, Inc. units to LCRI to measure *in situ* total coliform and E. Coli twice per week. Data will be streamed to the internet after each analysis and 7 analyses can be completed on a single battery charge. This is an experimental program approved by U.S. Fish and Wildlife through the State Parks system. State Parks will provide 75% of operating cost. LCRI share is approximately $1.0k per year. The two units will be deployed as follows: 1) Sunset Marina adjacent to the multiparameter probe. 2) Mill Bay Marina either adjacent to the Lake Chelan Reclamation District water intake or closer to the Sewage pumpout at Mill Bay Marina.

Funding Requirements:
This activity will be funded by the combined financial resources (Appendix A).

Direct funding requirements:

1. Data costs for 3 internet streaming connections (~$1.5/year)
2. Build costs for 2 osmotic pumps ($2.4k, analytical costs will likely fall in the next annual period)
3. Support for DTS system ($6k, already expended against WA Dept of Ecology grant extension, $0.7k for crab pot puller or capstan for lowing buoy anchors, funded from equipment budget, Task 10).
4. LCRI portion (25%) of consumable and data connection charges for Fluidion system, $1.0k.

Total: $12.0k ($6k has already been expended)

Task 4. BTEX/gasoline analyses before and after 4th of July weekend

Goals:
Obtain water samples of benzene, toluene, ethylbenzene, xylene (BTEX) and gasoline before and after the Fourth of July holiday.
Objectives:
Collect BTEX and gasoline samples before (June 28th) and after (July 5th) the Fourth of July holiday at 3 sample locations: off the T-shaped dock at Lakeside Park (LC-BTEX-1), off the end of the public dock at Sunset Marina (LC-BTEX-2) and off the City Marina dock (LC-BTEX-3 aka LC-47-1b).
Obtain 3 water sample duplicates for BTEX and 2 water sample duplicates for gasoline at each sample location and event. Measure the following water quality parameters: pH, temperature, Dissolved Oxygen, and specific conductance.

Data application:
Before after data will be used to assess the water quality effects, particularly concerning BTEX and gasoline, of heavy motor boat use corresponding with the Fourth of July holiday.

Funding source:

LCRI and Chelan County

Funding requirements:

Task	cost
Shipping (CCNRD)	$163
ARI lab costs (LCRI)	$1160
CCNRD sampling staff time (CCNRD)	$437
TOTAL	$1,760

Task 5. Mobile field parameters—surface and subsurface transects

Goal:
Obtain a more synoptic view of lake dynamics, especially transfer of water from the Lucerne Basin to the Wapato Basin and tracking of tributary flows into the lake.

Objectives:
A key feature of the lake in 1987 was the slight increase in specific conductivity from about 2/3rd of the way down the lake to its foot. Apparently specific conductivity serves as a tracer of water input to the lake from more saline tributaries closer to its foot. Collection of mobile field parameters using the multiple parameter probes described in section 3.3 will enable low-cost interrogation of this feature of the lake, covering parts of the lake not covered by our routine mid-lake sampling sites or our tributary sampling. We will be able to determine if the temperature and conductivity structure of the lake today is similar to what it was in 1987. Going forward we will be able to monitor any changes, shedding light on hydrodynamics of the lake under changing hydrodynamic conditions.

Data application:
Data will be collected in two modes: A) longitudinal near-surface monitoring transects and B) subsurface depth profiles integrated into subsurface transects. Longitudinal monitoring will be conducted by slow travel in a boat (~5-10 miles/hour) down the center of the lake and approximately 100 m from either shoreline. Longitudinal transects will be performed with the multiparameter probe and the ES-2/CDT-10 deployed at Lookout Marina. This system will be set up to record GPS location along with the collected data. Data will be used to assess the surface expression of the temperature and conductivity structure in the lake (compared to 1987). In addition, we expect to be able to assess the impact of individual tributaries at least during times of the year when streams may be warmer than the lake. In any case, there are very few scattered data on near-shore

temperature and conductivity and we expect these data will open a new window into Lake Chelan hydrodynamics.

In the second mode of data collection, individual profiles will be made with the multiparameter probe deployed at Sunset Marina. This probe will go to a depth of 250m and so can reach all depths in the Wapato Basin and much of the Lucerne Basin. Individual profiles will be measured when we perform monthly sampling starting in September. In addition, transects will be developed at three locations:

Transect A Across the lake at between Sunset Marina and Lookout Marina
Transect B Across the Lake at 47-LC-4 (deepest point in the Wapato Basin)
Transect C Across the Lake at 47-LC-8 (uplake from the sill)

These transects will be the first time that temperature, Specific conductivity, Dissolved oxygen, chlorophyll, Blue-green algae Phycocyanin (BGA-PC), and turbidity will be measured from shore to shore anywhere in the lake. Monitoring how these parameters change with time will almost certainly provide incredible insight into how Lake Chelan works.

At this time we are uncertain as to how frequently we can collect each mode of data. Cost of data collection is low because of volunteer time of key participants and volunteer boat time. Principal cost will be boat fuel and a one time cost for a down rigger for lowering the multiparameter probe for profiles. Ideally, data collection frequency would be monthly but manpower resources may limit our ability to do achieve this frequency of data.

Funding Source:
Combined financial resources (Appendix A).

Funding Requirements:
Estimated annual cost of $1.5k for fuel for volunteer boat time.
Automatic down rigger: $0.7k (Funded from equipment budet, Task 10).

Task 6. Uplake Control Samples

Goal:
Determine long-term trends in the upper part of Lake Chelan and in the Stehekin River and Railroad Creek.

Objectives:
(1) Obtain samples twice per year (Spring and Fall) for nutrient concentrations from Sites 47-LC-P8, 47-LC-P7, 47-SR-1a, and 47-RC-1.

(2) Compare the results from these samples to prior data sets and to the results samples collected as part of Section 3.1.

Data Applications:
High total phosphorus level observed in the Wapato Basin in the Spring and Summer of 2017 make it imperative that we know at least a minimal amount of information about nutrient status of the upper lake and that of the major tributary inputs to the Lucerne Basin.

Funding source:
This activity will be funded by combined financial resources (Appendix A).

Funding requirement:
This task is designed to minimize costs by limiting the lake samples to a single epilimnion sample and using volunteer boats. LCRI provides fuel for volunteers boats.

Task	Cost	Details
Fuel for volunteer boat	$150	
mileage	$50	
shipping	$115	
Cascade Analytical lab	$112	(4 samples at 28.00/each)
UW Oceanography lab	$83	(4 samples ranging from $13.80 - $27.50 each)
CCNRD sampling staff time	$1,191	
CCNRD admin	$100	
PER SAMPLING EVENT TOTAL	**$1,801**	
ANNUAL COST	**$3602**	

Task 7. Weather data

Goals:
A key need for monitoring and understanding Lake Chelan is high quality weather data. This weather data (which would include air temperature, humidity, precipitation, solar radiation, windspeed/direction and barometric pressure) will be a key input in modeling and analyzing Lake Chelan behavior.

Currently there are a very limited number of such weather stations on the lake. Consequently we intend to both add to the professional grade weather stations on the lake and collect data from what we believe are the highest quality personal weather stations on the lake (both current and existing). This will provide a temporally and spatially dense series of key measurements.

Objectives:
Integration of weather data into water quality analysis is crucial to understanding the controls on Lake Chelan water quality. Currently we lack both strategic placement and the number of weather stations required to understand the impacts of weather, especially precipitation and wind, on Lake Chelan. Ultimately we need on the order of 5 professional grade weather stations from Sunset Marina to Stehekin and will continue to seek partners willing to fund such stations. We also completely lack Community Collaborative Rain, Hail and Snow Networkstations in the Lake Chelan watershed (CoCoRaHS ; https://www.cocorahs.org/). We will recruit CoCoRaHS participants to enhance our precipitation data in the watershed.

Once weather stations have been identified the data from these weather stations will be automatically ingested in the Lake Chelan database. Data will be QA/QC'ed and mapped to common terminologies/units so that all data can be cross-compared.

Data application:
Weather data is a key input to interpreting a wide range of Lake Chelan water quality data. For example, wind and changes in atmospheric pressure directly impact the internal and surface seiche of Lake Chelan. Without this information, our ability to model the lake will be severely limited.

Funding source:
Irrigation Technology and Control (ITC) is donating a professional grade weather station to the LCRI Sunset Marina monitoring station (~$4.5k value). This installation includes the upload capability for Internet streaming of the weather data and will be our first professional grade weather station on the water.

Funding requirements:
There are currently no funding requirements identified for weather data. Note that ingestions and archiving of weather data is part of the Data Management effort, provided mostly *pro bono* by Subsurface Insights, LLC (**SSI**). In addition, up-lake weather stations are a critical need, but additional planning is needed to fit new weather stations into the context of all other Lake Chelan monitoring needs.

Task 8. Data Management

Goals:
Design, implement and populate a database which will hold Lake Chelan data (including the data generated under this work plan). This database will facilitate data analysis and data visualization.

Objectives:

(3) Ingest data from the 1989 Lake Chelan water quality report into a relational database, followed by ingestion of at least all total phosphorus data for Lake Chelan including data from 2016 and 2017 and data from various environmental sensors placed in and around Lake Chelan (weather, water quality, water level).

(4) Make this data available through a web interface, mobile apps and APIs (Application Programming Interface) to interested parties for analysis and visualization

Data application:
This Task supports data preservation and usage for Tasks 1 through 7.

Funding source:
Work performed under this work plan will eventually generate hundreds megabytes to several gigabytes of data annually. It is essential to ingest, qa/qc and manage this data for the long term and, subsequent to such management, perform data analysis, visualization and modeling using these data. To date, activities and advice in that area have been provided *pro bono* by Subsurface Insights, LLC (Roelof Versteeg) and the Chelan County DNR. At least a very minimal level of funding is needed for SSI to accelerate development and defray operational expenses. The bulk of the work on the database will still be pro bono and we will seek additional funding supplement this request.

Funding requirement:
$3.5k to help defray a small fraction of SSI's *pro bono* contribution. Note that this is about 4% of our financial contributions. For a project of this sort, Data Management would typically be on the order of 15% of the available funds.

Task 9. Quality Assurance Project Plan

Goals/objectives:
Create an updated Quality Assurance Project Plan (QAPP) that directs the technical and quality assurance details of the work described in Tasks 1-8.

Funding Source/requirements:

This Task will be funded by the Chelan County PUD ($5k). Funding mechanism and are currently under discussion.

Task 10. Equipment Procurement

Goals/objectives:
Task 10 supports basic equipment needs for executing the work plan such as a down rigger for tracking depth while lowering the multiparameter probe and replacement of equipment such as the van Dorn sampler when it wears out.

Data application:
This task supports most of the data collection tasks.

Funding Sources:
This activity will be funded by combined financial resources (Appendix A).

Funding requirements:
~$5k per year. Funding requirements will vary year to year. In some cases, funds will be rolled over from one year to the next in order to purchase items that cost more than $5k.

Future directions

This work plan is predominantly focused on nutrient status of Lake Chelan and tributaries in the Wapato Basin and on the hydrodynamic features of the lake that if left unmonitored limit our ability to interpret the nutrient data (e.g. weather data, and the internal seiche of the lake). There are aspects of the nutrient status and hydrodynamics studies that need to be expanded for a full understanding of the lake and its watershed. These include atmospheric deposition and improved quantification of tributary inputs to the lake. In addition, there are three key areas currently not addressed: 1) Lake physiography (bathymetry and sub-bottom sediments) as a prerequisite for understanding the role of sediments in controlling nutrients and DDT. 2) Understanding the dynamics of invasive species in the lake, and 3) The fate and transport of DDT and PCB's. Lake Chelan Research Institute, in collaboration with the Lake Chelan Watershed Planning Unit and others is assessing both priorities and funding sources for expansion of current monitoring and initiation of new activities. Appendix D provides an overview of the stewardship and research activities that will contribute to our understanding of the lake and the current prioritization activities reflected in this work plan. Both tables in Appendix D are updated as needed and addition of new ideas is encouraged.

References

Newell, E. and Coffin, C., 2011, Lake Chelan Wapato Basin Total Phosphorus Total Maximum Daily Load, Water Quality Effectiveness Monitoring Report. Publication No. 11-03-049. Washington State Department of Ecology, Olympia, WA.

Patmont, C.R., G.J. Pelletier, E.B. Welch, D. Banton, and C.C. Ebbesmeyer, 1989. Lake Chelan Water Quality Assessment. Final Report to Washington State Department of Ecology, Contract No. C0087072. Publication No. 89-e36. www.ecy.wa.gov/biblio/89e36.html

RH2, 2016, Quality Assurance Project Plan, Lake Chelan Water Quality Monitoring Study. Agreement Number: WQC-2016-ChCoNR-00247. Washington State Department of Ecology.

RH2, 2017, Addendum to the Quality Assurance Project Plan, Lake Chelan Water Quality Monitoring Study. Agreement Number: WQC-2016-ChCoNR-00247. Washington State Department of Ecology.

Appendix A: Funding sources

Funding sources	***Available amount***				
	2017	***2018***	***2019***	***2020***	***2021***
Financial Resources:					
Washington State Department of Ecology (**WA DOE**): $20k (extension to Lake Chelan Centennial grant, expended June 30, 2017)	$ 20,000.00	$ 10,000.00	$ 10,000.00	$ 10,000.00	$ 10,000.00
City of Chelan (**CoC**): $20k/year for 5 years starting 2017	$ 10,000.00	$ 20,000.00	$ 20,000.00	$ 20,000.00	$ 20,000.00
Lake Chelan Reclamation District (**LCRD**): $10k for 2017, likely ongoing at ~$10 to $15k/year	$ 10,000.00	$ 10,000.00	$ 10,000.00	$ 10,000.00	$ 10,000.00
Chelan County (**CC**): $10k	$ 10,000.00	$ 10,000.00	$ 10,000.00	$ 10,000.00	$ 10,000.00
Cascadia Conservation District (**CCD**): $5k	$ 5,000.00	$ 5,000.00	$ 5,000.00	$ 5,000.00	$ 5,000.00
Lake Chelan Research Institute (**LCRI**): ~$4k (includes contribution from Campbell's Resort and private individuals)	$ 1,000.00	$ 4,000.00	$ 5,000.00	$ 5,000.00	$ 5,000.00
U.S. Bureau of Reclamation (**USBR**): ~$10k for analytical services	$ 2,500.00	$ 20,000.00	$ 20,000.00	$ 20,000.00	$ 20,000.00
Chelan County PUD	$ -	$ 5,000.00	$ -	$ -	$ -
Total Finanical Resources	***$ 58,500.00***	***$ 84,000.00***	***$ 80,000.00***	***$ 80,000.00***	***$ 80,000.00***
In-kind support:					
State Parks System (75%)/Sunset Marina (25%) (**SPS/SM**): $12k* for YSI EXO3 Multiparameter probe that is part of the Sunset Marina sewage pump out system	$ 12,000.00	$ -	$ -	$ -	$ -
State Parks System (75%)/Sunset Marina (25%) (SPS/SM) Annual consumable costs for EXO3.	$ 1,000.00	$ 1,000.00	$ 1,000.00	$ 1,000.00	$ 1,000.00
State Parks System (**SPS**): Fluidion, Inc. e. coli and total coliform detector (x2): $28k	$ 28,000.00	$ -	$ -	$ -	$ -
State Parks System (SPS): Annual consumable costs for Fluidion system; 75% of $4k	$ 3,000.00	$ 3,000.00	$ 3,000.00	$ 3,000.00	$ 3,000.00
Irrigation Technology and Control (**ITC**): Weather station and IOT connection for streaming of weather, CDT-10, and EXO3 data; $5.5k	$ 5,500.00	$ -	$ -	$ -	$ -
Oregon State University (**OSU**): Distributed Temperature Sensing System (~$20k rental value waived, except for $1187.50 funded from WA DOE Centennial Grant)	$ 8,812.00	$ 10,000.00	$ 10,000.00	$ 10,000.00	$ 10,000.00
U.S. Forest Service (**USFS**): Boat time for DTS install and periodic sampling of Lucerne Basin (approximate value: $7k)	$ 7,000.00	$ 3,500.00	$ 3,500.00	$ 3,500.00	$ 3,500.00
Pinnacle Surveying (PS): Use of RTK GPS with personel; $2k	$ 2,000.00	$ -	$ -	$ -	$ -
Lake Chelan Chamber of Commerce (**LCCC**): Keep It Blue Campaign Support (approximate value, $5k)	$ 5,000.00	$ 5,000.00	$ 5,000.00	$ 5,000.00	$ 5,000.00
Subsurface Insights, LLC (**SSI**): Database development and automated data collection support (approximate value: $20k)	$ 20,000.00	$ 20,000.00	$ 20,000.00	$ 20,000.00	$ 20,000.00
Isenhart Irrigation District (**IID**): $1k*	$ 1,000.00	$ 1,000.00	$ 1,000.00	$ 1,000.00	$ 1,000.00
Lake Chelan Research Institute (**LCRI**): Volunteer Labor ($21k, sample collection and planning unit activities only)	$ 21,000.00	$ 30,000.00	$ 30,000.00	$ 30,000.00	$ 30,000.00
Manson Chamber of Commerce (**MCC**): TBD	$ -	$ -	$ -	$ -	$ -
Port of Chelan County (**PCC**): Support for a facilitated meeting on enhancing growth of Lake Chelan Research Institute, value TBD	$ -	$ -	$ -	$ -	$ -
Total in-kind suppoert:	**$ 114,312.00**	**$ 73,500.00**	**$ 73,500.00**	**$ 73,500.00**	**$ 73,500.00**

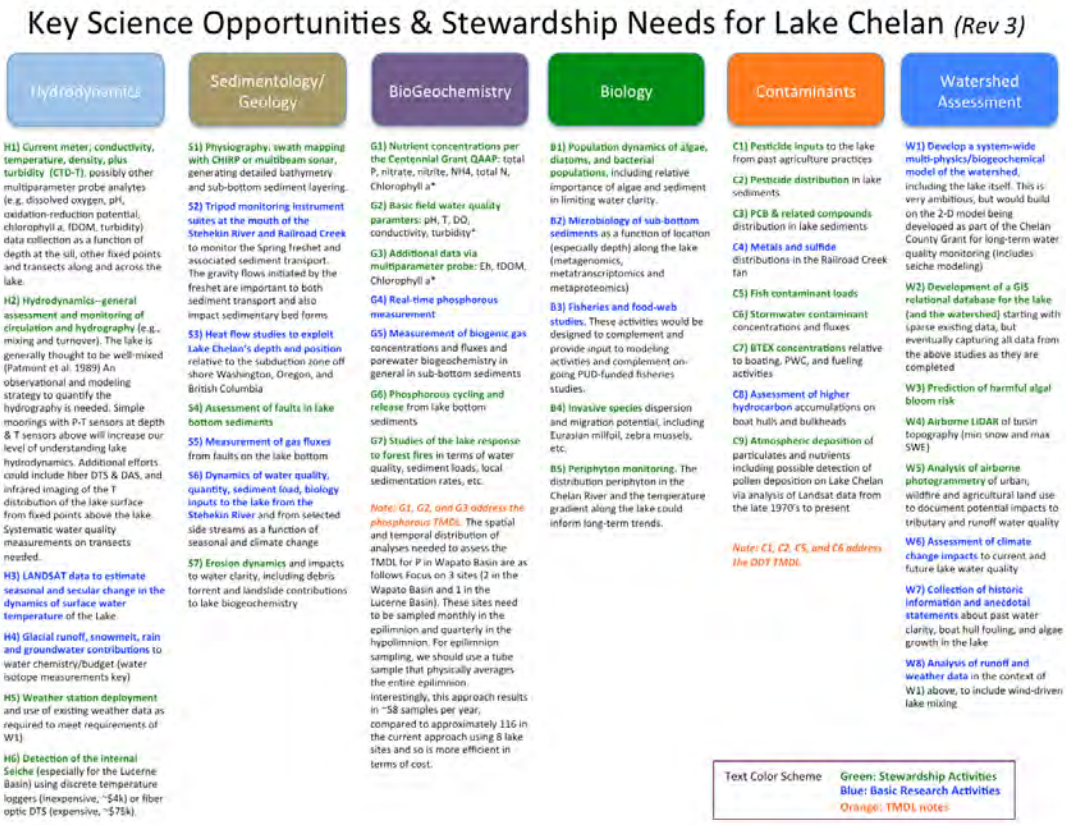
Appendix B. Location of High Frequency Monitoring Devices


Fiber Optic DTS north buoy
Fiber Optic DTS South Buoy
Mill Bay Boat Pumpout
Lake Chelan Reclamation District Water Intake
47LC2
Lookout Marina
ID water intake
Sunset Marina
Google Earth
Imagery Date: 5/7/2015 47°53'02.10" N 120°03'59.72" W elev 2020 ft eye alt 10.03 mi

Appendix C. Projected Expenditures By Task and Year

Projected Work Plan Expenditures By Year					
	2017	2018	2019	2020	2021
Tasks					
Task 1. Monthly Lake sampling for field parameters/nutrients	$ 20,000.00	$ 36,524.00	$ 40,000.00	$ 42,500.00	$ 45,000.00
Task 2. Tributary sampling	$ 5,000.00	$ 10,000.00	$ 10,000.00	$ 10,000.00	$ 10,000.00
Task 3. High frequency sampling/monitoring	$ 10,500.00	$ 14,400.00	$ 15,000.00	$ 15,000.00	$ 15,000.00
Task 4. BTEX/gasoline analyses	$ 1,760.00	$ 2,500.00	$ 2,500.00	$ 2,500.00	$ 2,500.00
Task 5. Mobile field parameters	$ 1,500.00	$ 2,200.00	$ 3,000.00	$ 3,000.00	$ 3,000.00
Task 6. Uplake Control Samples	$ 3,602.00	$ 7,500.00	$ 7,500.00	$ 7,500.00	$ 7,500.00
Task 7. Weather data	(in-kind support)				
Task 8. Data Management	$ 3,500.00	$ 3,500.00	$ 3,500.00	$ 5,000.00	$ 5,000.00
Task 9. Quality Assurance Project Plan	$ 3,000.00	$ 2,000.00			
Task 10. Equipment Procurement	$ 3,000.00	$ 5,000.00	$ 5,000.00	$ 5,000.00	$ 5,000.00
Total	***$ 51,862.00***	***$ 83,624.00***	***$ 86,500.00***	***$ 90,500.00***	***$ 93,000.00***
Available funds:	$ 58,500.00	$ 84,000.00	$ 80,000.00	$ 80,000.00	$ 80,000.00
Reserve or Deficit	$ 6,638.00	$ 376.00	$ (6,500.00)	$ (10,500.00)	$(13,000.00)
Original Core Tasks are 1, 2, & 8: total	$ 28,500.00	$ 50,024.00	$ 53,500.00	$ 57,500.00	$ 60,000.00

Appendix D. Key Science Opportunities and Stewardship Needs for Lake Chelan and Identification of Highest Priority Stewardship Activities



Highest priority stewardship activities for Lake Chelan Based on LCRI Board Input in Nov 2017

1. ***Phosphorous TMDL (G1, G2, G3; fundamental data needed to track ultraoligotrophic [?] status of Lake Chelan)***
   - P and other nutrient sampling and analysis (3 lake sites sampled on a monthly basis plus tributary snapshot)
2. ***Hydrodynamics (H1, H2, H6; fundamental information needed to interpret phosphorous TMDL)***
   - Thermal/EC structure and dynamics
     - Internal seiche
     - Electrical conductivity structure
   - Measurement of current at the sill and other locations
3. ***Physiography (S1, Prerequisite for sediment role in phosphorous and DDT TMDL)***
   - Bathymetry
   - Sub-bottom sediments
4. ***Invasive species (B4, Potential to irreversibly alter lake biology and ascetics)***
   - Plants (Eurasian Milfoil and others)
   - Bivalves (Zebra mussels and others)
5. ***DDT TMDL (C1, C2, C5, C6, Assess need to intervene in DDT biomagnification)***
   - Sediment distribution
   - Agricultural drain outflows
   - Remedial strategies