2-1-2017

Waughop Lake Management Plan Grant G1400475

James E. Gawel
University of Washington Tacoma, jimgawel@u.washington.edu

Recommended Citation
Gawel, James E., "Waughop Lake Management Plan Grant G1400475" (2017). *SIAS Faculty Publications*. 861.
https://digitalcommons.tacoma.uw.edu/ias_pub/861

Waughop Lake Management Plan
Grant G1400475

Prepared for
City of Lakewood, Washington
Prepared by
Brown and Caldwell
February 2017

This page intentionally left blank.

Waughop Lake Management Plan
Grant G1400475

Prepared for

City of Lakewood, Washington

Prepared by

Brown and Caldwell

February 2017

Table of Contents

List of Figures

List of Tables

List of Abbreviations

°C	degree(s) Centigrade
µg/L	microgram(s) per liter
µS/cm	microsiemen(s) per centimeter
ac-ft	acre-foot/feet
alum	aluminum sulfate
As	arsenic
BC	Brown and Caldwell
$CaCO_3$	calcium carbonate
CERES	Clouds and the Earth's Radiant Energy System
City	City of Lakewood
cm	centimeter(s)
County	Pierce County
Cu	copper
CWSRF	Clean Water State Revolving Fund
DO	dissolved oxygen
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
FCZD	Flood Control Zone District
ft/ft	feet/foot vertical per 1-foot horizontal
ft^2	square foot/feet
g	gram(s)
g/m^2-yr	gram(s) per square meter per year
GIS	geographic information system
GPS	Global Positioning System
IEH	IEH Aquatic Research Analytical Laboratory
in.	inch(es)
kg	kilogram(s)
kPa/C	Pascal(s) per degree(s) Centigrade
L	liter(s)
LID	Lake Improvement District
LMD	Lake Management District
LMP	lake management plan
m	meter(s)
m^2	square meter(s)
m^3	cubic meter(s)
mg/kg	milligram(s) per kilogram
mg/L	milligram(s) per liter
mg/m^3	milligram(s) per cubic meter
mL	milliliter(s)
N/A	not applicable
NALMS	North American Lake Management Society
NASA	National Aeronautics and Space Administration
ND	not detected
NRCS	Natural Resources Conservation Service
Pb	lead
PCD	Pierce Conservation District
ppb	part(s) per billion
QAPP	Quality Assurance Project Plan
Rn	mean net radiation
SEPA	State Environmental Policy Act
SRP	soluble reactive phosphate
S.U.	standard unit(s)
SWC	Stormwater Calculator
TN	total nitrogen
TP	total phosphorus
TPCHD	Tacoma-Pierce County Health Department
TSI	Trophic State Index
ULID	Utility Local Improvement District
UPS	University of Puget Sound
USDA	U.S. Department of Agriculture
UWT	University of Washington, Tacoma
VEM	Vigorous Epilimnetic Mixing
WAC	Washington Administrative Code
WSU	Washington State University
WTP	willingness to pay

This page intentionally left blank.

Executive Summary

Waughop Lake is the centerpiece of the popular Fort Steilacoom Park in the city of Lakewood, Washington. The park is on state-owned land that is leased to the City of Lakewood (City). Waughop Lake has a long history of cyanobacteria (i.e., blue-green algae) blooms that severely limit use of the lake. The City has made the protection and restoration of Waughop Lake a high priority.

In 2014, the City received a grant from the Washington State Department of Ecology (Ecology) to develop a lake management plan (LMP) for Waughop Lake. The overall goal of the LMP is to develop strategies to improve and protect the lake uses impaired by excess nutrients. The City retained Brown and Caldwell (BC) and the University of Washington Tacoma (UWT) to help develop the LMP.

BC and UWT prepared a Quality Assurance Project Plan (QAPP) to guide data collection in support of the Waughop LMP. The QAPP included monitoring the quality of the lake water, lake bottom sediment, stormwater, and groundwater to identify and quantify sources of phosphorus loading and support the evaluation of management measures.

The City provided opportunities for public stakeholder input during LMP development. The following bullets summarize the stakeholder outreach activities:

- Participated in an open house and farmer’s market to inform stakeholders about the LMP and learn about potential concerns (July and September 2014)
- Distributed questionnaires to solicit stakeholder input on concerns and potential management objectives for Waughop Lake (summer through fall 2014)
- Provided input to UWT’s study to assess the public’s willingness to pay for improvements to Waughop Lake water quality
- Periodically posted Waughop LMP information on the City website and provided LMP information to local newspapers
- Briefed the City Council on the lake monitoring results and LMP recommendations during two public meetings (February and September 2016)
- Briefed the City Parks and Recreation Advisory Board on the monitoring results and potential measures (September 2016)
- Presented the lake characterization results and draft LMP recommendations to the Chambers-Clover Watershed Council (November 2016)
- Solicited stakeholder comments on the draft LMP (Appendix E summarizes the comments and responses)

The monitoring program was conducted from October 2014 – October 2015. The monitoring found that phosphorus is the limiting nutrient for cyanobacteria blooms and the internal cycling of phosphorus from the lake bottom sediment to the water column is the largest source. Based on the monitoring results and stakeholder input, the City confirmed that the primary objective for the Waughop LMP should be to minimize the frequency of cyanobacteria blooms.

The project team evaluated a wide range of potential lake management measures and identified several that appear suitable for Waughop Lake. Table ES-1 below summarizes the estimated costs and potential benefits of these measures.

As noted in Table ES-1, dredging of lake bottom sediment would provide the greatest long-term benefit but would also have a high initial cost and extensive permitting requirements. Sediment cores would need to be collected throughout the lake and analyzed to develop a more accurate estimate of the volume to be dredged, determine sediment dewatering and disposal requirements, and refine the construction cost estimate. Dredging could take 6 to 8 months and have temporary impacts on park visitors and wildlife. Securing the funds needed for dredging may be difficult, especially if costs are closer to the high end of the range shown in Table ES-1. It could take several years or more to complete additional sediment characterization, secure funding, obtain permits, perform dredging, and properly dispose of the sediments.

Sediment phosphorus inactivation using whole-lake alum treatment would quickly reduce phosphorus concentrations in the lake, reduce the release of phosphorus from the sediment, and reduce cyanobacteria blooms. Compared to dredging, alum treatment has a much lower initial cost, less intensive data collection and permitting requirements, and less disruption for park visitors and wildlife (see Table ES-1). However, the benefits of alum treatment decline over time, so treatments would need to be periodically repeated. In addition, alum treatment could increase macrophyte growth by allowing sunlight to reach deeper into the lake.

Aeration of the lake bottom would help decrease the anoxic conditions that enable phosphorus release from sediments, while vertical mixing would disrupt cyanobacteria growth and favor benign algal species.

A pump and treat system could be installed to remove phosphorus from lake water using a coagulation facility or a constructed wetland treatment system. The estimated cost for this measure assumes 3 to 10 acres of upland area would be made available for the treatment system at no cost. Because of treatment capacity limitations, pump and treat systems are expected to be less effective than the other measures listed in Table ES-1, so they are not recommended at this time.

Table ES-1. Management Measures to Minimize Cyanobacteria Blooms in Waughop Lake

Option	Planning-level cost estimates		20-year costs (capital + ongoing)	Water quality benefit	How soon will water quality benefits occur?	How long will water quality benefits last?	Other potential benefits?	Other potential impacts/costs?
	Initial	Ongoing						
Dredging: (hydraulic, "wet" excavation, or "dry" excavation)	Costs could vary based on dredging and disposal methods. Onsite disposal ranges from $2.7M–$12.0M. Offsite disposal ranges from $8.5M–$17.9M.	None	$2.7M–$17.9M, depending on disposal and treatment requirements	Highest. Would remove ~100 years of phosphorus enriched sediment.	< 1 year	Long term	Increased lake depth, more groundwater inflow, more fish habitat.	Permitting challenges. Habitat disturbance during dredging. Equipment staging on shoreline. Odor from dredge spoils. Onsite dewatering/ disposal would require large area. Truck traffic (if offsite disposal is necessary.)

Table ES-1. Management Measures to Minimize Cyanobacteria Blooms in Waughop Lake

Option	Planning-level cost estimates		20-year costs (capital + ongoing)	Water quality benefit	How soon will water quality benefits occur?	How long will water quality benefits last?	Other potential benefits?	Other potential impacts/costs?
	Initial	Ongoing						
Phosphorus inactivation with whole-lake treatment	$210k for prep and initial treatment.	$120k every 3–10 years.	$0.7M (assumes follow-up treatment every 5 years)	High initially, slow decline over time.	Immediate	3–10 years	Minimal infrastructure, no conflicts with other lake uses.	Could increase macrophyte growth. Would need to be repeated every 3–10 yrs.
Lake bottom water aeration and mixing	$1.9M	$20k/year	$2.3M	Medium–high. Would increase DO, reduce phosphorus release from sediment, disrupt cyanobacteria blooms. Could be configured to include alum emitter.	2 years	Long term	Few conflicts with other uses. Increased DO should improve fish habitat.	Blower building would be required. Energy use.
Pump and treat: chemical treatment	$1.5M	$80k/year	$3.1M	Medium.	1 year	Long term	Flexible operation. Higher treatment capacity than wetland treatment system. Learning opportunity for college students.	Would require ~3 acres of land. Temporary impacts during construction.
Pump and treat: constructed wetlands	$3.1M	$100k/year	$5.1M	Medium (less than chemical treatment).	1 year	Long term	Flexible operation. Increased habitat for birds and other wildlife. Learning opportunity for college students.	Would require ~9 acres of land. Temporary impacts during construction.

The City does not currently have any funds to implement this LMP and implementation will depend on its ability to secure funding from other sources such as state budget allocations and grants (see Section 6). Therefore, the City proposes a phased approach for implementing this LMP, as described below.

Phase 1 would consist of a whole-lake alum treatment to remove phosphorus from the water column and inactivate phosphorus in the sediment, thereby reducing the potential for cyanobacteria blooms. The City (or partners) would monitor the lake to estimate the effectiveness and longevity of the alum treatment. During this phase, the City would collect the additional sediment data needed to refine the construction cost estimates and support permit applications for dredging. The City would also identify and pursue potential funding sources for long-term implementation.

Phase 2 would involve dredging to remove phosphorus-enriched sediment from the lake bottom, provided that the City can secure the necessary funds and permits. The lake monitoring study found that bottom sediment is by far the largest source of phosphorus contributing to cyanobacteria blooms. Dredging is expected to be the most effective long-term measure for reducing cyanobacteria blooms because it would remove sediments that have been accumulating because of farming and other human activities over the past ~100 years. Funding for dredging would be pursued along with collection of information regarding public support for improved lake use.

If the City cannot secure the funds needed for dredging and the Phase 1 monitoring indicates that alum treatment is likely to last at least several years, Phase 2 may consist of a follow-up whole-lake alum treatment. Conversely, if the City cannot secure sufficient funds for dredging and Phase 1 monitoring suggests that alum treatment benefits are short-lived, Phase 2 could include a pilot study to evaluate whether a bottom aeration and vertical-mixing system would significantly reduce phosphorus release from bottom sediments and disrupt cyanobacteria in the water column. If the pilot results are promising and the necessary capital and operating funds can be obtained, Phase 2 could include installation of a full-scale bottom aeration and mixing system.

Section 1

Introduction

Waughop Lake is a small lake located in the city of Lakewood, Washington (see Figure 1-1, below) and is the centerpiece of the popular Fort Steilacoom Park. The lake is used for fishing (for stocked fish), model boat racing, kayaking, canoeing, and bird watching. The shoreline area is heavily used by hikers, joggers, and dog walkers.

The lake has a surface area of approximately 33 acres, a mean depth of 7 feet, an approximate volume of 271,365 cubic meters (m^3) and catchment area of 497 acres (Ecology 1979). The contributing surface drainage area for Waughop Lake is about 217 acres. The Pierce College campus covers about 66 acres. Southwest of the lake is a residential area of approximately 130 acres, where the homes are served by septic systems.

Waughop Lake sits in a basin surrounded by slopes to the north, south, and west, with open flat meadows to the east. No creeks or other natural surface water channels flow into the lake. Stormwater runoff from a portion of the Pierce College campus is conveyed through a pipeline to the lake. There are no natural or man-made outlets to the lake; water leaves the lake via seepage and evaporation.

Waughop Lake is a glacial kettle lake that appears to be in direct contact with the shallow groundwater-flow system (see Figure 1-2, below). The surficial soils that surround the lake were formed in permeable recessional outwash material. Low-permeability glacial till underlies the surficial outwash soil and impedes the downward movement of water. Precipitation that infiltrates the surficial outwash soils tends to pond on top of the till, forming the A-1 aquifer, which provides much of the groundwater discharge to Waughop Lake (Tepper 2013).

Waughop Lake has a long history of toxic cyanobacteria blooms including species that produce the liver toxin Microcystin and the neurotoxin Saxitoxin. Cyanobacteria blooms have the potential to release toxic substances that are harmful to people, pets, and wildlife. The Tacoma-Pierce County Health Department (TPCHD) issues health advisories when potentially toxic blooms are observed to reduce the risk of adverse impacts to lake users. TPCHD algae advisories have been common for Waughop Lake during the past 10 years. In June 2010, TPCHD issued an advisory not to eat fish from the lake (TPCHD 2016). For a short period in 2011, toxin concentrations were so high that TPCHD closed the lake to all uses (City 2012).

Since 2007, toxicity data have been collected and maintained by Ecology on its Washington State Toxic Algae website. Of the 165 water samples collected from Waughop Lake from July 5, 2007, to May 25, 2016, 131 exceeded 6 micrograms per liter (µg/L), the state recreation guideline value for Microcystin (Ecology 2016).

Cyanobacteria blooms in surface waters are often associated with elevated nutrient loadings. Phosphorus is typically the nutrient that limits cyanobacteria growth in western Washington lakes.

Waughop Lake's water quality problems likely began more than 100 years ago when the surrounding area was first used to raise livestock and grow crops for the nearby state mental hospital. Manure and other agricultural wastes were discharged into the lake from about 1900–65 and likely contributed to the thick layer of fine, nutrient-rich sediment that now covers the lake bottom (Tepper 2013; LaFontaine 2012; City 2012). The thick bottom sediment layer has possibly reduced the rates of groundwater flow through the lake (see Figure 1-2).

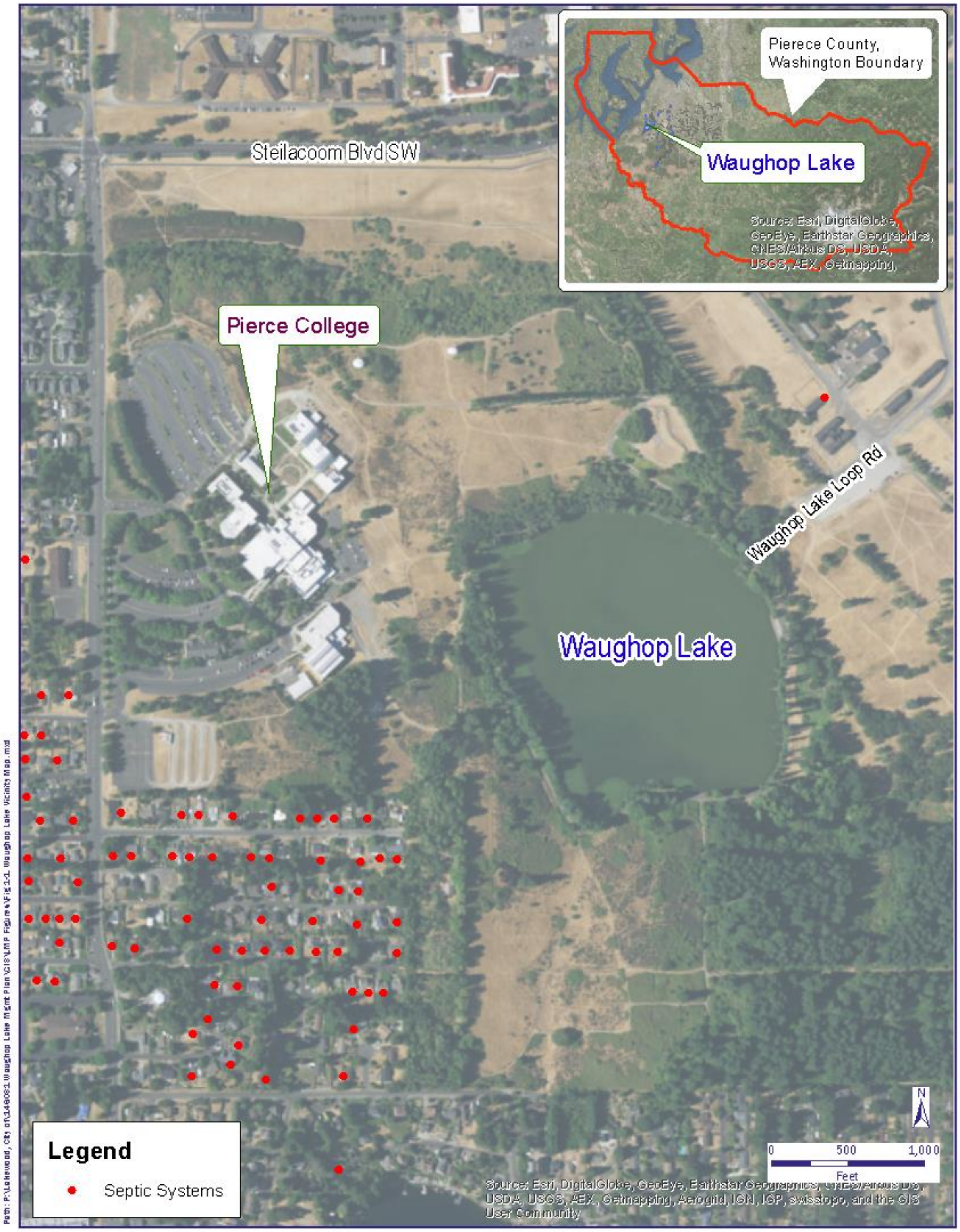


Figure 1-1. Areal map of Waughop Lake

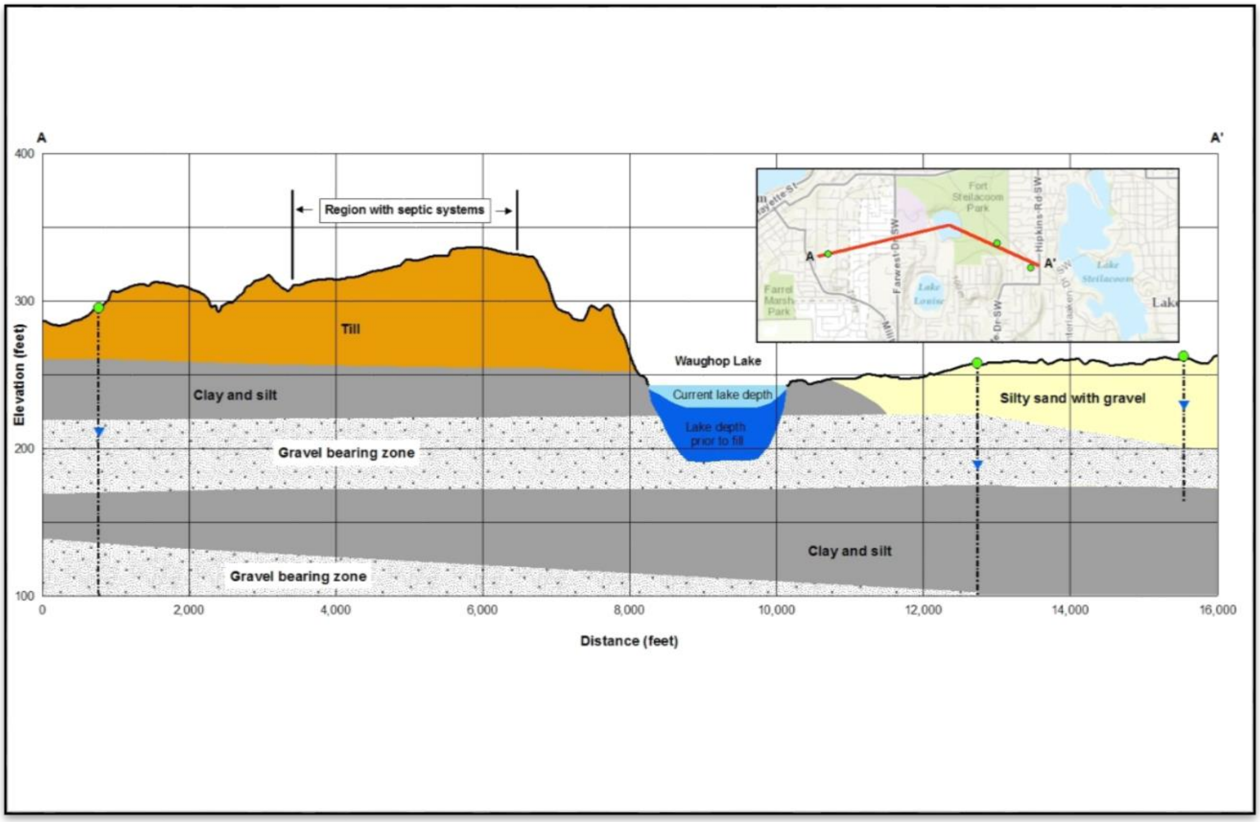


Figure 1-2. Regional geologic cross-section of Waughop Lake

1.1 Previous Water Quality Studies

Water quality studies have been conducted on Waughop Lake since the late 1960s. In 1968, the Pierce County Parks Department commissioned a biological survey of Waughop Lake to inform the Pierce County Parks Department in planning future uses of the lake. This study showed that the lake was rich in plant nutrients and capable of supporting numerous populations of rooted plants in addition to planktonic and filamentous algae (Carsner 1968).

Subsequent to this study, it became evident that the lake conditions were limiting the recreational potential of the lake. The lake was reported to be shallow and turbid with summer algae blooms common, and visibility often restricted to shallow depths of 3 feet or less. The first recorded algal bloom occurred in 1973 (Tepper 2013). In 1978, the Pierce County Parks Department commissioned a study to evaluate treatment options for the lake. The study found abundant aquatic weed growth along much of the shoreline area and a thick layer of organic sediments on the lake bottom (Entranco 1978). Although a remediation plan was proposed, no remedial action was undertaken following this study due to conflicts in ownership lease rights and the possible acquisition of the property between the Washington State Department of Natural Resources and U.S. Department of Interior, Bureau of Land Management Division (City 2012).

1.1.1 Groundwater

As noted above, Waughop Lake is a kettle lake that appears to extend below the elevation of the shallow groundwater-flow system. The Lakewood Water District monitors water elevations in

Waughop Lake to serve as an indicator of groundwater elevations in the shallow A-1 aquifer. However, prior to conducting groundwater monitoring for this project, the City was not aware of any groundwater quality data for the shallow aquifer. Previous groundwater quality sampling focused on the deeper aquifers.

1.1.2 Water Column

Water column monitoring of Waughop Lake has been conducted since 2007 by the University of Washington Tacoma (UWT), Ecology, Pierce Conservation District (PCD), and TPCHD. These studies have included monitoring for temperature, dissolved oxygen (DO), pH, conductivity, alkalinity and Secchi depth to measure water transparency. The lake has also been sampled for nutrients, including total phosphorus (TP), and algae. The current PCD monitoring program for Waughop Lake includes the sampling of additional analytical constituents, such as nitrates and nitrites.

The results from these previous water quality monitoring efforts and personal communication with Jim Gawel of UWT to Mike Milne of BC in May 2014 suggest that Waughop Lake is eutrophic.

1.1.3 Sediment

Gawel and Mason (2008), Tepper (2013) and Gawel et al. (2013) documented sediment quality in Waughop Lake indicating that the top meter (m) of the lake bottom sediments have elevated levels of TP, as well as other harmful constituents including lead (Pb), copper (Cu), arsenic (As), and other metals.

1.1.4 Waterfowl

Waughop Lake provides habitat for several species of waterfowl and other bird species. LaFontaine (2012) reported that more than 40 ducks, coots, and Canada geese were observed on the lake during late spring and early summer.

1.2 Lake Management Plan

In 2014, the City received a grant from Ecology to prepare the Waughop Lake Management Plan (LMP). The grant agreement states that “Waughop Lake has excess nutrients in the water and sediment, which results in frequent toxic algae blooms. A lake management plan will help determine what efforts are needed to improve water quality and restore the lake to a more usable condition” (Ecology 2014). Thus, the overall goal of this LMP is to develop strategies to improve and protect the lake uses impaired by excess nutrients, rather than attain specific numeric water quality targets.

The City selected the Brown and Caldwell (BC) team, including UWT, to help develop the LMP. UWT staff performed the field monitoring and sampling. IEH Aquatic Research Analytical Laboratory (IEH) in Seattle, Washington, analyzed the groundwater, surface water, and sediment samples for nutrients. The remaining parameters were analyzed by the laboratory at UWT.

This LMP provides a summary of the monitoring activities that were conducted to characterize Waughop Lake water quality and identify and quantify nutrient sources that are affecting the lake. The LMP also identifies actions toward achieving the City’s goals for the lake including recommendations for appropriate source control and/or treatment measures, including an implementation strategy.

Section 2 summarizes the results of the monitoring program. Sections 3 and 4 summarize the lake water and nutrient budgets, respectively. Section 5 describes the management measures and Section 6 discusses how the City may implement the measures.

Section 2

Monitoring Results

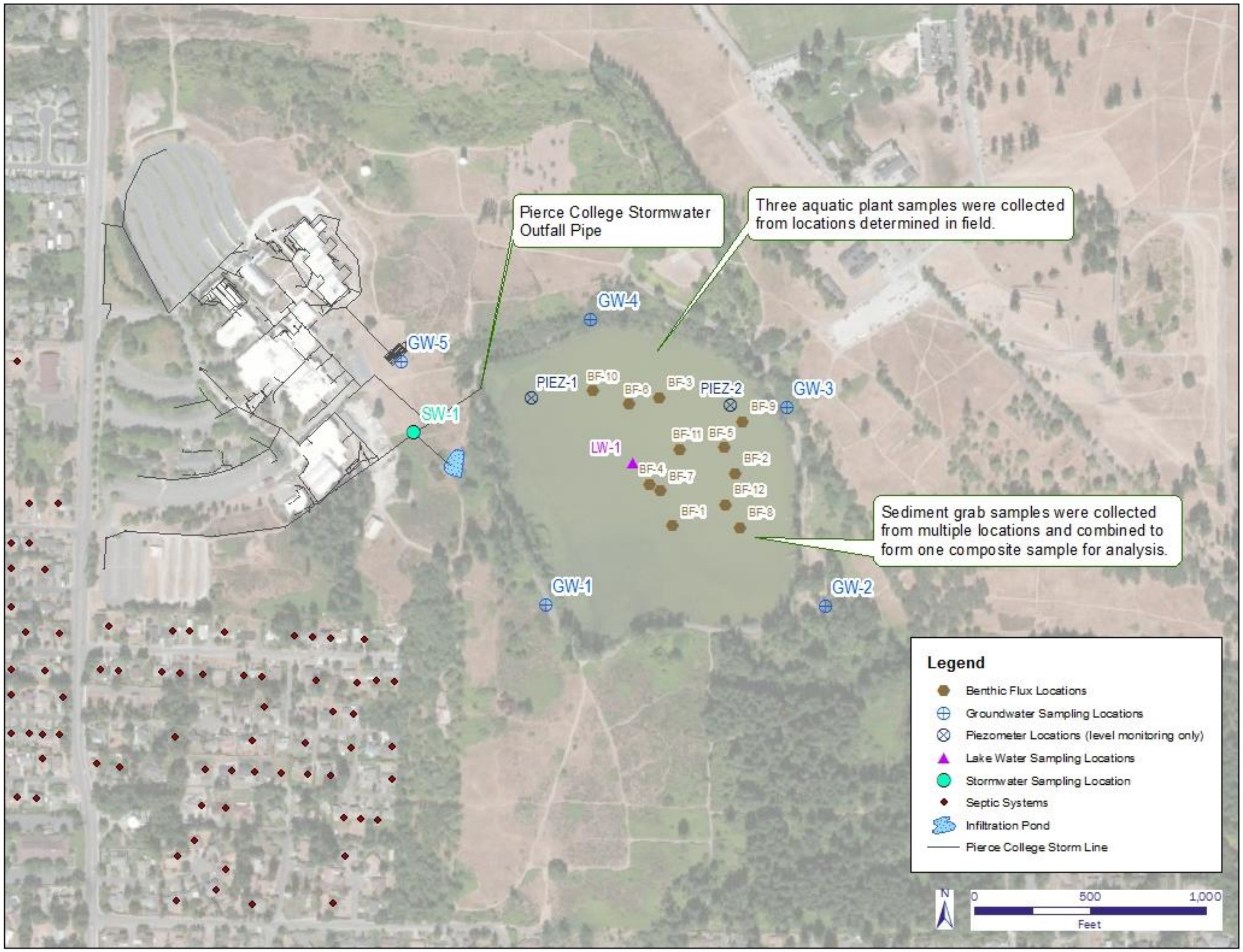
A QAPP was developed to guide the collection of field data needed to develop the Waughop LMP. The QAPP called for a streamlined monitoring program to fill key data gaps while keeping within the limited budget that was allocated for monitoring and modeling. The overall goal was to obtain a broad understanding of the watershed processes and lake water and nutrient budgets, as well as the lake management measures that could be effective. The QAPP noted that additional monitoring and modeling may be needed to support the design and implementation of specific lake management measures (BC 2014). Ecology reviewed and approved the QAPP in October 2014.

2.1 Water Quality Monitoring Activities

Field data for the Waughop LMP were collected from October 2014–15, including:

- Four rounds of groundwater sampling in five monitoring wells installed around the lake
- Eighteen rounds of lake water quality vertical profiling
- Seventeen rounds of water sampling at one location in the lake
- One round of aquatic plant sampling at 12 locations during maximum plant growth
- One round of lake bottom sediment sampling at 12 locations, made into one composite sample
- Twelve rounds of benthic flux sampling at various locations throughout the lake during the summer months
- Four rounds of storm event sampling from one location in the maintenance hole
- Year-round monitoring of waterfowl on a monthly basis

Figure 2-1 below shows the monitoring locations. Tables 2-1 and 2-2 list the LMP monitoring parameters and frequencies, respectively. Table 2-3 lists the minimum, average, and maximum observed values for key sample parameters. Appendix A provides copies of the field sheets, Appendix B provides copies of the laboratory results, and Appendix C provides copies of the monitoring logs and geologic cross-section diagrams.



Pierce College Stormwater Outfall Pipe

Three aquatic plant samples were collected from locations determined in field.

Sediment grab samples were collected from multiple locations and combined to form one composite sample for analysis.

Figure 2-1. Waughop LMP monitoring locations

Table 2-1. Waughop Lake Sampling Locations and Constituents

Sample type	Site ID	Level	TP	TN	Alkalinity	SRP	% solids	Particle size	Phytoplankton	Zooplankton	Chlorophyll-a	Water temperature	pH	DO	Conductivity	Transparency (Secchi depth)	Macrophyte species identification	Biomass estimates
Groundwater	GW-1, GW-2, GW-3, GW-4, GW-5	✓	✓									✓ [a]	✓ [a]	✓ [a]	✓ [a]			
Lake/ groundwater	Piez-1, Piez-2	✓																
	LW-1	✓	✓ [b]	✓ [b]	✓	✓ [b]			✓	✓	✓	✓	✓	✓	✓	✓		
Aquatic plants	Plant-1, Plant-2, Plant-3		✓	✓													✓	✓
Lakebed sediment	Sed-1		✓	✓			✓	✓										
Benthic flux (BF)	BF-1 to BF-12 [c]		✓	✓ [d]		✓						✓	✓	✓	✓			
Stormwater	SW-1		✓	✓		✓ [e]												

a. *These parameters were monitored during purging and were recorded during sample collection. In addition, turbidity was monitored during purging only.*

b. *TP, TN, and SRP were sampled by IEH. Copies of the laboratory reports showing these results are included in Appendix B. The remaining parameters were sampled by the UWT field equipment and lab.*

c. *The QAPP called for 4 benthic flux sample locations. Instead, 12 sample locations were sampled throughout the summer months.*

d. *Benthic flux samples were sampled for TN, which was not called for in the QAPP.*

e. *Stormwater samples were sampled for SRP, which was not called for in the QAPP.*

Table 2-2. Waughop Lake Sampling Locations and Frequencies

Media	Sampling location	Methods	Frequency
Groundwater	5 shoreline monitoring wells (GW-1, GW-2, GW-3, GW-4, and GW-5)	• Purge then collect grab sample using pump	• Quarterly
Waughop Lake water	LW-1: 1 location in the middle of the lake	• In-situ vertical (depth) profiling using datasonde • Grab sampling from surface and bottom [a]	• Twice per month during the summer months • Monthly during the remainder of the year
Aquatic plant	3 locations throughout the lake (Plant-1, Plant-2, Plant-3)	• Visual, plant rake	• Once during maximum plant growth (September 2015)
Lakebed sediment	3 grab sample locations combined to form 1 composite sample (Sed-1)	• Use clamshell sampler to collect 1 composite sample from each area	• Once during summer
Benthic flux	12 locations throughout lake (Flux-1–Flux-12) [b]	• Datasonde and grab (pump)	• During July, August, and September 2015
Stormwater	1 location from the Pierce College storm drainage line (SW-1)	• Grab sample	• 4 storm events [c]

a. *Lake water depth profile and grab samples were measured twice in May instead of once.*

b. *The QAPP called for 4 benthic flux sample locations. Instead, 12 sample locations were sampled throughout the summer months.*

c. *The QAPP called for up to 6 storm event samples. Because of few storms occurring during the monitoring period, only 4 storms were sampled.*

Table 2-3. Waughop Lake Water Quality Results for Key Parameters

Sample type	Location	TP (mg/L)			SRP (mg/L)			TN (mg/L-nitrogen)			N:P ratio			Chlorophyll-a (mg/m^3)			Secchi depth (m)		
		Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum
Groundwater	GW-1	0.01	0.03	0.08	0.004	0.01	0.01	1.68	3.56	6.95	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	GW-2	0.02	0.04	0.08	ND	0.002	0.003	0.67	1.64	3.82	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	GW-3	0.045	0.05	0.06	0.002	0.01	0.02	0.66	0.93	1.32	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	GW-4	0.001	0.003	0.04	ND	ND	ND	0.16	14.3	29.2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	GW-5	0.02	0.02	0.04	0.01	0.01	0.02	0.56	0.69	0.69	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Lake water	LW-1 (surface)	0.03	0.08	0.17	ND	0.01	0.02	0.99	1.69	2.42	12.0	23.0	40	4.72	37.0	110	0.43	1.10	1.98
	LW-1 (bottom)	0.05	0.08	0.14	ND	0.005	0.02	1.04	1.61	1.96	14.0	20.0	25	4.58	33.0	80.0			
Benthic [a]	Benthic Flux-1 to Benthic Flux-12 (2 hour)	0.07	0.40	1.99	ND	0.01	0.12	1.44	4.40	13.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Benthic Flux-1 to Benthic Flux-12 (24 hour)	0.04	1.59	10.0	ND	0.01	0.11	1.73	10.0	52.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Benthic Flux-1 to Benthic Flux-12 (48 hour)	0.07	5.73	43.4	0.003	0.04	0.19	0.52	12.0	77.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Stormwater	SW-1	0.03	0.13	0.37	0.0	0.04	0.14	0.19	0.61	0.93	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Notes:

Average values were calculated using half of the reporting limit for any sample results below the reporting limit.

ND = not detected.

a. Benthic Flux-5 was not included in this statistical summary due to a large amount of sediment material that entered into the sample.

2.2 Data Validation

As discussed in Section 1, the City prepared a QAPP to guide collection of the data needed to develop the Waughop LMP. The QAPP described in detail the following key elements of the sampling program:

- Goal and objectives for the LMP and summarizing the data needed to meet the project objectives
- Quality objectives pertaining to precision, bias, and lower reporting limits necessary to meet project objectives - Other considerations of quality objectives included representativeness and completeness.
- Field sampling and measurement procedures - The method(s) selected for this sampling and monitoring program had performance characteristics that met the measurement quality objectives for precision, bias, and sensitivity.
- Quality control (QC) measures that were integrated within the laboratory and field, as well as corrective actions.
- Data management procedures, including carefully maintaining field and laboratory analytical data from production to final use and archiving.
- Data review, verification, and data quality (usability) assessment

2.3 Groundwater Sample Results

Five shallow groundwater monitoring wells were installed around the lake (see Figure 2-1 above and Attachment C for copies of the monitoring well logs). Each groundwater well was sampled four times throughout the monitoring period: December 2014, February 2015, May 2015, and August 2015 (see Attachment A for copies of the field sheets). The August 2015 sample for GW-5 was collected with a bailer because the peristaltic pump was unable to draw enough water for a sample. The bailer was used instead, which caused significant turbidity in the sample, and yielded suspiciously high TP results. In September 2015, GW-5 was resampled with a peristaltic pump and yielded TP results that were comparable to the results observed from previous sampling events. The August 2015 sample results from GW-5 are thus omitted from this evaluation.

As shown in Table 2-3 above, the TP concentrations in the groundwater monitoring wells ranged from 0.001 to 0.080 milligram per liter (mg/L). The average TP concentration for the five groundwater wells combined was 0.032 mg/L. The narrative water quality criterion for TP is 0.02 mg/L. Figure 2-2 shows the TP concentrations measured in each monitoring well.

The soluble reactive phosphate (SRP) concentrations in the groundwater monitoring wells ranged from non-detect (less than 0.001) to 0.016 mg/L. The average SRP concentration for the five groundwater wells combined was 0.006 mg/L (see Table 2-3). Figure 2-3 below shows the SRP concentrations that were measured in each monitoring well.

Concentrations in groundwater wells surrounding the lake acted as an indicator of possible external sources of TP other than lake bottom sediments and were more accurately determined as advective processes.

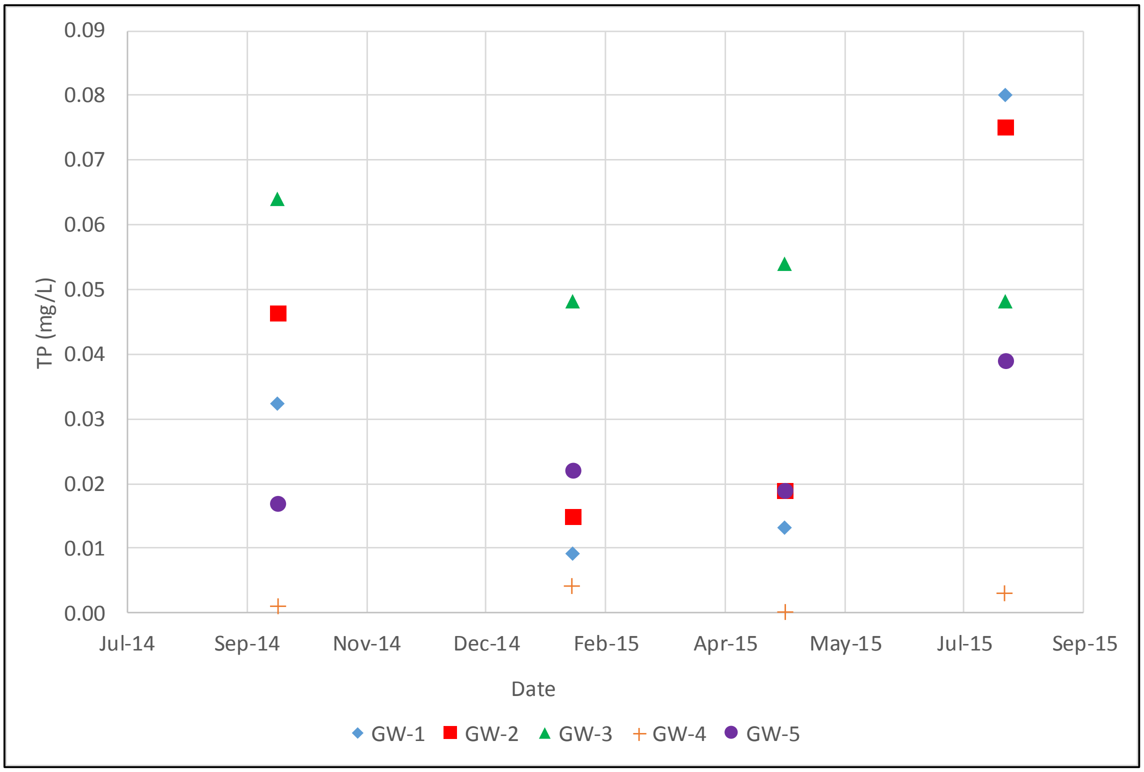


Figure 2-2. TP concentrations in groundwater samples collected near Waughop Lake

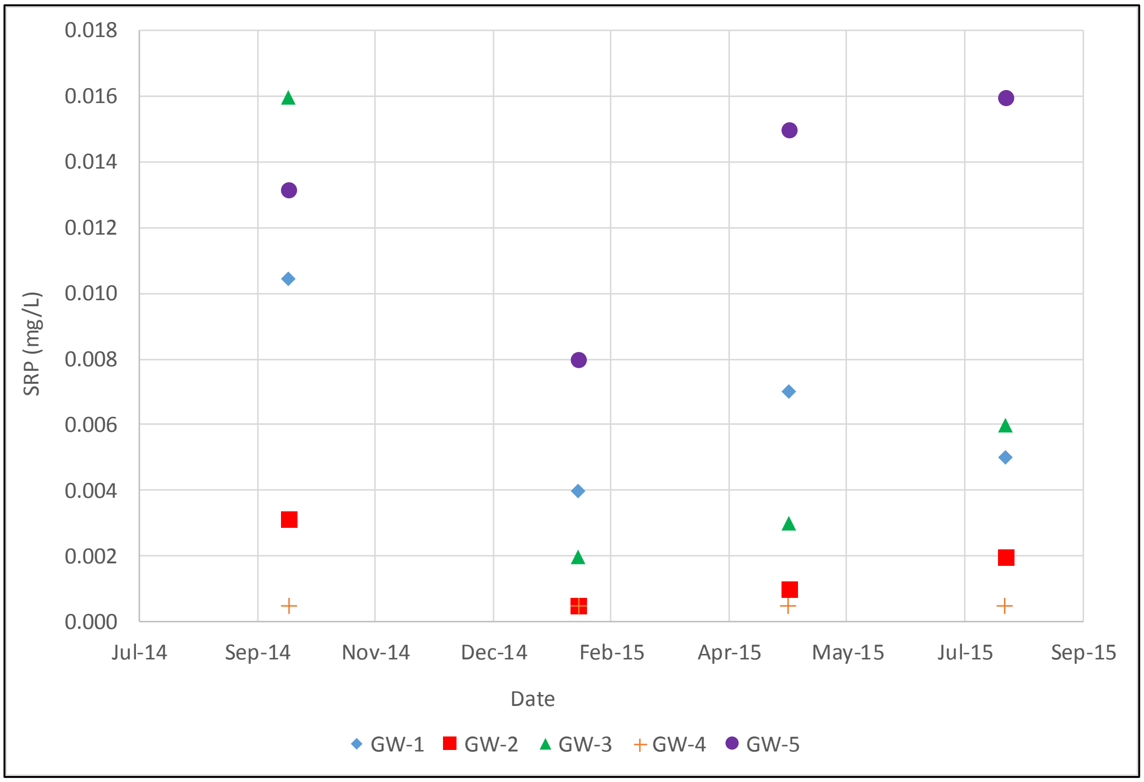


Figure 2-3. SRP concentrations in groundwater samples collected near Waughop Lake

As shown in Table 2-3 above, total nitrogen (TN) concentrations in the groundwater monitoring well samples ranged from 0.16 to 29 mg/L. The average TN concentrations for the five wells combined was 4.23 mg/L (see Figure 2-4 below). The highest concentrations were in GW-4, with an average concentration of 14 mg/L. Because of the high levels of TN in GW-4, in August 2015 GW-4 groundwater samples were also analyzed for species of nitrogen by UWT. The results were 0.086 and 0.022 milligram per nitrate nitrogen per liter (mg/NO_3-N/L) and 0.078 and 0.061 milligram per ammonia nitrogen per liter (mg/NH_3-N/L).

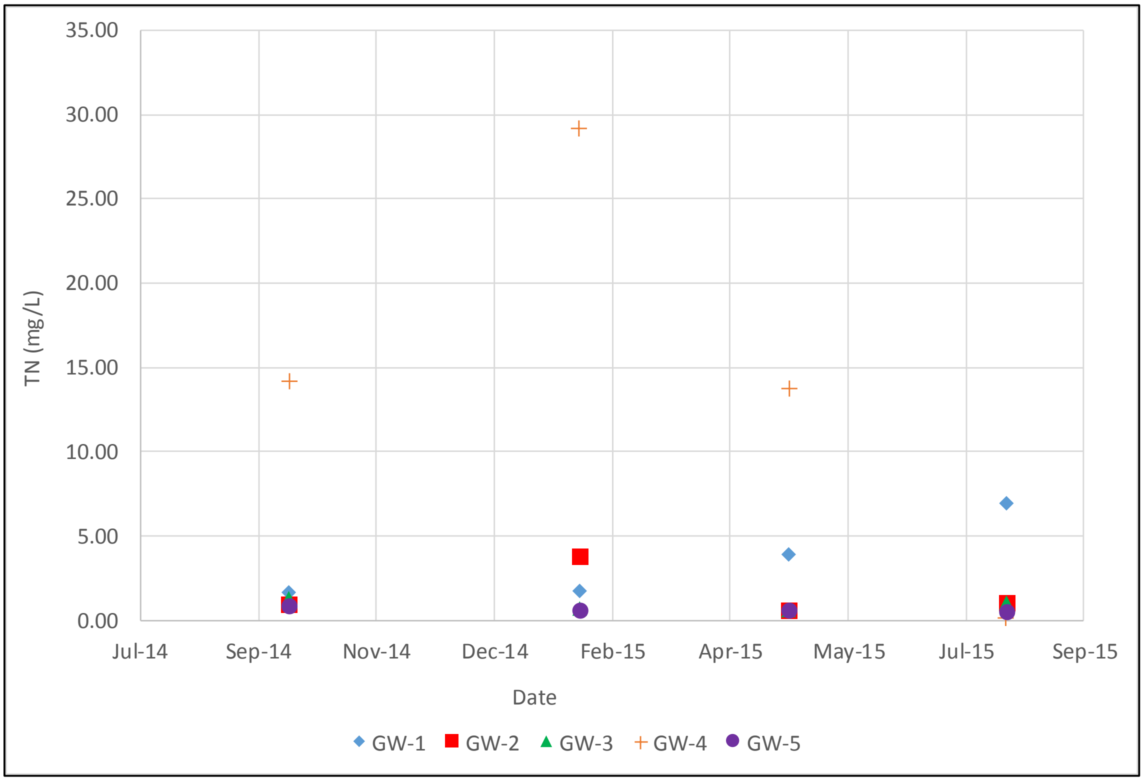


Figure 2-4. TN concentrations in groundwater samples collected near Waughop Lake

2.4 Lake Water Quality Vertical Profiling Results

Lake water quality was monitored in the deepest part of Waughop Lake (location LW-1 on Figure 2-1) from October 2014–15. This location was monitored for the analytes listed in Table 2-1. A multi-parameter datasonde was used to measure temperature, DO, pH, and conductivity at 0.5 m depth intervals throughout the water column at LW-1. A Secchi disk was used to measure water transparency. Water quality depth profiles were measured two times per month from June through October and one time per month between November and May. The water quality profiles that were collected in the summer and fall were used for characterizing seasonal anoxic conditions, internal phosphorus releases, and mixing.

During each profiling event, water grab samples were collected from two depths at LW-1; 0.1 m surface water (epilimnion) and near bottom water (hypolimnion if present). The samples were analyzed for TP, SRP, TN, alkalinity, and chlorophyll-a. Additionally, the water column was sampled for phytoplankton to estimate the presence of cyanobacteria.

Results from this study show that Waughop Lake does not strongly stratify because of its shallow bathymetry, but it does (weakly) stratify enough to result in anoxia in the near-bottom waters from May to early October. This is because of its organic- and nutrient-rich sediments, and the high sediment surface area to lake volume ratio.

During stratification, cooler, denser water in the bottom of the lake (hypolimnion) is prevented from mixing with the warmer, well-oxygenated surface water (epilimnion) by an abrupt temperature and water density transition (thermocline). DO within the hypolimnion becomes progressively depleted because of the decomposition of organic material in the sediment and the lack of re-aeration. By October, cooler surface temperatures eliminate this mixing barrier, allowing the lake waters to fully mix and reintroduce DO into the hypolimnion.

In the summer, more intense reducing conditions occur resulting in significant conductivity increases, suggesting rapid sediment remineralization and phosphorus release. In addition, intense summer photosynthesis and respiration result in pH values above 9 in the surface waters and below 6 in the bottom waters, potentially affecting aquatic life. Figure 2-5 shows the water quality parameter profiles that were measured once or twice per month in Waughop Lake during the monitoring period.

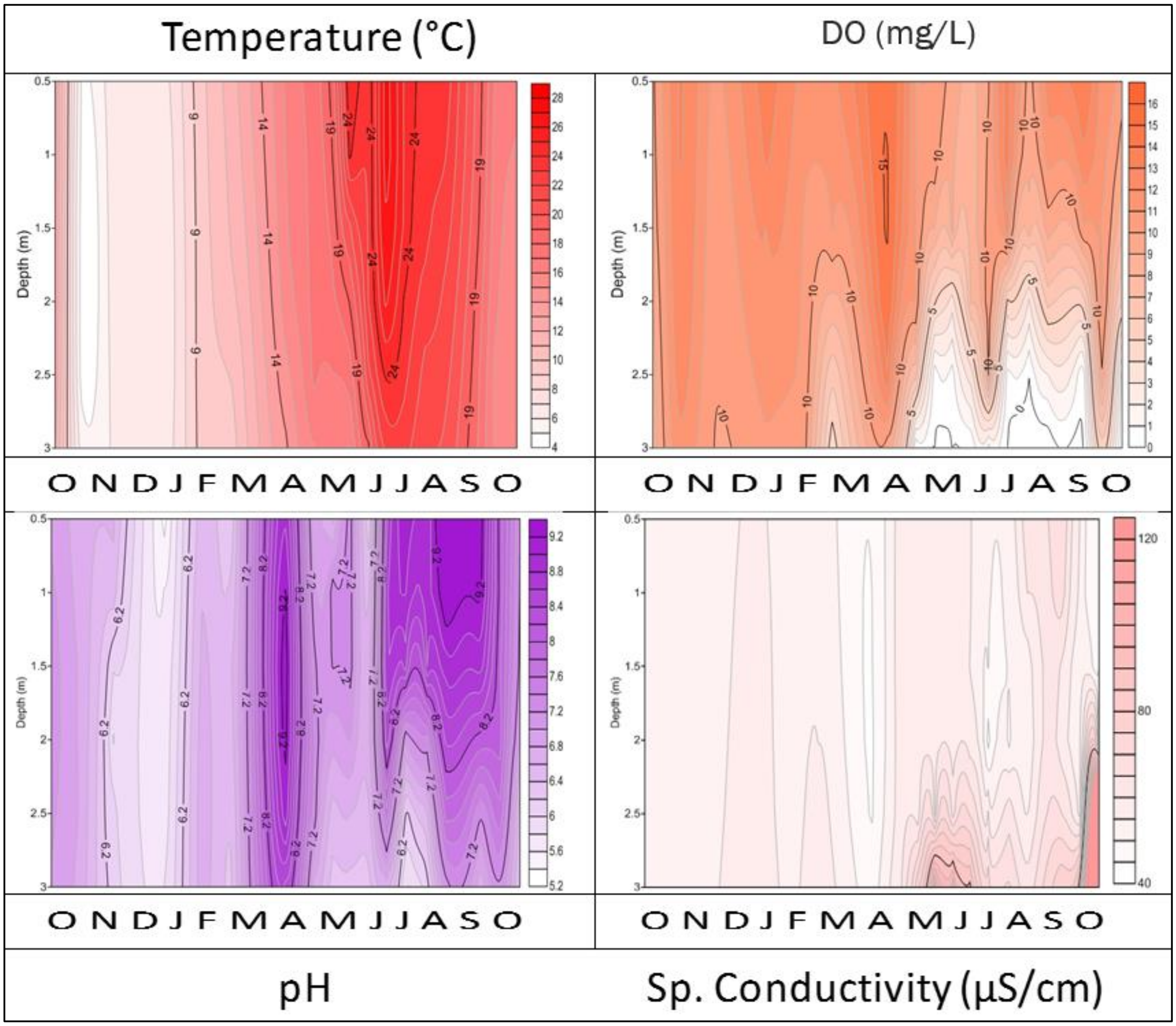


Figure 2-5. Water quality parameter profiles measured once or twice per month in Waughop Lake

As shown by the temperature-depth profile in Figure 2-5, Waughop Lake undergoes summer thermal stratification that is typical for a lake of its size and depth. Stratification began in late April and ended in early October 2015. Water temperature monitoring conducted throughout the water column in the summer months of 2015 showed a range of 27.3 degrees Centigrade (°C) at the surface water (July) to 15.9°C at the near bottom water (June).

Previous water column parameter monitoring and personal communication with Jim Gawel of UWT to Mike Milne of BC in May 2014 have revealed weak summer stratification, most likely because of light absorption by large concentrations of plankton. Water temperature monitoring that was conducted throughout the water column in June 2014 showed a range of 21.7°C at the surface to 17.5°C at the bottom. Per personal communication with Isabel Ragland of PCD to Sharonne Park of BC in May 2014, temperatures ranged from 16.2°C at the surface to 13.8°C at the bottom. Monitoring conducted in 2007 by LaFontaine showed much less variation throughout most of the year, with a June average of 18.8°C at the surface and 18.6°C at the bottom (LaFontaine 2012).

Figure 2-5 above also shows the DO vertical profiles for Waughop Lake during the 2015 summer stratification period. These profiles show a clear progression of anoxia (i.e., DO less than 1 mg/L) developing in the hypolimnion (near-bottom water) during the summer, with anoxic conditions frequently observed at depths greater than 3 m. Low DO in the hypolimnion can create conditions that allow for the release of available phosphorus from the lake bottom sediment into the water column, further degrading water quality. DO monitoring that was conducted throughout the water column in the summer months of 2015 showed a range of 13.2 mg/L at the surface (July) to 0.0 mg/L at the bottom (July).

Previous sampling for DO has revealed that DO concentrations throughout the water column vary greatly with depth. Monitoring that was conducted in May and June 2014 and personal communication with Isabel Ragland of PCD to Sharonne Park of BC in May 2014 showed DO levels of 9.9 mg/L and 9.8 mg/L at the lake surface and 0.2 mg/L and 0.4 mg/L at the bottom, respectively.

Figure 2-5 above also shows the pH profiles that were observed in Waughop Lake. The highest pH levels were observed in the surface water during the stratification period. These relatively high pH levels are likely because of the algal uptake of dissolved carbon dioxide during photosynthesis. The lowest pH levels were observed in the hypolimnion, likely because of decomposition and a lack of vertical mixing. The lake water pH was occasionally outside of the state water quality criterion range of 6.5 to 8.5 standard units (S.U.). Previous monitoring of pH has been conducted since 2007 and has shown a range of 6 to 10 S.U. (LaFontaine 2012).

Vertical profiles of the specific conductivity were also evaluated during this monitoring program (see Figure 2-5). Conductivity increases as the concentrations of dissolved salts or ions increase. The conductivity results generally increased in the lake water toward the bottom after Waughop Lake stratified. This is likely due to the release of metals from the sediment when the hypolimnion is anoxic, and the decomposition of dead algae and other organic detritus. Decomposition generates carbon dioxide, which quickly dissolves to form bicarbonate or carbonate ions, thereby raising the dissolved ion concentration and conductivity of the water, and releasing phosphorus from organic matter. Decomposition can also reduce iron oxide solids and release adsorbed phosphorus, further increasing conductivity and phosphorus concentrations. Specific conductivity monitoring that was performed throughout the water column in the summer months of 2015 showed that June and July experienced the greatest variation with a range of 55.5 microsiemens per centimeter (μS/cm) at the surface to 114 μS/cm at the bottom.

Previous monitoring of conductivity has shown a range between 55 and 92 μS/cm. Conductivity levels measured at various depths within the lake water column showed an increasing trend with depth, suggesting reductive remobilization of ions from sediments (LaFontaine 2012).

2.5 Lake Water Nutrient Sample Results

Lake water samples were collected from one location (LW-1) in the lake 17 times between October 2014 and October 2015. Grab samples were collected from the surface water (epilimnion) and near bottom water (hypolimnion) throughout the year.

As noted in Table 2-3 above and shown in Figure 2-6, TP concentrations in lake water samples ranged from 0.034 to 0.17 mg/L. Surface water samples were often similar to or higher than the near-bottom water samples from September to April. The higher surface water concentrations may be due to storm runoff inputs or greater waterfowl numbers. During summer months when the lake is stratified and waterfowl numbers are low, hypolimnetic phosphorus concentrations often exceed epilimnetic concentrations, suggesting phosphorus release from the sediments during anoxia.

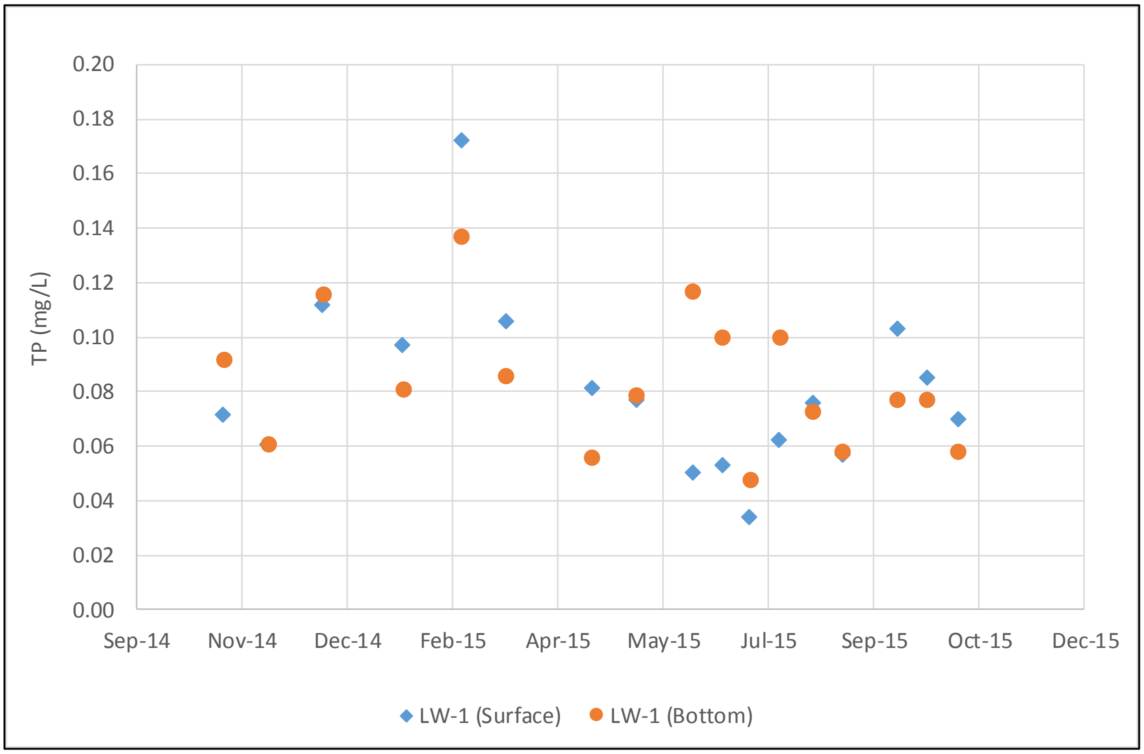


Figure 2-6. TP concentrations in Waughop Lake water samples collected at LW-1

The lake TP concentrations that were measured during this study were similar to the concentrations measured by others. LaFontaine monitored lake water quality from 2007–11. Water samples collected in summer 2007 contained TP concentrations as high as 0.085 mg/L (LaFontaine 2012). Samples collected between 2011 and 2014 by PCD showed an average TP concentration of 0.061 mg/L, with a maximum of 0.13 mg/L recorded in September 2012 (personal communication between Isabel Ragland of PCD and Sharonne Park of BC, May 2014).

Between June and October 2012, TPCHD collected lake water samples from depths of 1.0, 1.5, and 2.5 m. As learned via personal communication with Ray Hanowell of TPCHD to Mike Milne of BC in March 2014, TP concentrations ranged from 0.036 to 0.550 mg/L (1.0 m depth), 0.045 to 0.27 mg/L (1.5 m depth), and 0.048 to 0.54 mg/L (2.5 m depth).

In November 2013, per personal communication with Jim Gawel of UWT to Mike Milne of BC in May 2014, water samples that were collected when the lake was isothermal contained TP concentrations as high as 0.10 mg/L. Washington State water quality regulations recommend that lake-specific studies be conducted for lakes in the Puget Sound lowlands with TP concentrations above 0.02 mg/L (Washington Administrative Code [WAC] 173-201A-230). A study conducted by LaFontaine in 2007 suggested a general increase in TP concentration with increasing depth (LaFontaine 2012).

During this monitoring period, lake water samples were also collected for SRP, as shown in Table 2-3 and Figure 2-7. SRP concentrations in lake water samples ranged from non-detect (less than 0.001 mg/L) to 0.016 mg/L. In general, SRP concentrations were higher in the winter, likely due to lower phosphorus uptake by plankton and increased stormwater runoff. Overall, comparing SRP to TP, very little dissolved phosphorus is found relative to particulate phosphorus.

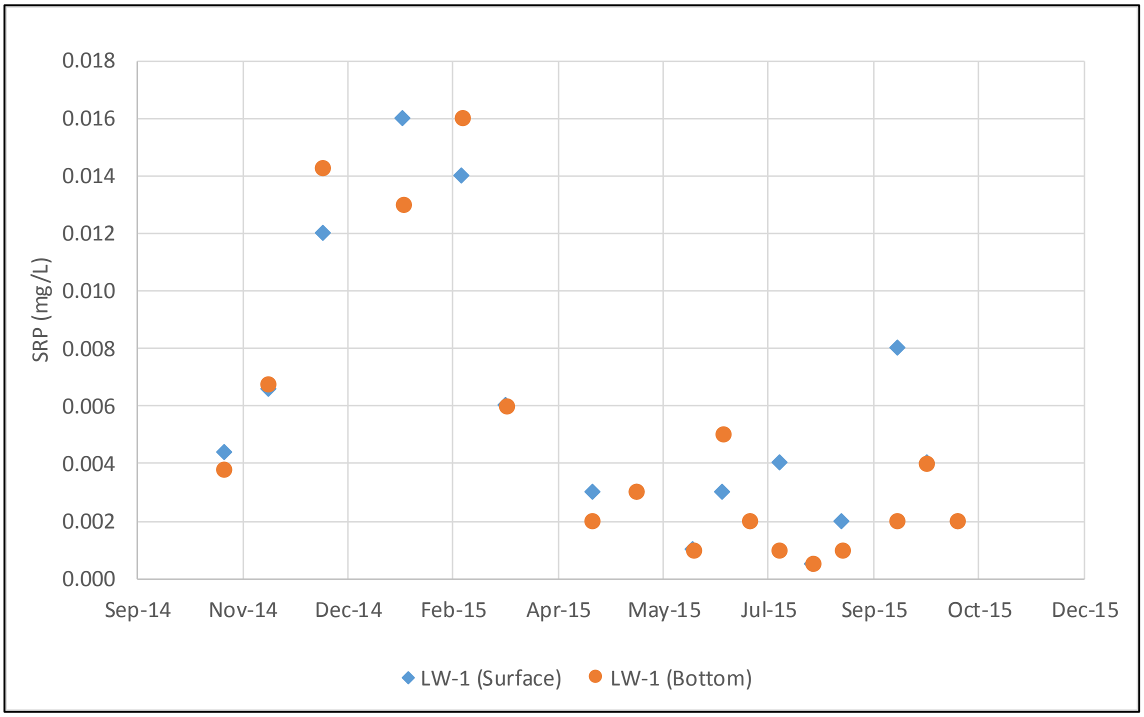


Figure 2-7. SRP concentrations in Waughop Lake water samples collected at LW-1

As shown in Table 2-3 above and Figure 2-8 below, TN concentrations ranged from 0.98 to 2.42 mg/L, with comparable results throughout the vertical water column. In a previous study TN ranged from 0.84 to 5.40 mg/L (1.0 m depth), 0.79 to 3.50 mg/L (1.5 m depth), and 1.0 to 5.0 mg/L (2.5 m depth) (personal communication between Ray Hanowell of TPCHD to Mike Milne of BC, March 2014), Volunteers have collected samples from the shallow parts of the lake since 2011 for the City's volunteer monitoring program. Only one sample exceeded the 0.05 mg/L detection limit for nitrate. Ammonia ranged from non-detect to 0.15 mg/L (Personal communication between Isabel Ragland of PCD and Sharonne Park of BC, June 2014).

Water samples collected for this LMP had nitrogen to phosphorus (N:P) ratios ranging from 12 to 40. Lakes with water column N:P ratios higher than 20 to 30 are generally considered phosphorus limited. The observed N:P ratios indicate that phosphorus is the main nutrient that is limiting algal growth in the lake.

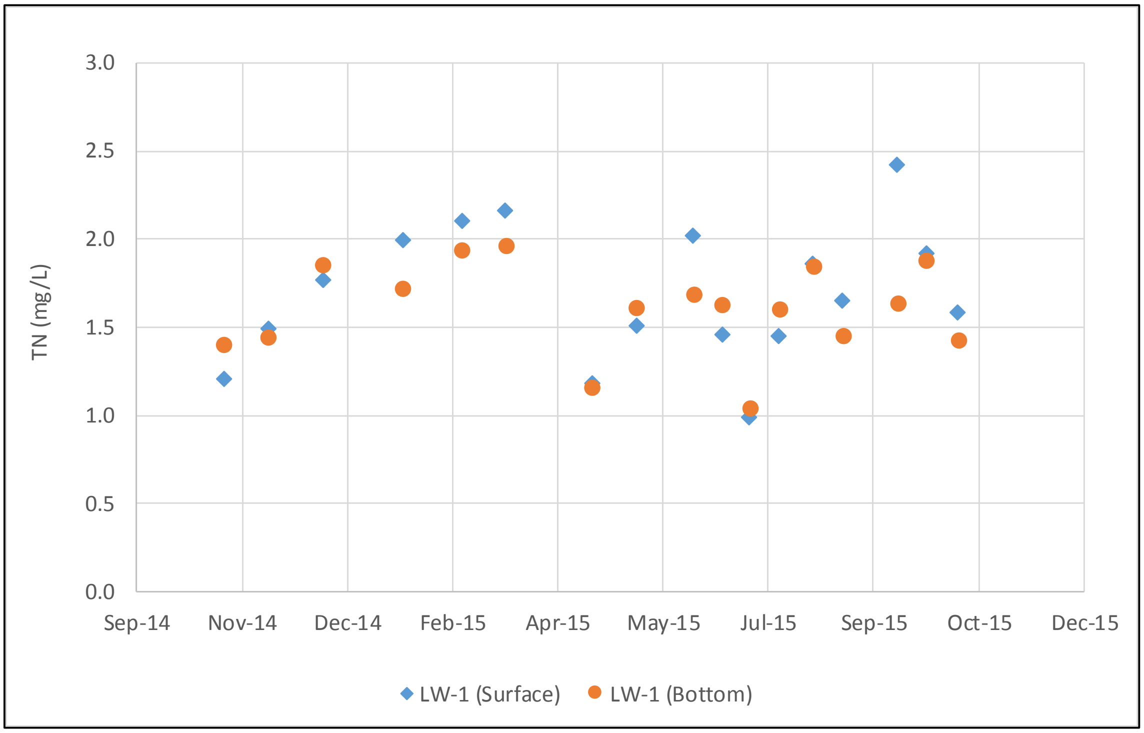


Figure 2-8. TN concentrations in Waughop Lake water samples collected at LW-1

Previous alkalinity samples had an average concentration of 26.8 mg/L as calcium carbonate ($CaCO_3$), with a range of 23.0 to 31.0 mg/L (PCD 2014).

Chlorophyll-a concentrations in this study ranged from 4.6 to 110.0 µg/L. The highest chlorophyll-a concentrations were found in the epilimnion (surface water) samples (see Figure 2-9 and Table 2-3). This is likely related to elevated TP concentrations and the algal blooms located at the surface of the lake.

As learned via personal communication with Ray Hanowell of TPCHD to Mike Milne of BC in March 2014, previous chlorophyll-a samples that were collected by TPCHD from June through October 2012 contained chlorophyll-a concentrations ranging between 5.5 and 93 µg/L.

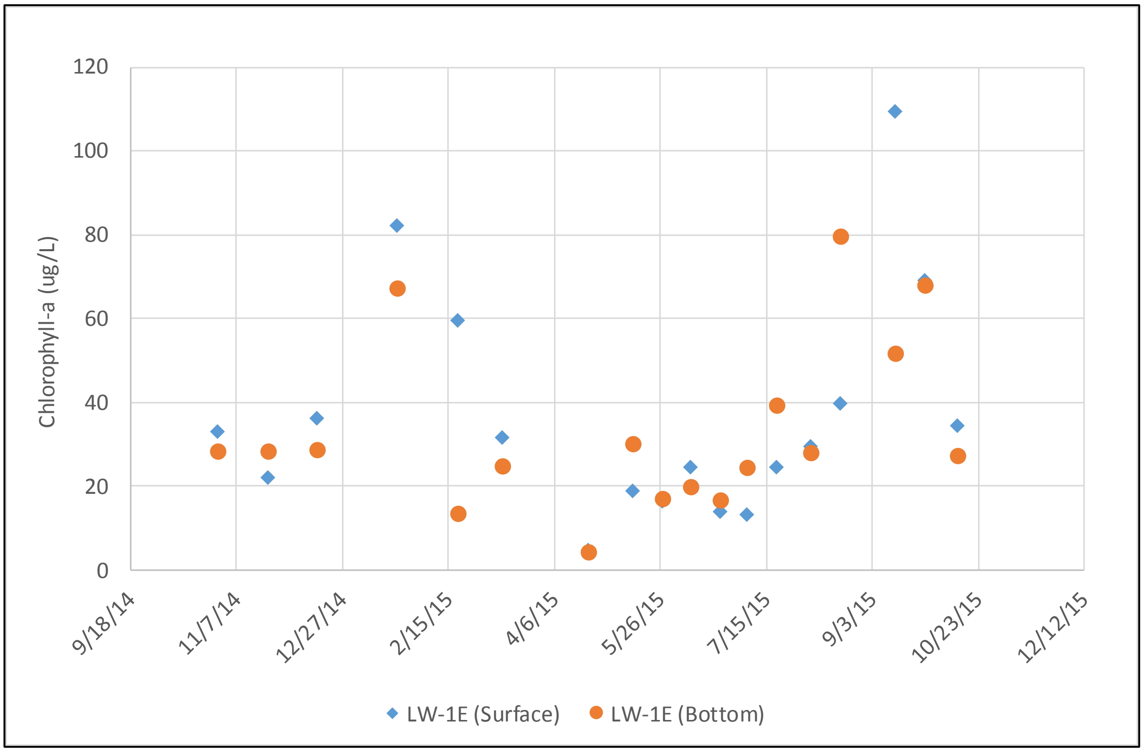


Figure 2-9. Chlorophyll-a concentrations in Waughop Lake water samples collected at LW-1

The phytoplankton community in Waughop Lake (see Table 2-4) was dominated in January and March, and from July through October by cyanobacteria (Cyanophyta), including Oscillatoria, Microcystis, and Anabaena. During the rest of the year, cyanobacteria were still a significant percentage in every sample, but the population was dominated by other phyla, including Chlorophyta and Chrysophyta.

Monitoring of algae within Waughop Lake has been conducted since 2007 by various agencies, including UWT, Ecology, PCD, and TPCHD. Monitoring has been conducted to identify the types and concentrations of cyanobacteria toxins. Since 2007, multiple cyanobacteria blooms have been observed with the three most common algae types identified as cyanobacteria, Microcystis aeruginosa, and Anabaena sp. and as mentioned above, at numerous times throughout the monitoring program, algae samples have shown levels above state recreational guidelines. In 2009, for example, more than 25 percent of the lake's algae samples had levels above state recreational guidelines (LaFontaine 2012). Algae counts collected by PCD in May 2014 noted heavy suspended algae with a recorded 21,200 algae count per milliliter (mL).

Table 2-4. Percent Abundance of Phytoplankton in Waughop Lake

Date	Cyanophyta	Other
10/2014	26%	74%
11/2014	17%	83%
12/2014	42%	58%
01/2015	64%	36%
02/2015	45%	55%
03/2015	53%	47%
04/2015	40%	60%
05/2015	43%	57%
06/2015	41%	59%
07/2015	87%	13%
08/2015	62%	38%
09/2015	81%	19%
10/2015	62%	38%

A Secchi disk was used to estimate lake water transparency during each sampling event and ranged from 0.4 to 2.0 m.

Measurements of transparency correspond to the levels of algae present: a high presence of algae corresponds to low visibility and after the algae blooms die off, visibility improves. During a UWT study in 2011, water transparency ranged from a low of 0.3 m in late May when there was an observed large algal bloom, to a maximum of 3.3 m in July 2011, after the algae were observed to have died off (LaFontaine 2012). In September 2013 per personal communication with Isabel Ragland of PCD to Sharonne Park of BC in May 2014, PCD observed a Secchi depth of 0.6 m, which corresponded to a substantial presence of suspended algae. PCD collected two Secchi disk observations in May and June 2014 with recorded levels of 1.5 and 1.8 m, respectively.

2.6 Aquatic Plant Sample Results

Aquatic plant sampling was conducted to evaluate the potential impact of aquatic plants on TP cycling in Waughop Lake. The approximate macrophyte biomass was estimated based on regular sampling from a boat along transects across the lake. Measurement locations were recorded using Global Positioning System (GPS) coordinates. Plant samples were taken with a plant rake for species identification and biomass estimates in September 2015, during maximum plant growth. The total reservoir of TP and TN in aquatic macrophytes was estimated multiplying the average TP and TN content of the grab samples analyzed (mass phosphorus or nitrogen/sample area) by the total surface area of the lake. The total mass of phosphorus and nitrogen from aquatic plants was estimated at 163 kilograms (kg) and 534 kg, respectively.

2.7 Lakebed Sediment Sample Results

Lakebed sediment samples were collected throughout the lake for chemical and grain size analysis. Throughout the lake 12 grab subsamples were collected from the top 10 centimeters (cm) to form one composite sample for TP and TN analysis. The results were 1,820 milligrams per kilogram (mg/kg) (or parts per million) dry weight of TP and 10,800 mg/kg dry weight of TN, which calculates to a total mass of TP and TN of 2,365 kg and 14,034 kg, respectively.

The sediment samples were collected to supplement the existing sediment grab and core data from previous studies, to support internal nutrient loading estimates, and the evaluation of potential management measures.

Previous studies of the sediment quality in Waughop Lake conducted by the University of Puget Sound (UPS) and UWT have revealed elevated levels of TP in approximately the top meter of lake bottom sediments. These studies have also identified elevated levels of Pb, Cu, As, and other metals, in the top meter of lake bottom sediments (Tepper 2013).

Between 2003 and 2007, Waughop Lake was included in a study that was evaluating metal concentrations in sediment (As and Pb) using surface grab samples or sediment cores (Gawel et al. 2013). Sediment core metal concentrations were determined to reflect inputs from the ASARCO, LLC smelter in Ruston, Washington. In 2008, surface sediments were mapped and analyzed for TP and a suite of other metals for a study done by UWT contracted by the City. The resulting sediment phosphorus map, provided as Figure 2-10 below, suggested either a current or historical source of TP on the east side of the lake, possibly from the Western State Hospital farm that operated into the 1960s (LaFontaine 2012). TP levels in surface sediments showed a range from 741 µg/g to 3,443 µg/g (Gawel and Mason 2008). The lowest levels were located at the northwest and southeast corners of the lake and the highest levels were found near the public beach. Based on the sampling results, the upper 20 cm of lake bottom sediment contained about 2,267 kg phosphorus (Gawel and Mason 2008).

Students and faculty in the UPS Geology Department conducted a sediment core study at Waughop Lake in 2012. The study found that since 1900, the sediment accumulation rate at Waughop Lake rose from 2,000 to 6,000 grams per square meter per year (g/m^2-yr). As a result, Waughop Lake has become about 1 m shallower during the past century (Tepper 2013). Chemical analysis and ^{210}Pb dating of the core showed that TP concentrations were low during most of the lake's history, but increased almost tenfold beginning around 1900 (Tepper 2013). The higher sediment TP concentrations coincided with higher nitrogen isotopic ratios, which are indicative of animal manure and agricultural waste. The study results suggest that bottom sediments are a significant source of the phosphorus that feeds the algal blooms in Waughop Lake (Tepper 2013).

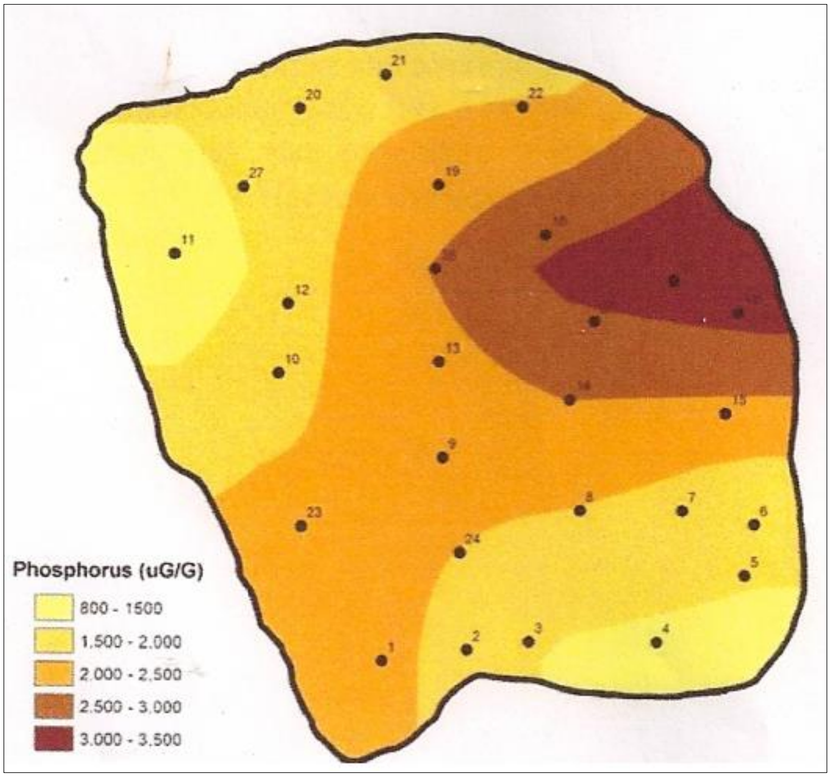


Figure 2-10. TP load in surface sediments collected in Waughop Lake in 2008

(Gawel and Mason 2008)

Three subsamples were collected throughout the lake for grain size analysis as shown in Table 2-5 and Figure 2-11. The particle size results indicate that the lake sediments are dominated by silt to very fine sand.

Table 2-5. Waughop Lake Sediment Sample % by Particle Size

Sample ID	Particle diameter (µm)									
	0.4	4	8	15	31	63	125	250	500	1,000
Subsample-1	0.82	1.6	4.7	15	28	29	16	3.5	0.27	0.00
Subsample-2	0.96	1.9	5.5	17	29	26	14	3.2	0.10	0.00
Subsample-3	1.00	2.1	6.0	18	30	25	13	2.2	0.92	0.01
Mean	0.94	1.8	5.4	16	29	27	14	3.0	0.43	0.01
Cumulative	0.94	2.8	8.3	25	54	81	96	99	99.00	100.00

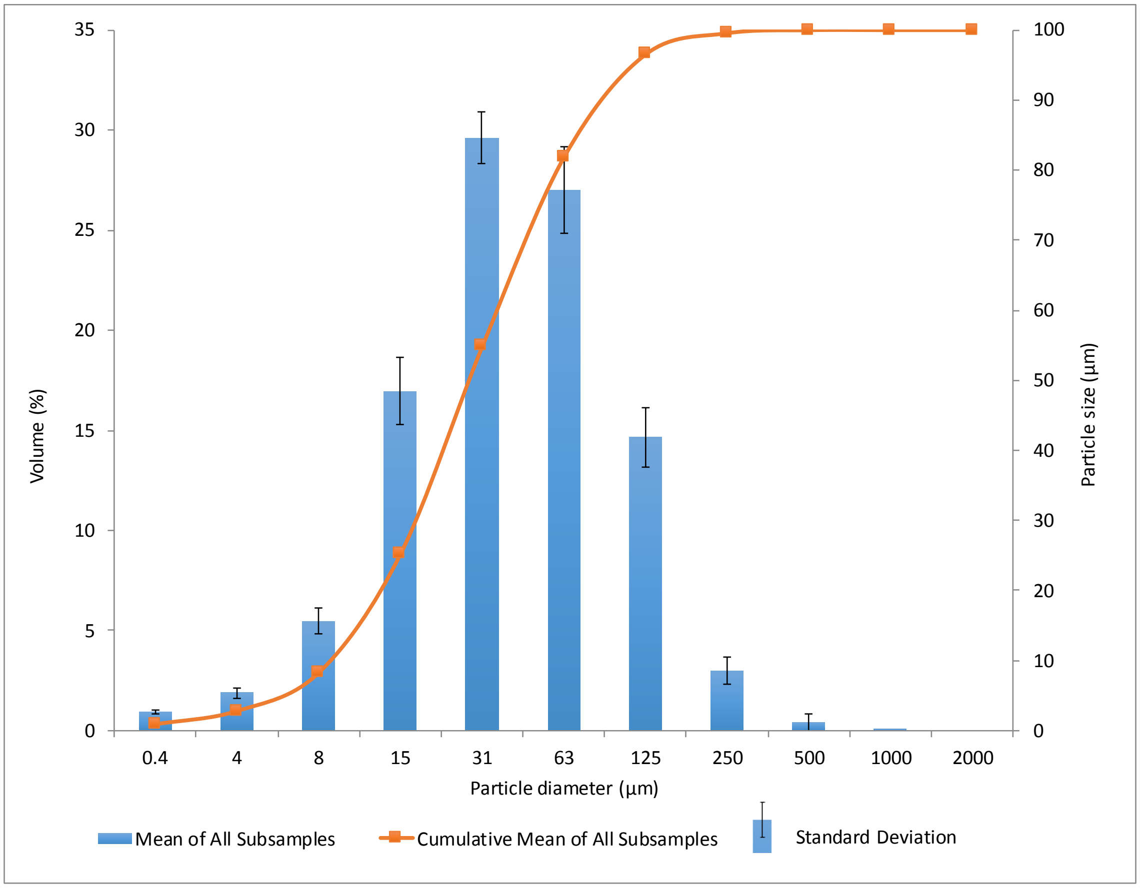


Figure 2-11. Mean particle size analysis from the three Waughop Lake sediment subsamples

2.8 Benthic Flux Sample Results

The internal loading of nitrogen and phosphorus from sediments in Waughop Lake to the water column was investigated using benthic flux chambers, modeled after a design developed by Ecology (Roberts 2015). Four flux chambers were randomly placed in the lake each month (July through September). Samples were collected at 2, 24, and 48 hours after deployment using a low-flow peristaltic pump. Some samples were not used in calculations as it was obvious that sediments were “floated” in the chambers by gas production, resulting in significant solids in the samples pumped from the chambers.

As noted in Table 2-3 above, TP concentrations in benthic water from the 2-hour, 24-hour, and 48-hour samples ranged from 0.07 to 1.99, 0.04 to 10.00, and 0.07 to 43.00 mg/L, respectively. TN concentrations in benthic water from the 2-hour, 24-hour, and 48-hour samples ranged from 1.44 to 13.00, 1.73 to 52.00, and 0.52 to 77.00 mg/L, respectively.

Flux rates were estimated per unit area using the difference between TN and TP concentrations in the chamber at 24 and 48 hours. The median flux rate from all chambers during all 3 months that were sampled was estimated and applied to the sediment surface area only for those months where bottom waters were anoxic (May through October) (see Figure 2-5, DO profile figure). In September and October one of two sampling periods showed anoxia, and so the median benthic flux was determined for half of each month. Table 2-6 below provides a summary of the calculated flux rates for TP, and TN.

Table 2-6. Benthic Flux Rates for TP and TN in Waughop Lake

Location	Month	TP flux rate (mg/day/m^2)	TN flux rate (mg/day/m^2)
Benthic Flux-1	July	86	18.10
Benthic Flux-2	July	9,909	-0.30
Benthic Flux-3	July	3192	-3.56
Benthic Flux-4	July	36	-2.37
Benthic Flux-6	August	12	1.19
Benthic Flux-7	August	2.1	1.19
Benthic Flux-8	August	2.9	0.89
Benthic Flux-9	September	17.8	0.30
Benthic Flux-10	September	8.3	0.59
Benthic Flux-11	September	241	55.80
Benthic Flux-12	September	2.6	0.59

2.9 Stormwater Sample Results

UWT collected stormwater samples from the Pierce College storm drainage outfall that discharges to Waughop Lake (see Figure 2-12). The LMP budget allowed for stormwater monitoring at one location. Monitoring at the stormwater outfall in the lake was ruled out because it is often inundated. The available storm sewer mapping indicated the outfall receives runoff from two catchment areas on the Pierce College campus, SW-1 (21.0 acres, mostly parking lots with some landscaped areas) and SW-2 (5.5 acres, mostly building roofs). SW-1 was selected for stormwater monitoring because it encompasses about 80 percent of the total drainage area for the outfall and runoff from parking lots and landscaped areas typically has higher phosphorus concentrations than roof runoff. Water entering SW-1 initially flows into an infiltration pond located southwest of Waughop Lake. During large storms, stormwater fills the infiltration pond and additional flow discharges directly to Waughop Lake.

Figure 2-12. Stormwater drainage outfall at Pierce College

During the project monitoring period, a pressure sensor was installed in the manhole where stormwater enters and then is shunted to the infiltration basin. During the monitoring period, stormwater grab samples were collected from the manhole during rain events. (An autosampler was originally planned for use during this monitoring period to collect an integrated storm sampling event; however, because of an access ladder that blocked equipment installation, grab samples had to be collected instead.)

Table 2-7 below summarizes the grab samples that were collected by UWT during four storm events. For each of the storm events sampled, the stormwater flowed into the infiltration pond. The storm events were not large enough to cause a discharge from SW-1 directly into Waughop Lake. It is important to note that the monitoring period was drier than normal.

Table 2-7. Precipitation for Pierce College Outfall Storm Event Sampling

Storm event	Day	Precipitation (in.)	Total event precipitation (in.)
1/5/2015	1/4/2015	0.80	1.31
	1/5/2015	0.51	
2/5/2015	2/4/2015	0.28	0.93
	2/5/2015	0.65	
9/17/2015	9/16/2015	0.06	0.28
	9/17/2015	0.22	
10/7/2015	10/6/2015	0.00	0.32
	10/7/2015	0.32	

Grab samples from each storm event were analyzed for TP, SRP, and TN. As noted in Table 2-3 above and shown in Figure 2-13, concentrations of TP, SRP, and TN in lake water samples ranged from 0.03 to 0.37 mg/L, 0.003 to 0.14 mg/L and 0.19 to 0.93 mg/L, respectively.

Stormwater samples show that TP concentrations are elevated in the fall, and could be a significant source of new phosphorus to Waughop Lake. However, the pressure sensor measurements revealed that the infiltration basin system is highly efficient, and very little water volume likely escapes the system to enter the overflow into Waughop Lake.

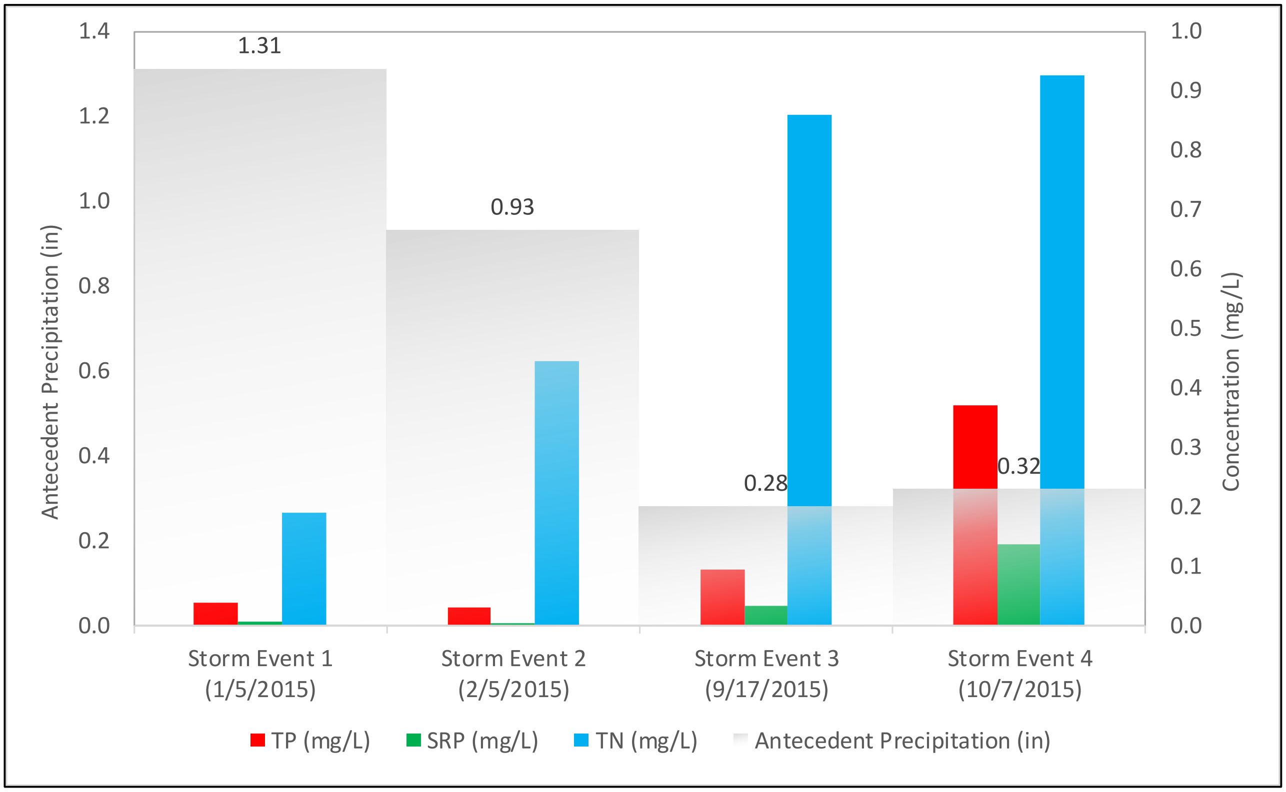


Figure 2-13. TP, SRP, and TN in stormwater samples collected at SW-1

2.10 Waterfowl

Waughop Lake provides habitat for various species of waterfowl and other birds. The lake characterization monitoring included regular period (monthly or more frequently) counts of waterfowl. As many as 1,200 ducks were observed on the lake in December 2014. Migratory ducks dominated the waterfowl population during the winter. Relatively few waterfowl were observed using the lake in the summer. Nighttime roosting behavior was not analyzed. Goose numbers were very low compared to the numbers observed at nearby Wapato Lake during a 2010 study (Chaichana et al. 2010).

Table 2-8 lists the estimated monthly phosphorus and nitrogen loads from waterfowl, based on the waterfowl counts made during this study and literature values on daily nutrient output from geese, ducks, and gulls.

Table 2-8. Waterfowl Contributions of Phosphorus and Nitrogen per Month to Waughop Lake

Date	Total waterfowl phosphorus (kg/month) [a]	Total waterfowl nitrogen (kg/month) [b]
10/2014	3.8	12.1
11/2014	7.0	22.0
12/2014	2.5	7.9
01/2015	2.9	9.0
02/2015	3.7	11.7
03/2015	0.1	0.4
04/2015	0.2	0.6
05/2015	0.4	1.3
06/2015	0.7	2.2
07/2015	0.4	1.2
08/2015	0.8	2.5
09/2015	0.7	2.3
10/2015	3.8	12.1

[a] *The annual average of phosphorus load assumed for geese, ducks, and gulls: 490, 178, and 38 mg phosphorus/individual/day, respectively (Chaichana et al. 2010).*

[b] *The annual average of nitrogen load assumed for geese, ducks, and gulls: 1,570, 562, and 122 mg nitrogen/individual/day, respectively (Chaichana et al. 2010).*

2.11 Monitoring Results Summary

UWT collected field data from October 2014–15 to support development of the Waughop LMP. Field data collection involved monitoring of groundwater, lake water, lake bottom sediment, benthic flux, stormwater, and waterfowl. The key findings include:

- During the monitoring period, nearly all of the stormwater runoff from Pierce College was infiltrated in the stormwater pond and did not discharge to Waughop Lake.
- TP concentrations in the hypolimnion samples ranged from 0.048 to 0.137 mg/L, while epilimnion (surface water) samples ranged from 0.034 to 0.172 mg/L. TP results were similar to the concentrations measured by others.
- N:P ratios indicate that phosphorus is the primary nutrient that limits algal growth in the lake.
- Cyanobacteria dominated the phytoplankton in the lake from July to October.
- Secchi depths (i.e., transparency) ranged from 0.4 to 2.0 m.
- TP concentrations in benthic water from the 2-hour, 24-hour, and 48-hour samples ranged from 0.07 to 1.99, 0.04 to 10.00, and 0.07 to 43.00 mg/L, respectively.
- TP concentrations in the storm event samples collected from SW-1 ranged from 0.03 to 0.37 mg/L. The Pierce College pond infiltrated all of the flow sampled during this study period.
- The average TP concentrations in the five groundwater monitoring wells ranged from 0.001 to 0.080 mg/L, with an overall (combined) average of 0.032 mg/L.
- Lakebed sediment TP concentration from a composite of 12 stations contained 1,820 mg/kg (parts per million).
- Most of the lakebed sediment samples were predominantly composed of fine particles (e.g., silt to very fine sand).

This page intentionally left blank.

Section 3

Lake Water Budget

Elements of the water budget are based on model-derived data for stormwater runoff from the Waughop Lake catchment area and empirically derived data collected during the project monitoring period. Field data collection sites are identified on Figure 3-1. The water budget spans from January to October 2015 and is based on the period of record containing sufficient information to estimate each element of the water and nutrient budget. This interval is limited by available lake stage data, piezometer readings, and groundwater monitoring well recordings.

Waughop Lake is a pluvial lake that does not receive surface water inflow or outflow from streams or creeks. Inflow is limited to precipitation on the lake, overland flow during high-intensity storm events, and groundwater influx. Outflow is predominately controlled by evaporation and groundwater flow. The lake is approximately 33 acres with a catchment area of 497 acres.

3.1 Precipitation

Precipitation data were downloaded from the Washington State University (WSU) Puyallup meteorological station located approximately 11 miles to the northeast of the site. WSU Puyallup recorded 21.9 inches (in.) of precipitation from January to October 2015, which is below average conditions. McChord AFB recorded 22.6 inches during the same period. Contribution to Waughop Lake from precipitation was estimated by multiplying the average monthly lake surface area by the total monthly precipitation (see Figure 3-1). Direct rainfall was the main water source to Waughop Lake. Groundwater and stormwater runoff were minor sources.

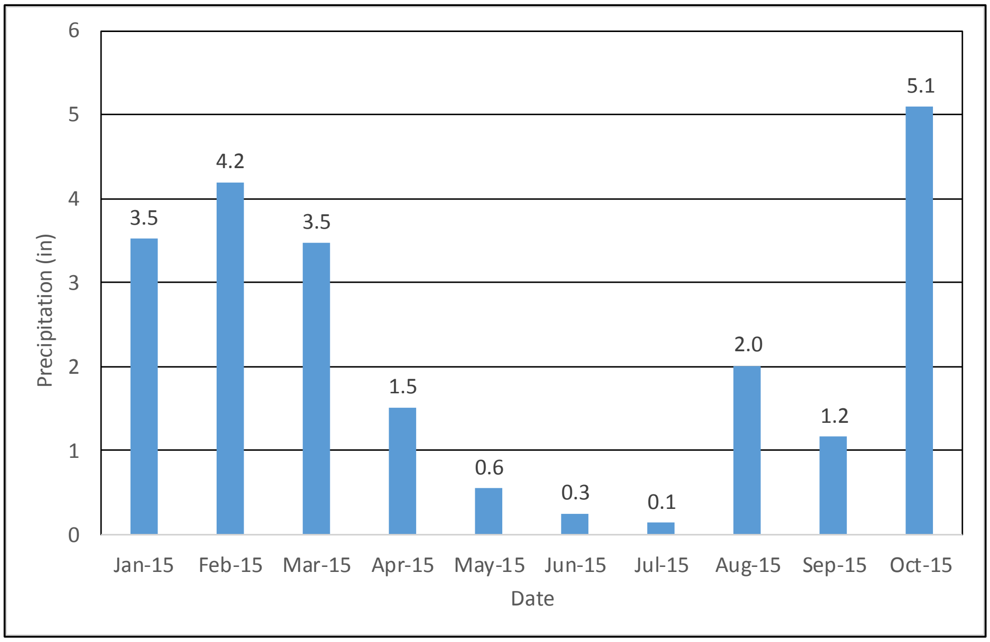


Figure 3-1. Precipitation measured from the WSU Puyallup weather station from January–October 2015

3.2 Evaporation

Measurements of daily evaporation rates from the lake were not available. Instead, evaporation was estimated based on an energy balance equation that accounts for radiation, temperature, humidity, and land surface elevation (Priestly and Taylor 1972). The Priestly/Taylor equation was chosen for this analysis above several similar techniques because of its general acceptance in the literature, and its straightforward parameterization. This approach does not account for localized features such as wind, aspect, or shading. It assumes that the ground surface is relatively flat, and that the water body is exposed to sunlight over its entire length. The Priestly/Taylor equation is:

$$E = \alpha \frac{\Delta}{\Delta + \gamma} E_r$$

In which,

E is evaporation (in./month)

α is a constant (set to 1.3, unitless)

γ is a psychrometric constant (60.1 Pascals per °C [kPa/°C], at 25°C and 500 feet elevation)

Δ is a function of temperature (kPa/C) equal to:

$$\Delta = \frac{2503878 e^{\left(\frac{17.27T}{237.3+T}\right)}}{(237.3+T)^2}$$

Er is radiative energy (megajoule/day/m2) equal to:

$$Er = 0.353 * Rn$$

Rn is net radiation (Watt/m^2)

The resulting evaporation rates are based on average monthly temperatures from the WSU Puyallup meteorological station and mean net radiation (Rn) extracted from monthly averages complied from National Aeronautics and Space Administration's (NASA) Clouds and the Earth's Radiant Energy System (CERES) program (NASA NEO 2016).

Daily evaporation amounts for each month were estimated by prorating the average monthly evaporation amount by the number of days in each month. Monthly evaporation amounts are shown on Figure 3-2, below. More localized or short-term controls on evaporation, such as cloud cover or storm events, would be expected to produce daily fluctuations in evaporation rates, but data were insufficient to control for these features, and it is expected that they should average out over monthly time-scales (Farnsworth and Thompson 1982).

The average evaporation rate that was estimated during this period of analysis was 2.2 in. per month. The evaporation rate was transformed from a depth per unit area to a volumetric flux by multiplying over the surface area of the lake. The resulting total evaporation between January and October 2015 was 100 acre-feet (ac-ft).

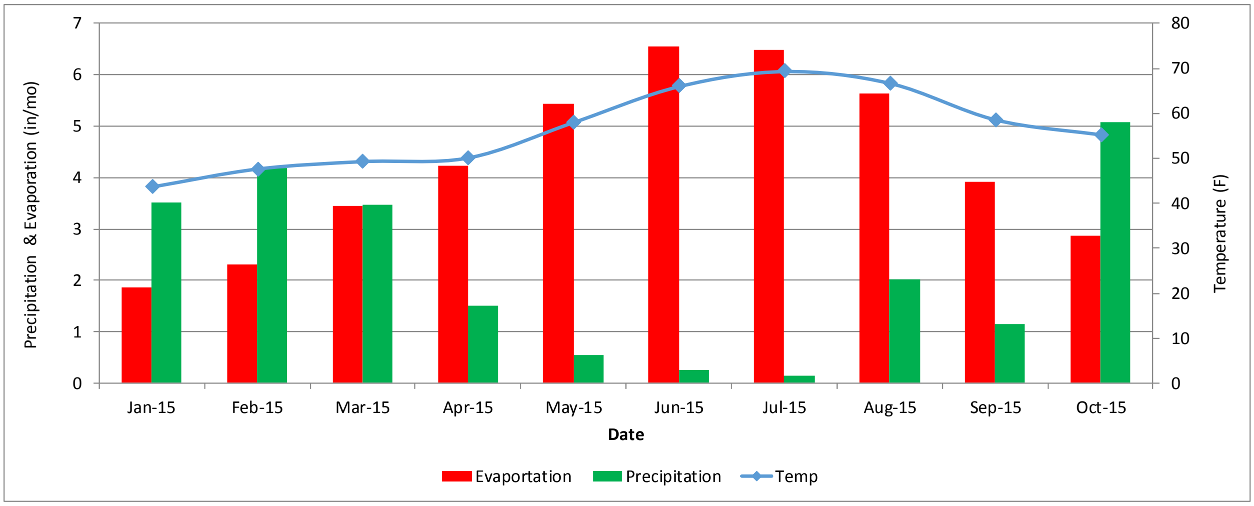


Figure 3-2. Evaporation, precipitation, and air temperature at Waughop Lake January–October 2015

3.3 Overland Flow

Runoff to Waughop Lake was estimated using the U.S. Environmental Protection Agency's (EPA) Stormwater Calculator (SWC). This application estimates the annual amount and frequency of runoff for a specific site, based on local soil conditions, user-defined land cover percentages, and climate data including precipitation and evapotranspiration. Soil data were sourced from the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Soil Survey. SWC parameterization consisted of a selected soil type with low to moderately low runoff potential, soil drainage rates ranging from 0.3 to 4.4 in. per hour depending on slope and soil type reported by the NRCS Soil Survey, and land cover percentages estimated from aerial photographs (NRCS and USDA 2016). Results from the simulations (see Figure 3-3 below) show that 1 percent of the total precipitation over the catchment area would reach Waughop Lake as runoff.

Approximately 27 impervious acres of the catchment are located on Pierce College and connected to a stormwater collection system. Runoff from most of Pierce College is routed to an infiltration basin near the lake. When the initial collection well tops 1.9 feet, water flows into Waughop Lake. In the 10-month monitoring period, the amount of water that flowed from the collection well into the lake was minimal and not included in final calculations.

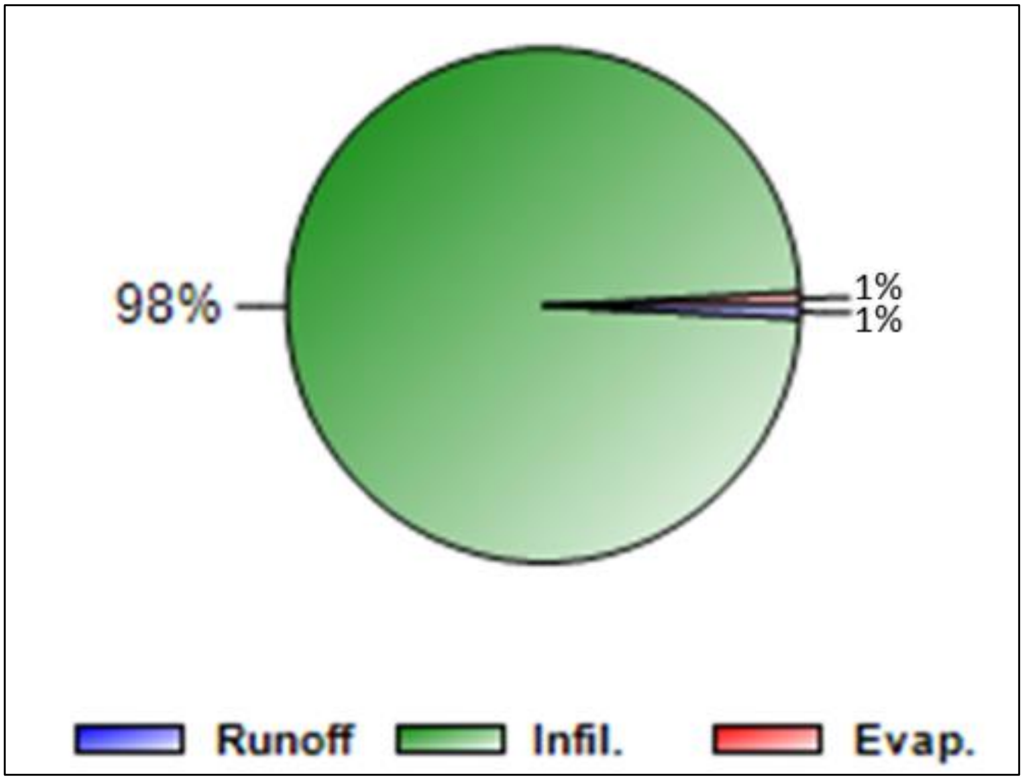


Figure 3-3. Results from the EPA SWC for the Waughop Lake catchment area

3.4 Lake Stage and Storage

Lake stage data consist of average elevations from readings on the outside of two piezometers installed in the lake. Lake storage estimates assume a simple cylindrical model with an effective radius of 672 feet. The stage-storage estimates show trends of gaining storage volume during the winter months and losing volume during the summer. The range of lake stage values is approximately 3 feet, indicating that lake storage varied by approximately 100 ac-ft during the monitoring period. Lake water levels collected in recent years by PCD varied between 3.2 and 7.5 feet, with the highest levels occurring mostly in May and July and the lowest levels observed during September and October (personal communication with Isabel Ragland, PCD, May 2014). The summer of 2015 was unusually dry, and water volume stored in the lake declined during the monitoring period (see Figure 3-4).

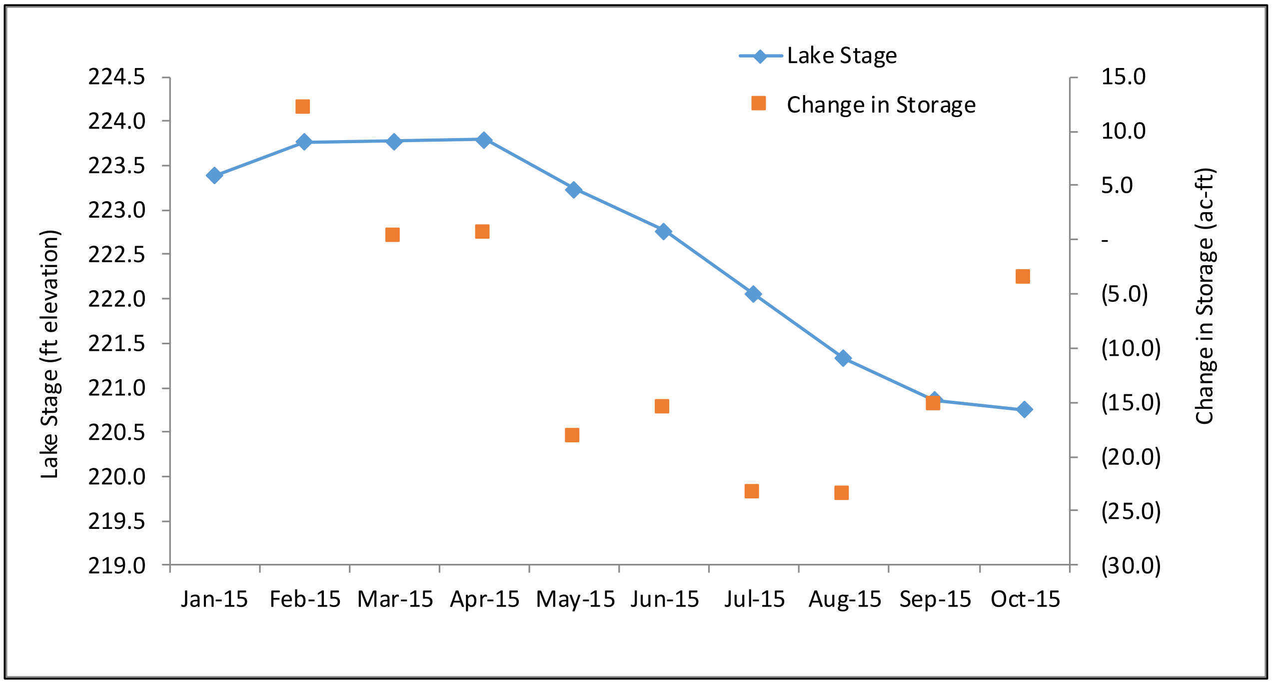


Figure 3-4. Waughop Lake stage and change in storage

3.5 Groundwater Seepage

To estimate the trends in groundwater movement in the vicinity of the lake, groundwater-level monitoring data were used to estimate changes in the localized potentiometric surface. Based on interpretations of the potentiometric surface, the lake appears to recharge from groundwater along the southern margin of the lake, primarily during winter months. During the monitoring period, groundwater levels suggest that recharge begins in January, from the south-southwest area of the lake, and continues through approximately mid-June. The lake also receives direct recharge from precipitation during this period, and may also discharge to the groundwater system along the northern margin of the lake. Throughout the summer and fall, the lake appears to lose water to the groundwater system in a radial pattern skewed slightly to the north, following the regional groundwater gradient. Figures 3-5 and 3-6 below show plan views of the groundwater flow pattern direction around the lake in summer (July) and winter (February). These patterns show that there was a lot of variation in groundwater elevations in monitoring wells and the lake. The lake was generally losing water to groundwater. Phosphorus concentrations in groundwater were lower than the lake concentrations, and thus it did not appear that groundwater is the main source. (See Appendix C for copies of the monitoring logs and geologic cross-section diagrams.)

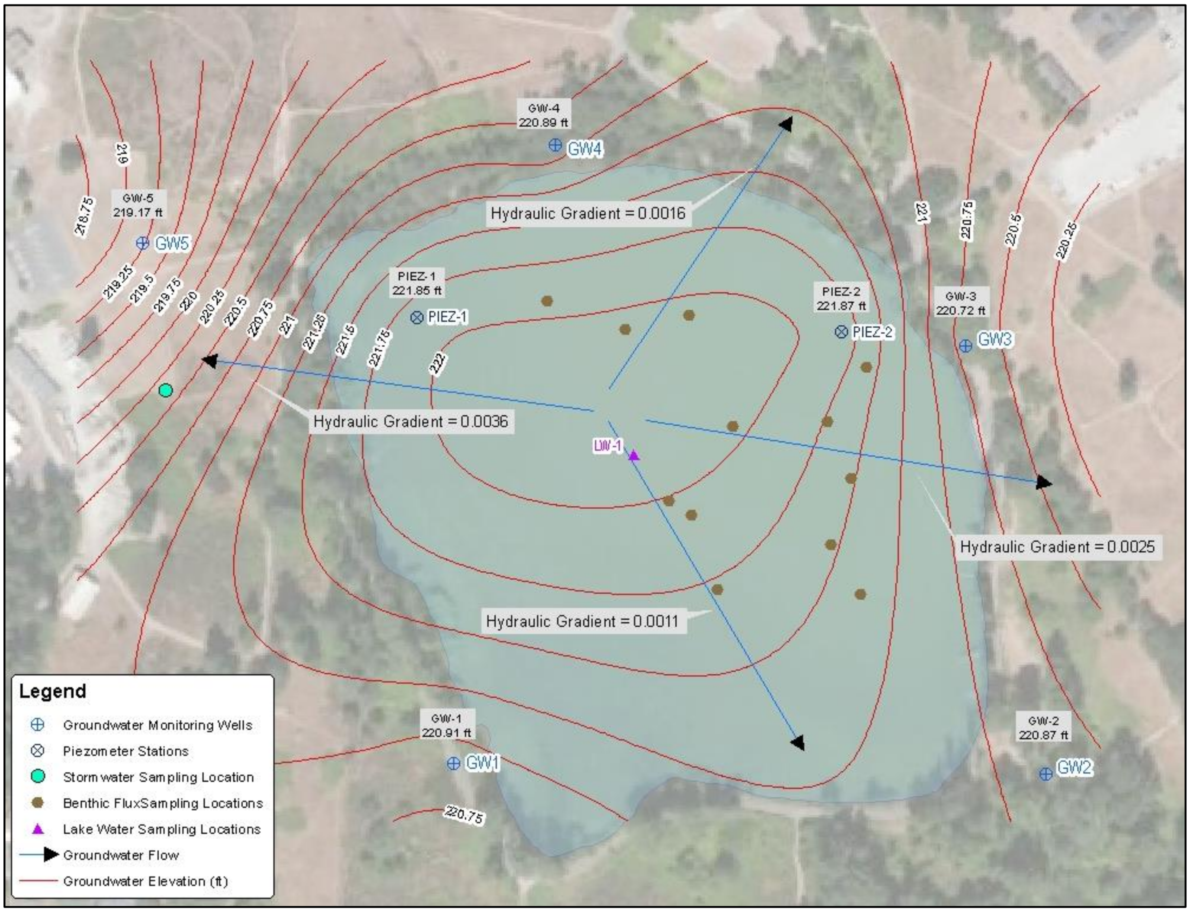


Figure 3-5. Plan view of groundwater flow direction around Waughop Lake in summer (July 2015)

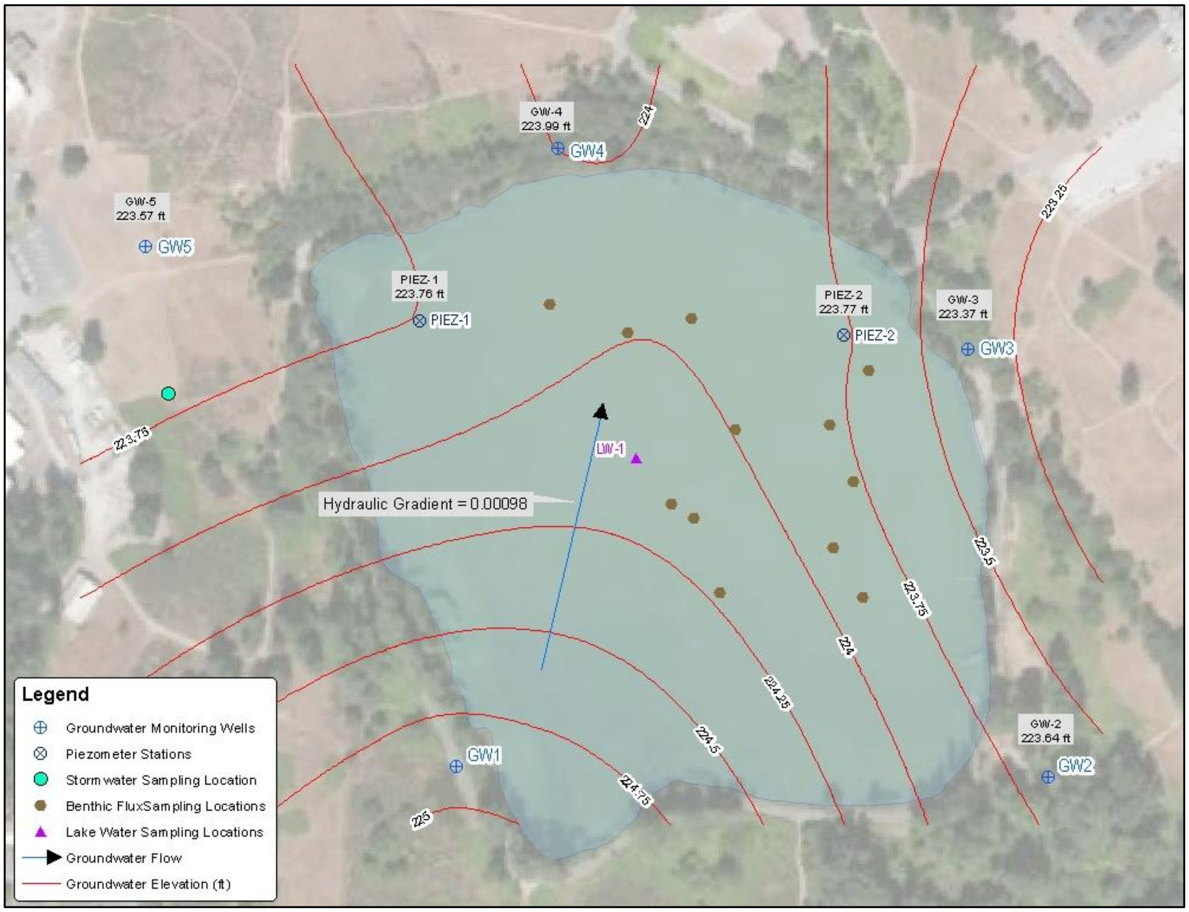


Figure 3-6. Plan view of groundwater flow direction around Waughop Lake in winter (February 2015)

Seepage (*Q*) into the lake was estimated from the flow through the cross-sectional area of the lake, perpendicular to the groundwater flow path. One half of the cross-sectional area was assumed for seepage calculations to account for the depth-narrowing profile of the lake. For months when the lake receives flow from the groundwater system, the hydraulic gradients ranged from 0.0013 to 0.0019 foot vertical per 1 foot horizontal (ft/ft). The cross-sectional area through which seepage occurs was assumed to range from 1,200 to 7,575 square feet (ft^2) based on seasonal variations in flow paths.

Horizontal groundwater flow through the upper 10 percent of the assumed cross-sectional area was estimated using the hydraulic conductivity of the aquifer material (100 feet per day), while the remaining 90 percent of the cross-sectional area was assumed to have a hydraulic conductivity of the lakebed sediments (1.28 feet per day). Conductivity values for lakebed sediments were estimated from particle size distributions of sediment samples (see Figure 3-7, below).

A modified version of Darcy's Law was used to estimate flow:

$$Q = -KiA$$

In which:

- K is hydraulic conductivity (feet/day)
- i is the hydraulic gradient (ft/ft)
- A is the cross-sectional area around the lake (ft^2)

Estimates of seepage out of the lake (losses) were estimated using the same Darcy equation noted above, but assumed a seepage reduced to 1,000,000 ft^2 (approximately 23 acres) to account for the lake bottom intersecting the groundwater table. Hydraulic gradients during periods where the lake is only discharging to groundwater ranged from 0.135 to 0.245 ft/ft. Figure 3-8 shows the lake stage and groundwater elevation from January to October 2015.

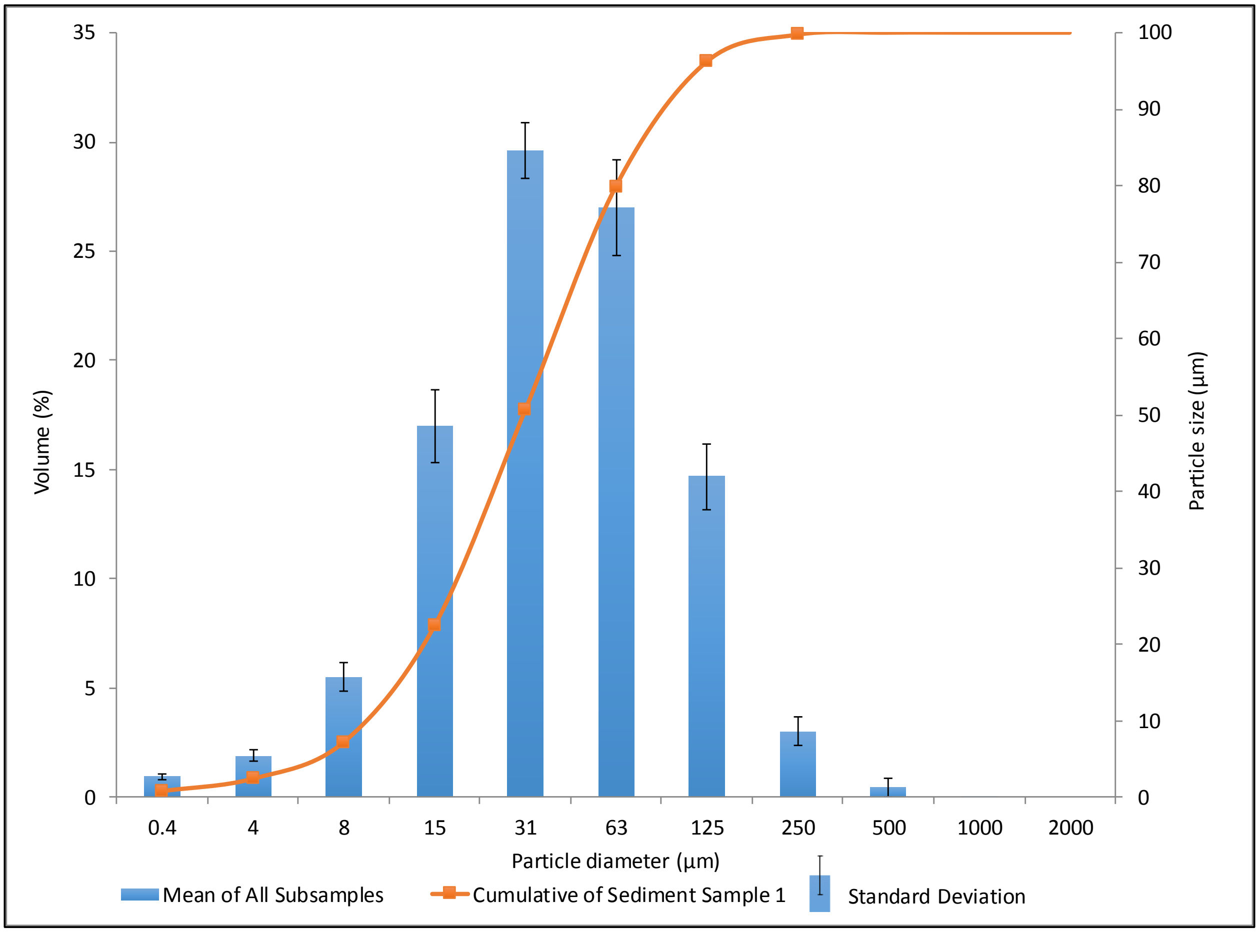


Figure 3-7. Particle size analysis from example Waughop Lake sediment sample 1

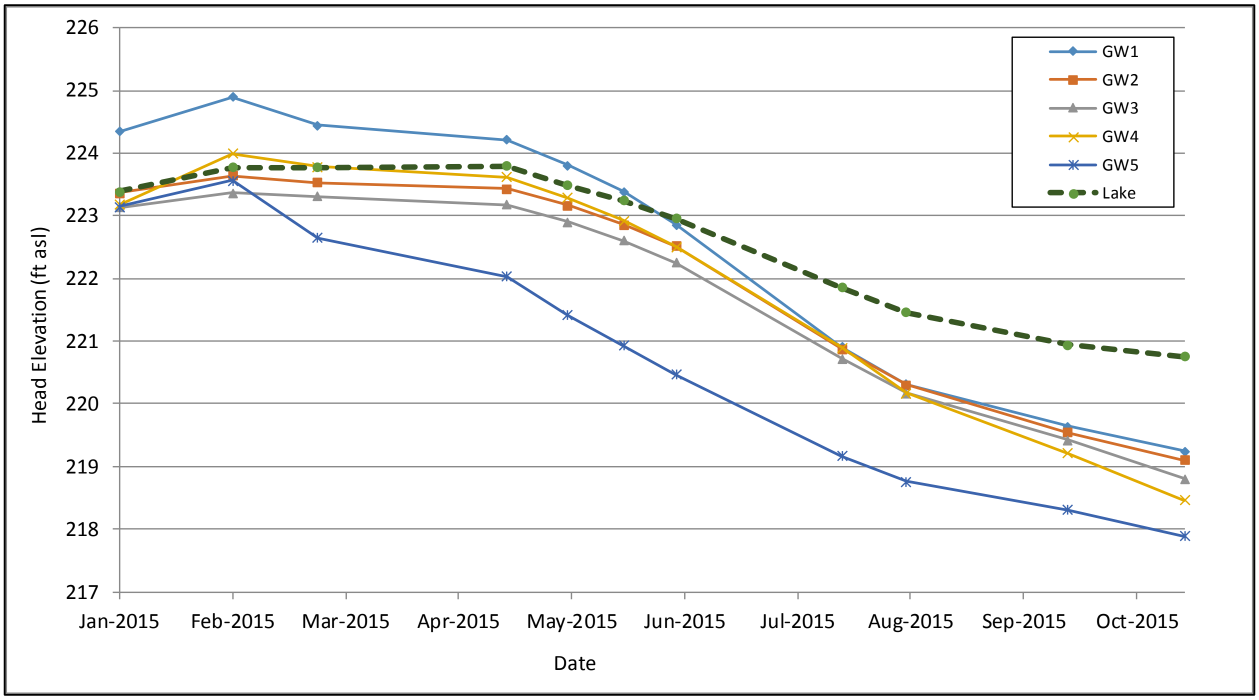


Figure 3-8. Waughop Lake stage and groundwater elevation from January–October 2015

3.6 Water Budget Summary

Table 3-1 and Figures 3-9 and 3-10 below show the monthly Waughop Lake water budget summary for January through October 2015. In a perfectly balanced water budget, the sum of the flux terms should equal the change in storage of the lake; however, inaccuracies in the data or unaccounted flux terms can lead to discrepancies between the two. The stage data indicate that the lake may have lost additional water that was not accounted for in the water budget. Possible unaccounted sources include vertical groundwater seepage or underestimation of evaporation. Alternatively, the stage-volume relationship of the lake may be overestimating the volume of lake water that was lost.

Table 3-1. Waughop Lake Water Budget Summary

Date	Lake stage (feet) [a]	Change in lake storage (ac-ft) [b]	Inflow	Outflow	Inflow	Inflow	Outflow	Total inflows (ac-ft)	Total outflows (ac-ft)	Net flux (inflows – outflows)
			Groundwater inflow (ac-ft)	Discharge to groundwater (ac-ft) [c]	Precipitation (ac-ft)	Inflow-runoff (ac-ft)	Evaporation (ac-ft)			
01/2015	223.4	-	0.14	-	8.87	1.29	4.69	10.30	4.69	5.61
02/2015	223.8	12.19	0.12	-	10.90	1.53	6.01	12.55	6.01	6.54
03/2015	223.8	0.33	0.09	-	9.04	1.27	9.00	10.41	9.00	1.41
04/2015	223.8	0.65	0.10	-	4.08	0.55	11.42	4.73	11.42	-6.68
05/2015	223.2	(18.13)	0.12	-	1.38	0.20	13.67	1.70	13.67	-11.97
06/2015	222.8	(15.44)	-	0	0.60	0.09	15.60	0.69	15.60	-14.91
07/2015	222.0	(23.24)	-	11.90	0.31	0.05	14.48	0.36	26.38	-26.02
08/2015	221.3	(23.48)	-	13.22	4.21	0.74	11.80	4.95	25.02	-20.07
09/2015	220.9	(15.11)	-	18.51	2.32	0.43	0.84	2.75	19.36	-16.60
10/2015	220.8	(3.49)	-	21.60	10.09	1.89	5.83	11.98	27.42	-15.44

a. *Lake stage was calculated using average outside piezometer readings for each month.*

b. *Change in lake storage was calculated assuming an effective lake radius of 671.5 feet.*

c. *January–May could potentially have both inflow from groundwater from the south, and outflow to groundwater toward the north. No outflow is assumed; however, this could be used to balance the difference between storage and flux.*

Notes:

Discharge to groundwater likely occurs in January–May. This could be used to better balance the water budget numbers during these months. Ideally, the net flux (inflows – outflows) should closely match the change in lake storage. Comparison of flux vs. change in storage highlights the monthly discrepancy in the water balance.

Note that groundwater levels were measured each month, however the October 2014 levels are suspicious. The hydrologic evaluation needed both the groundwater and piezometer levels, so only groundwater levels from January–October 2015 were used for this evaluation. Piezometers were installed in January 2015. Piezometer level readings are only available from January–October 2015.

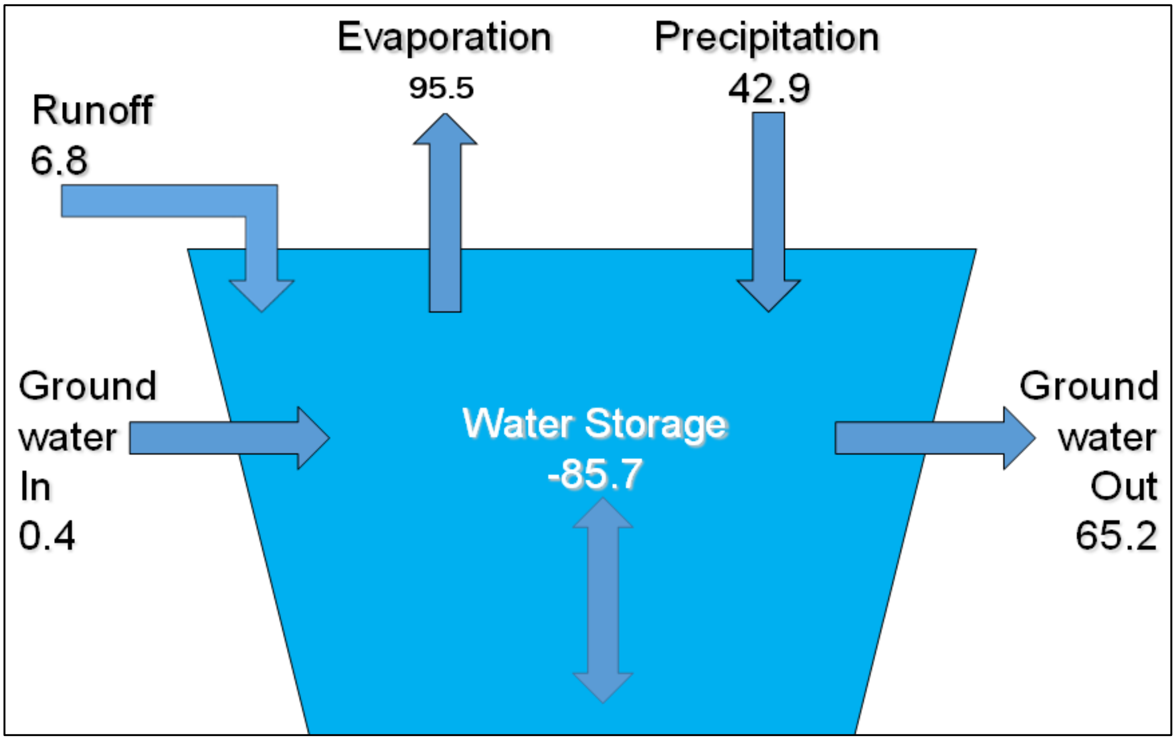


Figure 3-9. Waughop Lake hydrology model summary (ac-ft)

Note that these numbers do not include data from January.

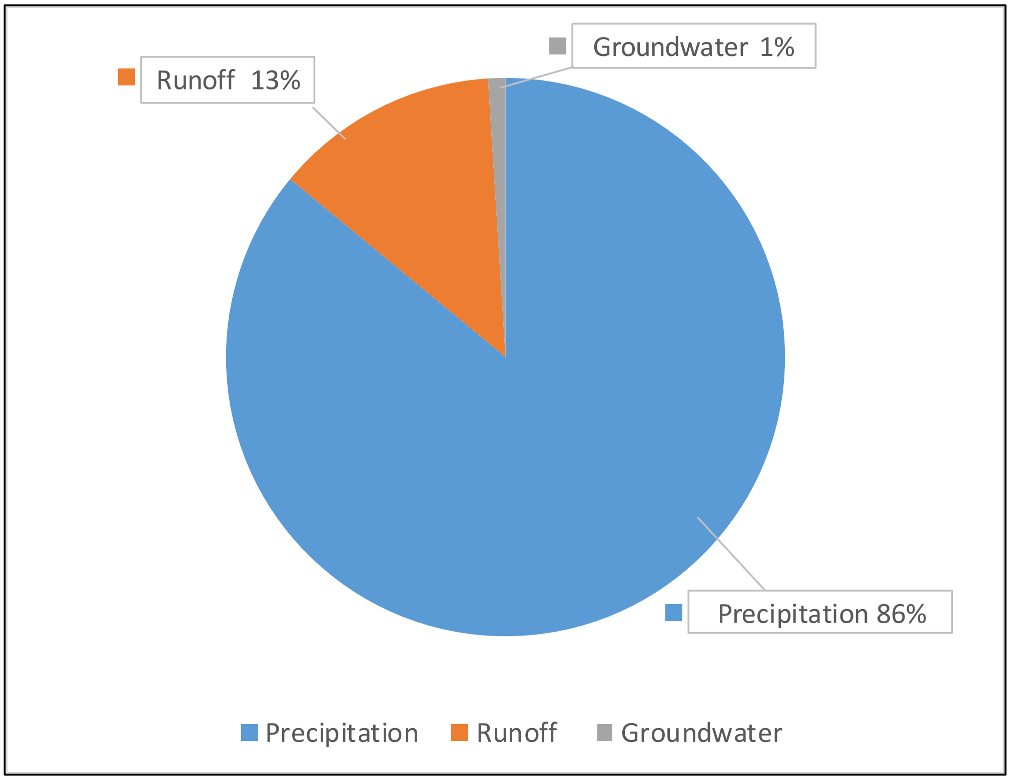


Figure 3-10. Waughop Lake water sources

This page intentionally left blank.

Section 4

Lake Nutrient Loading

The water quality data summarized in Section 2 and the lake water budget data described in Section 3 formed the basis of the nutrient budget for Waughop Lake. As noted in Section 2, the observed N:P ratios in lake water samples indicate that phosphorus is the limiting nutrient for algal productivity. However, contributions of nitrogen were also considered to be detrimental to the lake; therefore, the nutrient loading focused on phosphorus and nitrogen.

The nutrient loading for Waughop Lake consists of loading components attributed to groundwater, precipitation, waterfowl, runoff, benthic flux, and sedimentation. Septic systems would contribute through groundwater if significant. A simple mass balance model (see Figure 4-1) with a 1-month resolution was applied to Waughop Lake to characterize phosphorus and nitrogen reservoirs and fluxes into and out of the water column. This model was populated using measurements and literature-based estimates of TN and TP. All nitrogen and phosphorus chemical analyses were carried out by IEH on samples collected by UWT staff. The following sections describe how each component was estimated.

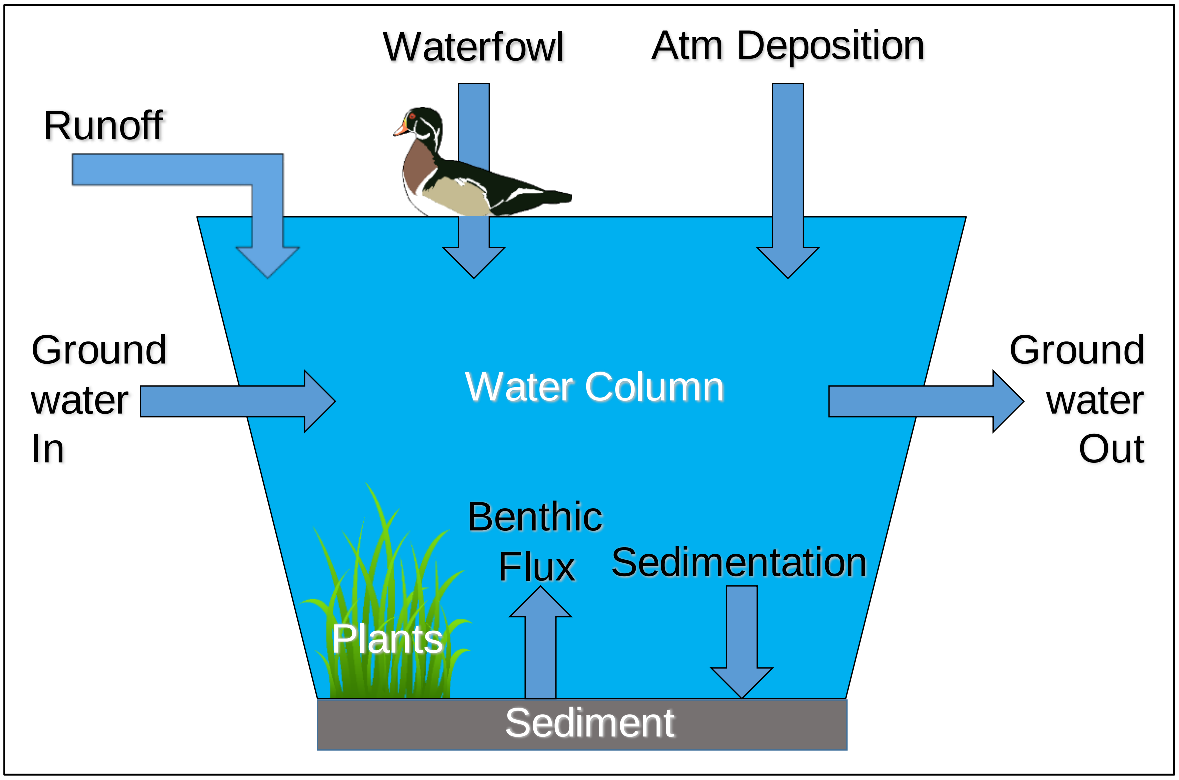


Figure 4-1. Conceptual nutrient model for Waughop Lake

(Note: reservoirs are depicted with white labels: water column, plants, and sediment.)

4.1 Trophic State Index and N:P Ratio

The lake water quality monitoring data were used to assess the trophic state of Waughop Lake. Lakes and ponds are typically categorized according to trophic states as follows:

- **Oligotrophic:** Low biological productivity. Oligotrophic lakes are very low in nutrients and algae, and typically have high water clarity and a nutrient-poor inorganic substrate. Oligotrophic water bodies are capable of producing and supporting relatively small populations of living organisms (e.g., plants, fish, and wildlife). If the water body is thermally stratified, hypolimnetic oxygen is usually abundant.
- **Mesotrophic:** Moderate biological productivity and moderate water clarity. A mesotrophic water body is capable of producing and supporting moderate populations of living organisms (e.g., plant, fish, and wildlife). Mesotrophic water bodies may begin to exhibit periodic algae blooms and other symptoms of increased nutrient enrichment and biological productivity.
- **Eutrophic:** High biological productivity because of relatively high rates of nutrient input and nutrient-rich organic sediments. Eutrophic lakes typically exhibit periods of oxygen deficiency and reduced water clarity. Nuisance levels of macrophytes and algae may result in recreational impairments.
- **Hypereutrophic:** Dense growth of algae throughout the summer. These have dense macrophyte beds, but the extent of growth may be light-limited because of dense algae and low water clarity. Summer fish kills are possible.

Waughop Lake is considered to be eutrophic to hypereutrophic based on chlorophyll-a, TP, TN, and Secchi depth values measured during the monitoring period (See Table 2-3 and Figure 2-5 above). The water near the lake bottom becomes anoxic. When anoxic, the bottom sediments release large amounts of phosphorus into the lake water. Waughop Lake's trophic state is also characterized with the Carlson Trophic State Index (TSI), one of the most commonly used means of characterizing a lake's trophic state (Carlson 1977). As illustrated in Figure 4-2, the TSI assigns values that are based upon logarithmic scales, which describe the relationship between three parameters (TP, chlorophyll-a, and Secchi disk water clarity) and the lake's overall biological productivity. TSI scores below 40 are considered oligotrophic, scores between 40 and 50 are mesotrophic, scores between 50 and 70 are eutrophic, and scores from 70 to 100 are hypereutrophic as shown in Tables 4-1 and 4-2, below. The resultant mass balance models for TP and TN are provided in Tables 4-3 and 4-4. Figure 4-3 shows the Waughop Lake phosphorus sources. A discussion of these figures and tables are provided in the subsequent sections.

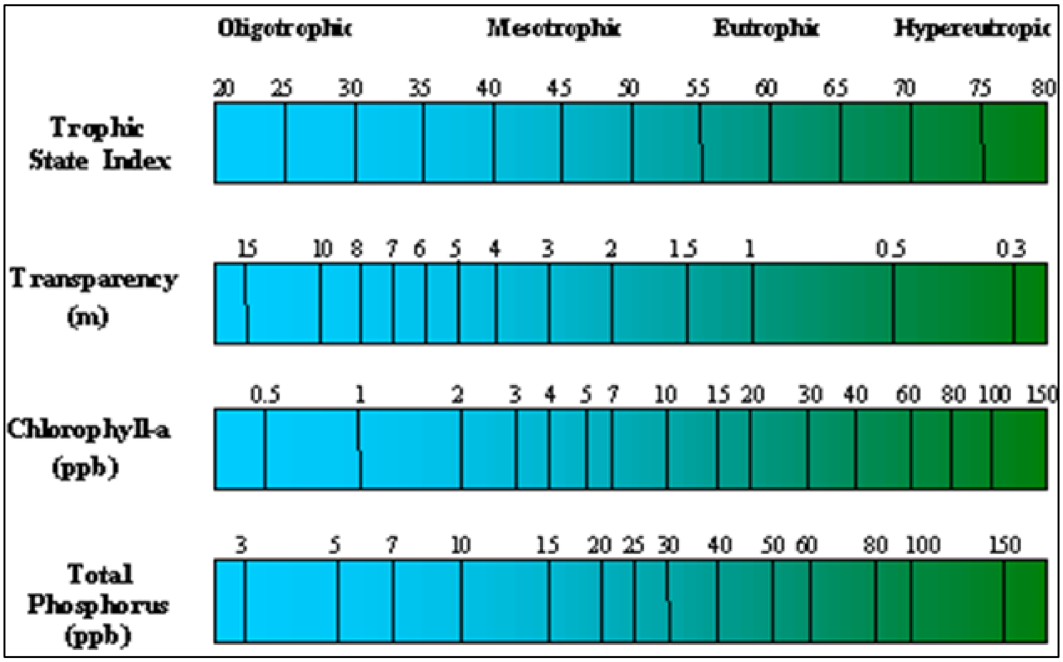


Figure 4-2. Carlson TSI

(EPA 1988)

Table 4-1. TSI Ranges

Trophic state	TSI	TP [a] (ppb)	Secchi disk (m)	Chlorophyll-a [b] (ppb)
Oligotrophic	<40	<12	>4.0	<2.6
Mesotrophic	40–50	12–24	4.0–2.0	2.6–7.3
Eutrophic	51–70	25–96	2.0–0.5	7.4–56.0
Hypereutrophic	>70	>96	<0.5	>56.0

a. *For TP, ppb = µg/L.*

b. *For chlorophyll-a, ppb = mg/m^3.*

Table 4-2. TSI Calculated for Waughop Lake using Chlorophyll-a, TP, TN, and Secchi Depth

Date	TSI (using chlorophyll-a)	TSI (using TP)	TSI (using TN)	TSI (using Secchi depth)
10/29/2014	65	66	57	57
11/22/2014	61	63	60	56
12/15/2014	66	71	64	55
1/22/2015	74	70	64	59
2/19/2015	71	77	66	63
3/12/2015	64	71	66	58
4/22/2015	46	66	57	52

Table 4-2. TSI Calculated for Waughop Lake using Chlorophyll-a, TP, TN, and Secchi Depth

Date	TSI (using chlorophyll-a)	TSI (using TP)	TSI (using TN)	TSI (using Secchi depth)
5/13/2015	59	67	60	61
6/9/2015	62	61	65	56
6/23/2015	56	62	59	50
7/6/2015	56	55	54	55
7/20/2015	62	64	60	58
8/5/2015	64	67	63	63
8/19/2015	67	62	62	62
9/14/2015	77	71	67	72
9/28/2015	72	68	64	68
10/13/2015	65	65	61	61

Table 4-3. TP Mass Balance Model for Waughop Lake

Date	Groundwater input (kg-TP) [a, c]	Groundwater output (kg-TP) [b, c]	Precipitation (kg-TP) [d]	Waterfowl (kg-TP) [e]	Benthic flux (kg-TP) [f]	Runoff (kg-TP) [g]	Sedimentation (kg-TP) [h]	TP in (kg)	TP out (kg)
01/2015	0.002	0.00	0.26	2.51	0.00	0.11	7.62	2.89	7.62
02/2015	0.001	0.00	0.32	2.86	0.00	0.13	7.62	3.31	7.62
03/2015	0.001	0.00	0.27	3.71	0.00	0.10	7.62	4.08	7.62
04/2015	0.002	0.00	0.12	0.14	0.00	0.05	7.62	0.31	7.62
05/2015	0.002	0.00	0.04	0.17	73.70	0.02	7.62	73.93	7.62
06/2015	0.000	0.00	0.02	0.39	71.32	0.01	7.62	71.74	7.62
07/2015	0.000	0.62	0.01	0.69	73.70	0.00	7.62	74.40	8.24
08/2015	0.000	0.68	0.12	0.38	73.70	0.06	7.62	74.26	8.31
09/2015	0.000	0.96	0.07	0.80	35.66	0.04	7.62	36.56	8.58
10/2015	0.000	0.86	0.30	0.72	36.85	0.16	7.62	38.03	8.48

a. *Only GW-1 TP concentrations were used for inflows.*

b. *Average TP concentrations from GW-2–GW-5 were used for outflows.*

c. *Average nutrient concentrations (TP, TN) were calculated per quarter: October–December, January–March, April–June, and July–September.*

d. *Precipitation concentrations obtained from Roberts 2013 and Dion et al. 1983.*

e. *The majority of ducks in winter were feeding in the lake and were possibly recycling nutrients already there, but conservative literature values were used from Chaichana et al. 2010.*

f. *The median flux rate from all chambers during all 3 months that were sampled was determined and applied to the sediment surface area only for those months where bottom waters were determined to be anoxic (May through October) (Figure 2-5 [DO profile figure]). In September and October one of two sampling periods showed anoxia, and so the median benthic flux was determined for half of each month.*

g. *Runoff concentrations taken from WA Dept. of Ecology Publication No. 11-03-010 (Herrera 2011).*

h. *Flux to sediments amount were from estimates made by Jeff Tepper (personal communication with Jim Gawel May 2016) using the sediment core.*

Table 4-4. TN Mass Balance Model for Waughop Lake

Date	Groundwater input (kg-TN) [a, c]	Groundwater output (kg-TN) [b, c]	Precipitation (kg-TN) [d]	Waterfowl (kg-TN) [e]	Benthic flux (kg-TN) [f]	Runoff (kg-TN) [g]	Sedimentation (kg-TN) [h]	TN in (kg)	TN out (kg)
01/2015	0.293	0.0	1.75	7.94	0	1.58	318	11.56	318
02/2015	0.247	0.0	2.15	9.03	0	1.88	318	13.30	318
03/2015	0.201	0.0	1.78	11.70	0	1.55	318	15.24	318
04/2015	0.503	0.0	0.80	0.44	0	0.67	318	2.42	318
05/2015	0.553	0.0	0.27	0.55	1,216	0.25	318	1,218.00	318
06/2015	0.000	0.0	0.12	1.26	1,177	0.11	318	1,178.00	318
07/2015	0.000	11.3	0.06	2.19	1,216	0.06	318	1,218.00	330
08/2015	0.000	12.6	0.83	1.19	1,216	0.91	318	1,219.00	331
09/2015	0.000	17.6	0.46	2.51	588	0.53	318	592.00	336
10/2015	0.000	116	1.99	2.29	608	2.32	318	615.00	434

a. *Only GW-1 TP concentrations were used for inflows.*

b. *Average TP concentrations from GW-2–GW-5 were used for outflows.*

c. *Average nutrient concentrations (TP, TN) were calculated per quarter: October–December, January–March, April–June, and July–September.*

d. *Precipitation concentrations obtained from Roberts 2013 and Dion et al. 1983.*

e. *The majority of ducks in winter were feeding in the lake and were possibly recycling nutrients already there, but conservative literature values were used from Chaichana et al. 2010.*

f. *The median flux rate from all chambers during all 3 months that were sampled was determined and applied to the sediment surface area only for those months where bottom waters were determined to be anoxic (May through October) (Figure 2-5 [DO profile figure]). In September and October one of two sampling periods showed anoxia, and so the median benthic flux was determined for half of each month.*

g. *Runoff concentrations taken from WA Dept. of Ecology Publication No. 11-03-010 (Herrera 2011).*

h. *Flux to sediments amount were from estimates made by Jeff Tepper (personal communication with Jim Gawel May 2016) using the sediment core.*

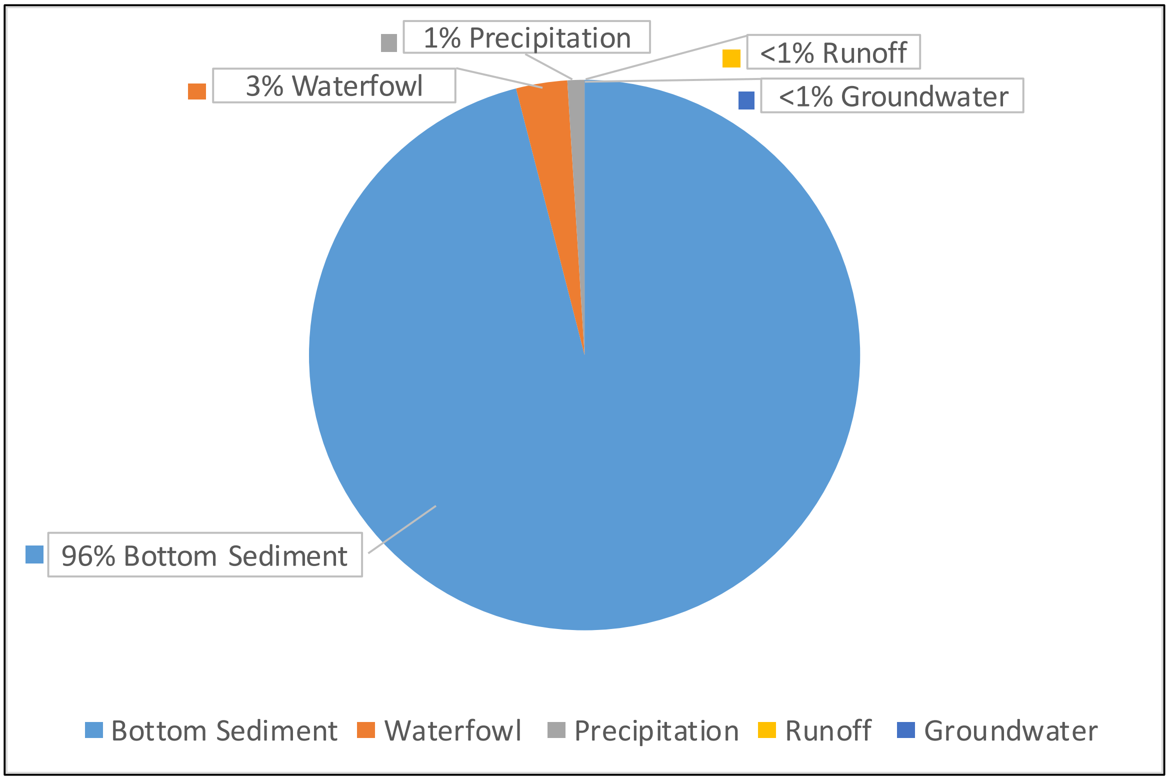


Figure 4-3. Waughop Lake phosphorus sources

4.2 Groundwater

As discussed in Section 3, the direction of groundwater flow in the vicinity of Waughop Lake is generally to the north, with groundwater levels at GW-1 (the southern monitoring well) as the up-gradient well. During high groundwater periods, generally from December to June, the lake receives recharge from the groundwater system from the southern shoreline area in the vicinity of GW-1. In mid-summer (mid-June during the 2015 monitoring period), groundwater levels drop below the lake surface elevation and seepage from the lake results in flux back to the groundwater system. Of the five monitoring wells installed around Waughop Lake, only GW-1 had greater head levels than the lake surface elevation from January to June. GW-4 had one greater head level in February. All other wells at all other times of the year had head levels that were lower than the lake surface from June to October. Thus, groundwater nutrient influx (i.e., inflow) was calculated using TN and TP concentrations measured in GW-1, and groundwater efflux (i.e., outflow) was calculated using the average TN and TP measured in GW-2 to GW-5. As groundwater samples were only analyzed quarterly, the quarterly values were applied to all months in that quarter. (Specifically, analytical results from groundwater samples collected in December 2014 were used to represent October to December, samples collected in February 2015 were used to represent January to March, samples collected in May 2015 were used to represent April to June, and samples collected in August 2015 were used to represent July to September.)

Overall, the hydrologic mass balance for Waughop Lake greatly influences the nutrient mass balance in the lake. Phosphorus concentrations in groundwater in the nearby aquifer are, in general, much less than in the lake's water column and the advective flux of groundwater into the lake is very low (see Table 4-3). This results in very little influence for groundwater on phosphorus loading into the lake. During the year the lake loses much more volume to groundwater than it gains. Moreover, measurements of TP in the groundwater suggest that concentrations in groundwater increase when the lake is losing water to the aquifer. Thus, groundwater acts as a net sink for phosphorus for the lake rather than a source.

Groundwater also acts as a net sink for nitrogen in the lake during the year (see Table 4-4). However, TN concentrations are in general higher in groundwater than in the lake's water column during most of the year, although concentrations were highly variable in the different monitoring wells. Trends in nitrogen in groundwater are very difficult to interpret without further measurements of nitrogen transformations and chemical speciation.

4.3 Precipitation

Concentrations of nitrogen and phosphorus in precipitation were not measured during this monitoring period. Rather, estimates for nitrogen and phosphorus loading in precipitation were garnered from published literature values (see Tables 4-3 and 4-4, above). Precipitation concentrations were taken from Roberts for phosphorus, and from Dion et al. for nitrogen (Roberts 2013; Dion et al. 1983).

Nutrient inputs to Waughop Lake in precipitation are greater than groundwater inputs, but less than waterfowl, and are comparable to runoff amounts. Greater certainty in estimating precipitation and dry deposition inputs of nutrients to the lake might be warranted in the future only if internal loading of nutrients from sediments is addressed.

4.4 Waterfowl

This evaluation estimates that waterfowl are the second-biggest source of nitrogen and phosphorus to Waughop Lake (after benthic flux); however, it is likely that this overestimates the contribution of these waterfowl (see Tables 4-3 and 4-4 above). For this study, it was found that during the winter the population of waterfowl was strongly dominated by Northern Shovelers. These are dabbling ducks that strain their food (e.g. small crustaceans) from the lake water column. They recycle nitrogen and phosphorus already in the lake, rather than importing nitrogen and phosphorus from external sources. Thus, the estimated winter nitrogen and phosphorus inputs from waterfowl are likely overestimated.

4.5 Benthic Flux

Internal loading of phosphorus to the water column as determined by benthic flux chambers was 30 times greater than any other source (see Table 4-3). Internal loading of nitrogen was 150 times greater (see Table 4-4). These estimates may overestimate nutrient fluxes from sediments by forcing lower oxygen levels in the chambers than occurs in the shallow lake otherwise, but the chambers may also underestimate the flux by depressing advective mixing or turbulent diffusion. These results are a strong indicator that internal loading of nitrogen and phosphorus to the lake is by far the greatest source of nutrients to Waughop Lake at this time.

4.6 Runoff

The amount of direct overland flow volume into Waughop Lake is likely very small due to the relatively flat, vegetated area that surrounds the lake and an asphalt walkway that separates the lake shore from the surrounding contributing area; stormwater runoff appears to be a minor source to the lake. The largest potential source of runoff into the lake is through the stormwater system that drains a large portion of the Pierce College parking lot and roof area with an outlet emptying directly into the lake.

Some of the stormwater samples collected at the inlet to the pond contained elevated TP concentrations. However, as discussed in Section 2, most of the runoff from the Pierce College campus was retained in an infiltration pond. This facility is designed to bypass flows that exceed the storage and infiltration capacity of the pond. During the monitoring period for the Waughop LMP (Oct. 2014 – Oct. 2015), all of the inflow reaching the pond was infiltrated, so there was no bypass. Therefore, nitrogen and phosphorus inputs from runoff are estimated to be lower than inputs from precipitation and waterfowl, and much lower than inputs from lake bottom sediment (see Tables 4-3 and 4-4 above).

4.7 Sedimentation

Estimates of sedimentation rates for nitrogen and phosphorus were provided via personal communication with Dr. Jeff Tepper of UPS to Jim Gawel of UWT in May 2016. Dr. Tepper collected multiple sediment cores in a previous study using a piston corer. Cores were sectioned and dated using ^{210}Pb. The sedimentation rate for surface sediments was applied evenly across the year (see Tables 4-3 and 4-4) (Tepper 2013).

Overall, sedimentation rates for nitrogen and phosphorus are much greater than all inputs except benthic flux rates, further supporting internal loading from lake bottom sediment as the most significant source of nutrients to the water column. The mass of phosphorus lost to sedimentation during the period from January to October was approximately 20 percent of the estimated benthic flux, while the loss of nitrogen to sedimentation was about 50 percent of the benthic flux. A better estimate for sedimentation rates might be warranted in future work as sediment cores are not very good at estimating fluxes on an annual scale. Sediment traps would be a better choice for estimating the loss to sediments.

4.8 Reservoirs of Nutrients

The reservoir of nitrogen and phosphorus in sediments, aquatic macrophytes, and the water column was estimated. Water column values were determined by average TN and TP water column values. The sediment reservoir in the top 10 cm (assumed to be more easily available as a benthic source) was estimated by a composite sample collected from 12 regular sampling locations throughout Waughop Lake using a petit ponar dredge. The composite sample was well mixed, dried, digested, and analyzed for TN and TP. For aquatic macrophytes, sampling was conducted in August to estimate the maximum reservoir size at the assumed height of plant biomass production. Samples were collected using a plant rake that was rotated 360 degrees near the bottom from the boat at 12 regular sampling locations throughout the lake. Samples were composited into three samples, well rinsed to remove sediment, and then dried, ground, digested, and analyzed for TN and TP.

The nutrient reservoir in the surface sediments is about 100 times greater for phosphorus (2,400 kg phosphorus) and 30 times greater for nitrogen (14,000 kg nitrogen) than the average in the water column (24 kg phosphorus and 481 kg nitrogen). The maximum size for the nutrient reservoir in the aquatic macrophytes is approximately seven times greater for phosphorus (163 kg phosphorus) and only slightly greater for nitrogen (484 kg nitrogen) than the average in the water column. Thus, sediments represent a significant store of nitrogen and phosphorus for adding to the water column, while aquatic macrophytes may be significant only for phosphorus. Senescence of aquatic plants in the fall may result in a significant increase in phosphorus.

This page intentionally left blank.

Section 5

Management Measures

5.1 Lake Management Objectives

The overall goal of this LMP is to develop strategies to improve and protect the Waughop Lake uses impaired by excess nutrients. As described in Section 4, the lake characterization monitoring found that phosphorus is the limiting nutrient for cyanobacteria and internal cycling from the lake bottom sediment is the largest phosphorus source.

In summer 2014, the City participated in an open house and farmer's market to obtain stakeholder input on the Waughop LMP objectives. The City posted Waughop LMP information on the City website and provided LMP information to local newspapers. The City also distributed questionnaires to solicit stakeholder input on concerns and potential management objectives for Waughop Lake. City staff briefed the City Council on the lake monitoring results during a public meeting in February 2016.

Researchers with UWT conducted a survey to estimate Lakewood residents' willingness to pay for general improvements in Waughop Lake water quality (McGuire et al. 2016). Six thousand households were invited to take the survey but only 192 responded. The survey results indicated a willingness to pay $43 annually for improved water quality in Waughop Lake. The UWT researchers cautioned that because of the low response rate, the survey results may not be representative of the average willingness to pay for all Lakewood citizens. The 192 respondents who took the time and effort to complete the survey may feel more strongly about lake water quality than many who did not complete the survey. Therefore, the survey results might overestimate the average willingness to pay for the general public (McGuire et al. 2016).

Algae blooms and poor water clarity were the most common concerns that were identified by stakeholders in the questionnaires and meetings. Based on stakeholder input and monitoring results, the City determined that the primary objective for the LMP should be to minimize the frequency of cyanobacteria blooms in Waughop Lake.

5.2 Potential Management Measures

The project team used the 2014–15 lake monitoring results to develop an initial screening list of potential watershed and in-lake management measures to reduce cyanobacteria blooms in the lake (Table 5-1).

Table 5-1. Potential Waughop Lake Management Measures: Initial Screening

Watershed	In-lake	
Stormwater treatment/removal	Bottom aeration or oxygenation	Whole lake treatment, phosphorus inactivation
Septic system improvement or sewering	Vigorous epilimnetic mixing	Sediment oxidation
Waterfowl management	Circulation and destratification	Settling oxidation
Public education	Dilution and flushing	Settling agents
	Drawdown	Selective nutrient addition

Table 5-1. Potential Waughop Lake Management Measures: Initial Screening

Watershed	In-lake	
	Dredging	Nutrient input reduction
	Light-limiting dyes and surface covers	Enhanced grazing (fish, zooplankton)
	Mechanical removal (algae/plants)	Bottom-feeding fish removal
	Selective water withdrawal	Fungal/bacterial/viral pathogens
	Algaecides	Competition and allelopathy
	Pump and treat system	Floating wetlands

The project team performed an initial screening evaluation of these measures based on the lake monitoring results. The City solicited input on the preliminary list from City staff, local citizens, TPCHD, and PCD. In addition, City staff briefed the City Council and City Parks and Recreation Advisory Board on the potential management measures in September 2016.

Based on the screening evaluation and stakeholder input, the following measures were identified as high priority for additional analysis:

- Dredging
- Whole-lake treatment, phosphorus inactivation
- Bottom aeration with vigorous epilimnetic mixing
- Pump and treat systems

Table 5-2 below provides a brief summary of these management measures, including initial and ongoing planning-level cost estimates, water quality benefits, the timeline over which benefits could be expected to occur, and expected duration of the benefits. The text below provides a brief discussion of the measures and Appendix D contains fact sheets for each.

Table 5-2. Management Measures that Passed Initial Screening: Options for Control of Cyanobacteria

Option	Planning-level cost estimates		20-year costs (capital+ ongoing)	Water quality benefit	How soon will water quality benefits occur?	How long will water quality benefits last?	Other potential benefits?	Other potential impacts/costs?
	Initial	Ongoing						
Dredging (hydraulic, "wet" excavation, or "dry" excavation)	Costs could vary widely based on dredging and disposal methods. Onsite disposal ranges from $2.7M–$12.0M. Offsite disposal ranges from $8.5M–$17.9M.	None	$2.7M–$17.9M, depending on disposal and treatment requirements	Highest. Would remove ~100 years of phosphorus enriched sediment.	< 1 year	Long term	Increased lake depth, more groundwater inflow, more fish habitat.	Permitting challenges. Habitat disturbance during dredging. Equipment staging on shoreline. Odor from dredge spoils. Onsite dewatering/ disposal would require large area. Truck traffic (if offsite disposal is necessary.)
Phosphorus inactivation with whole-lake treatment	$210k for prep and initial treatment.	$120k every 3–10 years.	$0.7M (assumes follow-up treatment every 5 years)	High initially, slow decline over time.	Immediate	3–10 years	Minimal infrastructure, no conflicts with other lake uses.	Could increase macrophyte growth. Would need to be repeated every 3–10 yrs.
Lake bottom water aeration and mixing	$1.9M	$20k/year	$2.3M	Medium to high. Would increase DO, reduce phosphorus release from sediment, disrupt cyanobacteria blooms. Could be configured to include alum emitter.	2 years	Long term	Few conflicts with other uses. Increased DO should improve fish habitat.	Blower building would be required. Energy use.
Pump and treat: chemical treatment	$1.5M	$80k/year	$3.1M	Medium	1 year	Long term	Flexible operation. Higher treatment capacity than wetland treatment system. Learning opportunity for college students.	Would require ~3 acres of land. Temporary impacts during construction.
Pump and treat: constructed wetlands	$3.1M	$100k/year	$5.1M	Medium (less than chemical treatment)	1 year	Long term	Flexible operation. Increased habitat for birds and other wildlife. Learning opportunity for college students.	Would require ~9 acres of land. Temporary impacts during construction.

5.3 Dredging

Various types of dredging techniques could be used to remove the most phosphorus-rich sediment from the lake bottom to decrease internal loading and improving water quality. Permanent removal of phosphorus-enriched sediment through dredging would provide the greatest and most long-lasting water quality benefits. Additionally, removal of fine-grained sediments may increase hydraulic connectivity with the surrounding aquifer where phosphorus levels are relatively low, thereby increasing flushing and reducing hydraulic residence time. Other potential benefits include increased lake depth and fish habitat. Potential impacts include habitat disturbance during the dredging activity, odor from the dredge spoils, and the need for large areas for sediment dewatering and disposal. Off-site disposal (if required) could lead to short-term noise and traffic congestion.

The limited sediment core data indicate that the upper 100 cm of sediment contains high phosphorus concentrations. Removing the upper 100 cm would generate approximately 121,000 cubic yards of material. The estimated cost to remove approximately 121,000 cubic yards from the bottom of Waughop Lake ranges from $2.7M to $17.9M, depending on the dredging method, and dewatering and disposal requirements. Cost will be toward the high end of this range if the dredged material must be hauled away for re-use or disposal. However, once the dredging has been completed there would be no ongoing costs.

Additional sediment sampling and analyses are needed to refine the estimated sediment volume to be dredged and determine the dewatering and disposal requirements.

5.3.1 Dredging Methods

A variety of methods and equipment could be used to accomplish dredging of Waughop Lake. Dredging methods are typically categorized as either hydraulic or mechanical with each method utilizing different methods of removal, dewatering, and transport within the process.

Hydraulic dredging uses a floating barge or floating line system on a boom, with a relatively smaller barge footprint than a mechanical dredge (Figures 5-1 and 5-2). The hydraulic dredge consists of a boom or ladder with a cutter head that rotates/excavates material and pumps the sediment - water slurry through a pipe to a dewatering area. The spoils can discharge to a barge or the discharge line can be floated to shore and discharge directly to a dewatering area.

Figure 5-1. Hydraulic dredging

(MSA Professional Services)

Figure 5-2. S.A.M.E. auger dredging, Australia

The additional water pumped during hydraulic dredging requires additional management. Settling basins are typically used for larger dredge discharge volumes, but mechanical dewatering, or geotextile tubes or geotubes can be used in areas where dewatering and sediment placement options are limited to small footprints. One advantage of this method is that the dredged material can be pumped to a dewatering site away from the lake, so there would be less equipment traffic and disruption near the lake as compared to wet or dry excavation methods.

Wet excavation, or mechanical dredging, typically includes a crane and clam bucket or dragline bucket. A hydraulic excavator may also be used. Excavated material is placed in nearby spoils area and transferred by pump or other trucks. Dredging from shore using heavy equipment is typically limited to approximately 40 to 50 feet from the shoreline without prior dewatering of the lake. With an average diameter greater than 1,000 feet, dredging from the shore will not accomplish the dredging goals for Lake Waughop. Mechanical dredging requires different pieces of equipment at different steps, handling, moving or loading sediment multiple times. This method would involve more shoreline disruption than hydraulic dredging.

Figure 5-3. Mechanical dredging equipment

(Royal IHC)

Dry excavation requires dewatering of the lake and removing the bottom sediments using land-based excavation equipment. Dry excavation could be difficult to implement at Waughop Lake. The existing data suggest that the lake bed sediments are fine-grained and high in organic matter, so they may not dewater under gravity (i.e., as a result of lake level dewatering) to a consistency that would support excavation equipment. Draining the lake would take considerable time and would require identification of a suitable water discharge location. Groundwater inflow could hamper dewatering. Dewatering the lake would likely increase the duration of lake disturbance and could have adverse short-term impacts on aquatic habitat. This method would require more shoreline disruption than hydraulic dredging.

5.3.2 Sediment Dewatering and Disposal

After the sediment has been removed from the lake using one of the methods outlined above, it will require dewatering and proper disposal. The water removed from the sediment will contain nutrients and other pollutants and may need to be treated prior to discharge.

Sediment dewatering and water management can be designed as passive or mechanical systems. Passive dewatering uses settling ponds to allow sediment to settle and drain over time. This method can be cost-effective when sediment volumes are small, but requires the greatest amount of land surface area. Geotubes also are considered passive dewatering systems. The tubes are typically custom made for the project using polypropylene fabrics. Polymer flocculating agents can be used to speed the settling process within the geotubes. Given the large sediment quantity (approximately 120,000 cubic yards), geotube-based dewatering may be impractical for Waughop Lake.

Mechanical systems can separate water from the slurry using physical, mechanical, and integrated systems. Typical physical/mechanical methods include: centrifuges, hydrocyclones, thermal drying, filter press (belt or plate), and proprietary methods using a combination of methods in one consolidated unit. These technologies typically require the least land area but are costlier than passive dewatering. Many dewatering systems include in-line dewatering equipment, with final systems tailored to the attributes of the dredged sediments. Additional physical and chemical data will be needed to better define the sediments characteristics prior to selecting the most appropriate excavation and dewatering technologies.

Dredging costs will be higher if the dredged material cannot be accommodated in the vicinity of Waughop Lake and must be transported offsite for long-term disposal. Cost will be closer to the high end of the range listed in Table 5-2 if the dredged material contains contaminants that require special disposal at a regional facility such as the Columbia Ridge or Roosevelt facilities on the central Washington/Oregon border.

5.3.3 Treatment

Any water returned to the lake from the dewatering process may require treatment. Treatment may range from basic settling and filtration to more advanced treatment systems including coagulation and precipitation, or advanced filtration, for the removal of potential contaminants including turbidity, metals, and nutrients.

As stated above, the City or its agents would need to collect additional data prior to selecting the dredging option and developing the dredging and disposal design. See Appendix D for fact sheets containing additional information on dredging.

5.4 Lake Aeration and Mixing

The lake aeration and mixing option would inject air near the lake bottom to produce oxic conditions (i.e., decreased phosphorus release from sediment under anoxic conditions) and create vertical currents that disrupt cyanobacteria (see Figure 5-4). Note that Figure 5-4 shows an idealized cross-section for a deeper lake where a significant hypolimnion may develop. In contrast, Waughop Lake is shallow and while it stratifies, it does not have a significant, cooler hypolimnion. The initial planning-level costs are $1.9M for construction and $20k per year for operation and maintenance of the system. This option would decrease phosphorus release from sediment, disrupt cyanobacteria and increase DO for fish. An electric motor-driven blower housed in a small building would produce compressed air for mixing. Plastic pipes placed along the lake bottom would distribute air to diffusers that are spaced about 10 times the water depth apart. Operation and maintenance costs are based on an assumed 8-month per year operation. See Appendix D for a fact sheet containing additional information for this option.

Bottom aeration adds air to the lake water, increasing the concentration of oxygen by transferring it from gas to liquid and generating a controlled mixing force. Aeration is used to prevent hypolimnetic anoxia (i.e., low oxygen in the bottom layer), thereby decreasing the release of phosphorus from the bottom sediments. Aeration also retards the buildup of undecomposed organic matter and compounds (e.g. ammonium) near the bottom of the lake, and can increase the amount of water that is available to zooplankton and fish living in the lower, colder waters. Hypolimnetic aeration typically has low potential for adverse side effects (NALMS 2001).

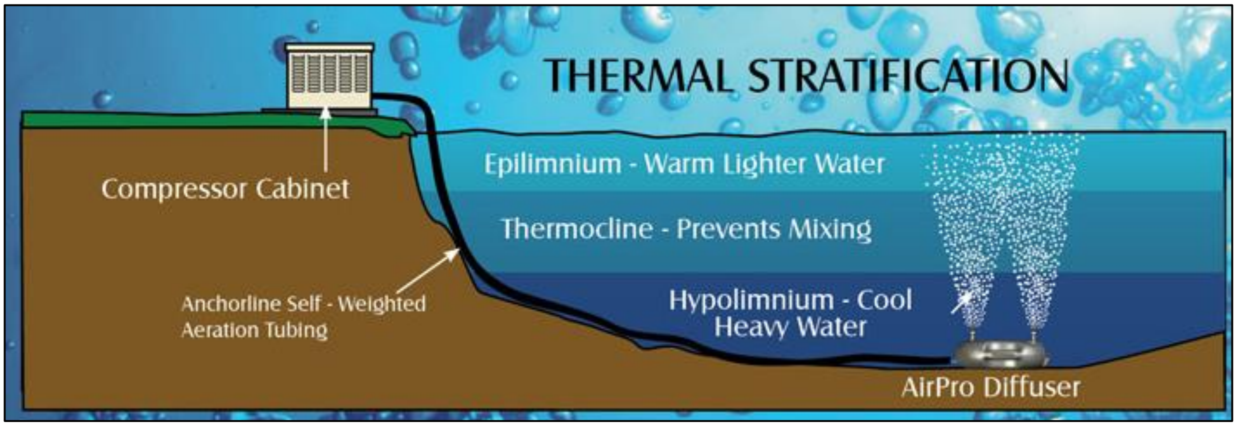


Figure 5-4. Example of lakebed aeration

(Aqua Control)

Epilimnetic mixing is a form of aeration that creates vertical currents designed to disrupt cyanobacteria growth. These systems create “tiny bubbles” that move lake water from the bottom depths to the surface. At the surface the water mixes with the atmosphere, fully oxygenating the water, which then cycles back to the bottom.

Bottom aeration has significant capital and operating costs, and requires adequate iron in the sediments to bind all the phosphorus. Aeration of bottom waters has produced mixed results (Grochowska and Gawronska 2004; Engstrom and Wright 2002; Ottolenghi et al. 2002). Some aeration methods increase the vertical mixing in the lake, exacerbating eutrophic conditions by more effectively transporting phosphorus to the photic zone while ineffectively aerating surface sediment pore water to prevent phosphorus release. Sediment resuspension during aeration also may be an issue in Waughop Lake because of the fine-grained, organic-rich nature of the sediments. Therefore, this treatment technique is considered to be less desirable than whole-lake phosphorus inactivation or dredging, but if configured to promote mixing, could still have significant value for Waughop Lake by discouraging cyanobacteria growth. Prior to implementing a lake aeration and mixing system, the City should collect additional data to fill key gaps (e.g., bathymetry data) and perform a pilot study to confirm that this approach would be suitable for the lake.

5.5 Phosphorus Inactivation

Internal phosphorus loading in Waughop Lake may be controlled with liquid alum (i.e., aluminum sulfate), or similar coagulants, to bind/inactivate phosphorus in the sediment, precipitate phosphorus from the water column, reduce internal loading, and mitigate algae problems. Phosphorus inactivation is the most effective in-lake management action today (Wilson et al. 2016). Whole-lake alum treatments have been used successfully throughout the United States for many years. Green Lake, Lake Stevens, Lake Ketchum, and other lakes in Washington have been successfully treated using alum (Burghdoff et al. 2012).

Alum is applied to the lake surface, usually from a boat or barge, with long arms to spread the alum into the lake from nozzles or trailing tubes. The treatment is typically done using computerized dosing control to apply the appropriate amount of alum for the water depth and volume at any point in the lake.

The aluminum in alum combines with phosphorus in the water column to form an aluminum phosphate precipitate, which settles to the bottom of the lake. Aluminum also reacts with particulate matter in the lake such as algae and suspended solids to form an aluminum hydroxide precipitate, which also settles to the lake bottom. The aluminum hydroxide floc also captures pathogens and other pollutants in the lake water column. The floc resembles snowflakes. The aluminum in the precipitates binds the available phosphorus in the sediment to prevent the phosphorus from being released into the water column even under anoxic conditions (see Figure 5-5) (Burghdoff et al. 2012). This is accomplished by converting saloid- and iron-bound phosphorus to aluminum-bound phosphorus.

Figure 5-5. Alum treatment in Lake Stevens, Washington

(AquaTechnex)

Alum addition to a lake can rapidly lower pH levels of the water, making the lake more acidic, especially in lakes with soft water and low buffering capacity. For this reason, alum treatments are often buffered by adding another complementary alkaline coagulant, such as sodium aluminate, to balance the pH and prevent negative impacts to organisms living in the lake (Burghdoff et al. 2012). The successful whole-lake treatment on Green Lake included alum and sodium aluminate. Jar testing with the lake water and different coagulants and doses must be performed to determine the optimum mix of coagulants and doses.

It is extremely important for an experienced and qualified firm to conduct the treatment. The North American Lake Management Society (NALMS) has determined that alum treatments are an effective and safe lake management tool (NALMS 2004). Alum treatments are approved by EPA and many state environmental agencies including Ecology.

As shown in Table 5-2 and in Appendix D, this management measure option assumes the addition of ~20,000 gallons of alum and ~10,000 gallons of sodium aluminate to remove phosphorus from the water column and form an alum floc layer on the sediment. These coagulant volumes are based on the amount of phosphorus in the lake and the top 10 cm of sediment. BC assumed that a lower dose may be needed subsequently, every 3 to 10 years. The initial planning-level cost estimates are $210k for preparation and initial treatment and $120k every 3 to 10 years. The water quality benefit would be high initially, with a slow decline over time. This option requires minimal infrastructure and does not conflict with other lake management options. However, the increased water clarity could increase macrophyte growth and the floc could negatively impact some filter feeder fish. The reduced phosphorus concentrations in the water column could help to offset the effects from increased sunlight transparency by limiting the phosphorus available for macrophytes like coontail that absorb nutrients directly from the water.

5.6 Pump and Treat

The initial screening process identified two potentially viable pump and treat measures: chemical treatment and constructed wetland treatment.

A chemical pump and treat system would pump water from the lake, add a coagulant to precipitate phosphorus (aluminum phosphate and aluminum hydroxide) in an offline settling basin, and return the treated water to the lake. Chemical treatment is capable of removing approximately 85 to 90 percent of the phosphorus and over 95 percent of pathogens from the treated water. As noted in Section 5.4, alum treatment could increase macrophyte growth by increasing light penetration.

The initial planning-level cost estimate is $1.5M for construction and $80k per year for operation and maintenance. This option would require approximately 3 acres of land. The required infrastructure includes a wet settling pond, floc drying area, water intake and discharge pipes, water pump station, water flow meter, chemical feed system and storage tank, and a small equipment structure. This structure is typically a concrete block building with shingle or metal roof. The operation would be flexible and would have a higher treatment capacity than the constructed wetlands option. It would also be a good learning opportunity for Pierce College students to be involved in this type of treatment project.

The cost estimate for the chemical treatment option assumes that the system would be run at 2,500 gpm for approximately 6 months and that the treatment facility could be sited within 1,000 feet of the lake. At this pumping rate, the system would treat one lake volume every 21 days. The cost estimate assumes the system would treat about 1,600 ac-ft of lake water during the first year, removing about 136 kg of phosphorus (roughly 36 percent of the estimated phosphorus load for the monitoring period). The estimate assumes the volume treated would be reduced to about 800 ac-ft in subsequent years. The treatment volume could easily be increased to remove more phosphorus, but this would increase energy and chemical costs. This option could be combined with a small constructed wetland treatment system. The cost estimates in Table 5-2 do not include cost for land or for periodic removal of floc from the settling pond.

The constructed wetland treatment option includes pumping water from the lake into an approximately 8-acre wetland treatment system, with gravity discharge of the treated water returning to the lake. The initial planning-level cost estimate is $3.1M for construction and $100k per year for operation and maintenance. This option requires considerably more land than chemical treatment. When levee and access roads are included, the constructed wetland treatment option would require approximately 9 acres of land. An 8-acre wetland treatment facility would be able to treat about 1,000 gpm, and remove on the order of 50 kg of TP per year, which is about 13 percent of the estimated phosphorus load for the monitoring period.

The required infrastructure includes intake and discharge pipes, a water pump station, and a constructed wetland. The operations would be flexible and would provide increased habitat for birds and other wildlife. It also could provide a good learning opportunity for students from PCC, UWT, and other nearby schools. The cost estimate for this option assumes that the wetland treatment system would operate at 1,000 gpm for approximately 6 months per year, and that the wetland system could be sited within 1,000 feet of the lake. The cost estimate does not include land acquisition.

5.7 Summary and Recommendations

Dredging is expected to have the greatest long-term benefits among the measures that passed the initial screening. Capital costs are high, but once dredging has been completed there would be no ongoing costs. If the City can obtain the necessary funds, dredging should be conducted to remove phosphorus-rich sediment from Waughop Lake.

The existing data suggest that hydraulic dredging may be the most practical method, but dredging could be done using a variety of methods. The City may wish to specify the minimum performance requirements in requests for bids so that contractors have the flexibility to develop creative and cost-effective approaches for dredging. Appendix D contains more information on the dredging option.

Whole-lake alum treatment would quickly reduce phosphorus and cyanobacteria blooms in the lake, but could also increase macrophyte growth. The effects of alum treatment diminish over time so periodic follow-up treatments would be needed to maintain lake water quality. Whole-lake alum treatment would have a much lower initial cost than dredging but does have ongoing costs because of the need for follow-up treatments. The estimated 20-year cost for alum treatment is substantially lower than the other options considered. As noted in Appendix D, alum has been used to bind phosphorus in lake bottom sediment and control phosphorus and algae in many lakes throughout the United States, including lakes in the state of Washington. Whole-lake alum treatment is recommended if the City cannot obtain the funds needed for dredging.

Bottom aeration is a well-established method for reducing the anoxic conditions that favor phosphorus release from sediments. Epilimnetic mixing is a relatively new method intended to physically disrupt cyanobacteria growth. If dredging cannot be funded and an alternative to recurring alum treatments is desired, a combined aeration and mixing system could help reduce cyanobacteria blooms in Waughop Lake. However, this option would have significant capital and operating costs and the benefits are less predictable than dredging or alum treatment. Before implementing aeration and mixing in Waughop Lake, a pilot study should be conducted to evaluate effectiveness. Appendix D contains additional information on this option.

The pump and treat systems would entail similar capital but higher operating costs than bottom aeration/mixing. Coagulant treatment can be very effective at removing phosphorus from the treated water (e.g., 85 percent removal). However, the cost estimates are based on treatment rates of 1,000 gpm for a constructed wetland system and 2,500 gpm for chemical treatment, which could reduce phosphorus loads by roughly 13 percent to 36 percent. The actual TP load reductions to the lake could vary depending on the rate of phosphorus release from the lake bottom sediments. Given the relatively high costs and modest benefits, a pump and treat system (either chemical or wetland) does not appear to be a cost-effective solution for Waughop Lake.

Section 6

Implementation

6.1 Implementation Strategy

Current City revenue sources such as the City Parks and Recreation programs (General Fund) and the Stormwater Management Program (Utility Fund) are fully allocated and not expected to provide appreciable funding for lake management activities. Implementation of this LMP will require new funding sources, and the availability of funding may determine which of the recommended measures can be implemented. Therefore, the City proposes a phased approach for implementing this LMP, as described below:

- Phase 1 would consist of a whole-lake alum treatment to remove phosphorus from the water column and inactivate phosphorus in the sediment, thereby reducing the potential for cyanobacteria blooms. The City (or partners) would monitor the lake to evaluate the effectiveness and longevity of the alum treatment. During this phase, the City would collect the additional sediment data needed to refine the construction cost estimates and support permit applications for dredging. The City would also identify and pursue potential funding sources for LMP implementation.
- Phase 2 would involve dredging to remove phosphorus-rich bottom sediment from the lake bottom, provided that the City can secure the necessary funds and permits. The lake monitoring study found that bottom sediment is by far the largest source of phosphorus for cyanobacteria blooms. Dredging is expected to be the most effective long-term measure for reducing cyanobacteria blooms because it would remove phosphorus-rich sediments that have been accumulating from farming and other human activities over the past ~100 years. Funding for dredging would be pursued along with collection of information regarding public support for improved lake use.

If the City cannot secure the funds needed for dredging and Phase 1 monitoring indicates that alum treatment is likely to last at least several years, Phase 2 may consist of a follow-up whole-lake alum treatment. Conversely, if the City cannot secure sufficient funds for dredging and Phase 1 monitoring suggests that alum treatment benefits are short-lived, Phase 2 could include a pilot study to evaluate whether a bottom aeration and vertical-mixing system would significantly reduce phosphorus release from bottom sediments and disrupt cyanobacteria growth in the water column. If the pilot results are promising and the necessary capital and operating funds can be obtained, Phase 2 could include installation of a full-scale bottom aeration and mixing system.

6.2 Potential Funding Sources

This section describes a number of potential funding sources. Some sources, such as grants, loans, or state budget allocations, may be more suited to fund initial capital improvements, Sources that generate a steady and longer-term revenue streams, such as the Flood Control Zone District Opportunity Fund, might help pay for ongoing lake management activities. Successful implementation of the Waughop LMP will likely involve different funding mechanisms for various purposes throughout the life of the lake management efforts.

6.2.1 Grants and Loans

Both federal and state grant programs are administered by Ecology. Grant and loan funding is limited, generally applies to specific types of projects/activities depending on the funding program, and the competition for funds can be significant. However, some of these funding sources could potentially be applied to Waughop Lake management efforts, including Centennial Clean Water grants, Section 319 Clean Water grants and Clean Water State Revolving Fund loans, and non-traditional lake management funding sources, as discussed below. Additionally, there are Aquatic Invasive Plant Management grants and Freshwater Algae Control grants.

6.2.1.1 Centennial Clean Water Grants

The Centennial Clean Water program is a Washington State-funded grant program administered by Ecology. Local governments, special purpose districts, conservation districts, and federally recognized Tribes are eligible for these funds applicable to water quality infrastructure (e.g., wastewater treatment facilities) and nonpoint source pollution projects to improve and protect water quality. Nonpoint source pollution projects require a 25 percent match.

6.2.1.2 Section 319 Clean Water Grants

EPA provides Section 319 grant funds to Washington State with the state required to provide a 40 percent match in funding. The Section 319 program provides grants to eligible nonpoint source pollution control projects similar to the state Centennial Clean Water program. Eligible projects include lake water quality planning, riparian and wetlands habitat restoration and enhancement, as well other water quality improvement efforts. Non-profit organizations are also eligible for these funds. A 25 percent match is required and grants may be limited to $250k or $500k depending on the match type.

6.2.1.3 Clean Water State Revolving Fund Loans

The Clean Water State Revolving Fund (CWSRF) program is funded via an annual EPA capitalization grant, state matching funds, and principal and interest repayments on past CWSRF loans. This program provides low interest and forgivable principal loan funding for wastewater treatment construction projects, eligible nonpoint source pollution control projects, and eligible green projects. Local governments, special purpose districts, and Tribes can apply for these funds. No match is required and CWSRF loans can be used to match Centennial Clean Water and Section 319 grants. No more than 50 percent of the total available funds can go to any one applicant.

6.2.1.4 Non-traditional Lake Management Funding

There are also a number of giving foundations and charitable trusts operating within the state of Washington that are funded by one or more donors. Some of these foundations provide very significant grants for environmental works. Further research into these foundations as potential lake management funding sources may be worthwhile. Partnering with non-profit organizations may enhance access to various grant funding opportunities.

6.2.2 State Legislative Budget Allocation

State funding of some lake management measures may be appropriate, provided sufficient political support can be generated in the state legislature for selected Waughop Lake restoration efforts. Legislative budget allocations may be particularly well suited to one-time capital expenditures as opposed to ongoing activities requiring stable, long-term funding sources. Successful pursuit of a legislative budget request could address the Waughop Lake capital investment needs depending on the specific lake management actions or projects that are selected. Other funding mechanisms could provide the ongoing operation and maintenance resources necessary to protect those capital investments.

6.2.3 Special Purpose Districts

Another option for the City to consider is the development of special purpose districts. Special purpose districts are generally created through the local legislative authority to meet a specific need of the local community. The needs may include new services or higher levels of existing services. Lake management efforts may be financed through the creation of a special purpose district, such as a Lake Management District (LMD), Local Improvement District (LID) or Flood Control Zone District (FCZD).

Special-purpose districts can be political subdivisions of the state and come into existence, acquire legal rights and duties, and be dissolved in accordance with statutory procedures. Enabling legislation sets forth the purpose of the district, procedures for formation, powers, functions and duties, composition of the governing body, methods of finance, and other provisions. The districts may be quasi-municipal corporations, though some districts can be statutorily defined as municipal corporations. Although the general provisions for some special district statutes have been consolidated, such as for diking and drainage districts, there is no set of uniform provisions covering all special districts in Washington, like there is with cities and counties.

As part of this project, BC provided support for stakeholder involvement by working with UWT to assess Lakewood residents’ willingness to pay (WTP) for improvements in water quality in Waughop Lake. The survey team was led by Assistant Professor of Economics at UWT William McGuire.

Although 6,000 households were invited to participate in the survey, only 192 respondents (3.2 percent) completed the survey. Therefore, it is difficult to extrapolate the results of the survey to the wider Lakewood population. The UWT survey team believes it likely that these relatively few respondents self-selected into participating in the survey. As a result, the team concludes that this respondent group are likely already interested in the lake and are perhaps somewhat more willing to pay to improve it than would the average Lakewood resident. The question also arises as to whom should pay, because the lake is located in a park used by Lakewood residents and non-residents.

Survey findings include an estimated mean WTP of about $46 per household per year. It found no significant differences in WTP by water quality level, or across sociodemographic groups. Because of the low survey response rate, the survey team noted that the $46 per household per year should be considered as a high-level cost estimate. The “true” WTP for the water quality improvements in the survey is likely less than that amount. Further survey information regarding survey methodology and results can be found in the *Measuring Lakewood Residents’ Willingness to Pay for Improvements to Waughop Lake* (McGuire 2016).

6.2.3.1 Lake Management District

An LMD is a form of special-service district that funds lake management activities through charges on lake-area properties. An LMD can finance a range of activities, including:

- Controlling aquatic vegetation
- Improving water quality, including control of stormwater and agricultural runoff
- Performing water quality studies to pinpoint problems and identify solutions
- Maintaining ditches or streams associated with the lake
- Maintaining lake levels
- Maintaining beaches

An LMD is formed with property owners within the proposed district voting by mail, each granted one vote for each dollar they would be assessed under the proposed LMD. The City Council and affected property owners must approve the district formation; revenues are collected by the County Treasurer as a specific item on the annual property tax statement. An LMD is established for a specific time frame, up to 10 years. Both private and publicly owned lakefront property and upland lots with access to community beach areas are commonly included. It may be possible to include the entire watershed in an LMD.

LMD assessments or charges can be based on any reasonable factors, including: benefit, use, front footage, acreage, improvements, and services to be provided. LMD charges may include differing benefit zones throughout the district. For example, upland lots with access to a community beach may be included at a lower rate than waterfront lots. Waterfront lots could be further designated into different zones, which reflect a reduced benefit where wetlands or other factors limit the shoreline use. Public and private recreational areas may be placed in a special class and assessed based on the benefit to users from the lake management program.

Income from LMD rates is used only for activities specified in the legislation establishing the LMD. Allowances may be included for low-income property owners. A separate elected commission is not necessary for an LMD, as there would be for a drainage district or water district, and the City Council may serve as the governing board. However, ongoing involvement by the lake property owners (in this case, Washington State) and users is crucial to a successful program. Forming a committee of lake users is the preferred approach to achieve appropriate working relationships with City staff and elected officials in initiating and implementing an LMD program.

6.2.3.2 Local Improvement Districts

LIDs are a means of financing needed capital improvements through the formation of a special assessment district. Special assessment districts allow improvements to be financed and paid for over a period of time through assessments on the benefiting properties. A variation of the LID is the Utility Local Improvement District (ULID). The difference between ULIDs and LIDs is that utility revenues are pledged to the repayment of the ULID debt, in addition to the assessments on the benefiting properties. State statutes provide that an LID can be converted to a ULID after formation. The reverse is not possible.

The LID financing mechanism is a process to finance infrastructure improvements and does not provide a mechanism to construct those improvements. Construction projects must be managed by the City. LID project financing is based on the sale of bonds to investors and the retirement of those bonds via annual assessments on the property owners within a district. The assessment per parcel must not exceed the special benefit of the improvement to that parcel.

6.2.3.3 Flood Control Zone District

An FCZD can be a source of funding for lake water quality management activities. An FCZD is governed by a board, which can be the local legislative authority. The board may initiate the creation of a zone or additional zones within the FCZD for the purpose of undertaking, operating, or maintaining flood control projects or stormwater control projects or groups of projects, that are of special benefit to specified areas within the FCZD. Formation of a zone may also be initiated by a petition signed by 25 percent of the electors within that proposed zone (based on the vote cast in the last county general election).

Pierce County (County) created a FCZD in 2012. The County FCZD is a special-purpose district governed by a board of supervisors and an executive committee. The County Council serves as board of supervisors. An advisory committee, with County participation, provides input and recommendations to the board to carry out FCZD-approved projects and programs.

Funding for the County's FCZD comes from a county-wide property levy of $0.10 per $1,000.00 of assessed value. The levy raises approximately $8M per year. Ten percent of the County's FCZD levy proceeds are assigned to an Opportunity Fund, which is made available to jurisdictions throughout the County's FCZD on a proportional basis, based on assessed valuation. The Opportunity Fund for 2015 was $733,833 with grants dispersed among the 24 jurisdictions in the county based on certified assessed values. The Opportunity Fund grants can be used for a number of lake management activities including:

- Water quality and water resource and habitat protection and management
- Major equipment used for stormwater control or water quality protection
- Operation and maintenance of stormwater control improvements that were constructed or acquired by the jurisdiction
- Water quality monitoring and environmental assessment
- Aquatic plant management (e.g., targeted removal of invasive plants)
- Outreach and education
- Local match for other grants

Opportunity Fund recipients may choose to bank their allocation for use in future years, saving up for larger projects and efforts. The City has been banking its opportunity fund allocations to help pay for a vactor truck (used to vacuum trash and debris from the stormwater system), but has not yet received approval.

The County's FCZD holds the right to review any banking activity. Opportunity Fund allocations are issued on a reimbursement basis following a jurisdiction's invoice submittal, although the County's FCZD has some ability to grant funds in advance within pre-defined constraints as a percentage of the jurisdictions total current allocation. Given the County FCZD approval process and criteria, it would be prudent to discuss possible projects with them well in advance of project funding need.

6.2.4 Future Considerations for Lake Management Financing

Implementation of the Waughop Lake management actions could require funding from multiple sources. For example, for some levels of grant funding, it may be necessary to procure capital investments prior to receiving grant funds. Short-term startup costs may need to be borne by a combination of utility revenues and grants, while long-term operations and maintenance may be appropriate to special benefit district funding or perhaps some level of funding within the City budget. There are a number of potential funding sources that warrant further investigation. Additionally, Waughop Lake ownership may affect some potential lake management funding opportunities. Legal review of potential funding mechanisms could include assessment of the need for interlocal agreements, memoranda of understanding, lease agreements, easements, etc. as may be necessary to establish specific lake management funding mechanisms.

The City and Washington State are discussing the potential transfer of the lake property to the City. Given the past agricultural use of Waughop Lake while under state ownership, perhaps the transfer agreement could include state funding for lake improvement measures.

This page intentionally left blank.

Section 7

References

Aqua Control. 2015. Website accessed at: http://www.aquacontrol.com

AquaTechnex. 2015. Website accessed at: http://aquatechnex.com/wp-content/uploads/2013/06/IMG_5531.jpg

Brown and Caldwell (BC). 2014. *Waughop Lake Management Plan Quality Assurance Project Plan* (QAPP), Grant G1400475. Prepared for City of Lakewood, Washington. October.

Burghdoff, M. et al. 2012. *Lake Ketchum Algae Control Plan*. Prepared for Snohomish County, Washington. Surface Water Management Division. With the assistance of Tetra Tech, Inc. June.

Carlson, Robert E. 1977. “A trophic state index for lakes.” *Limnology and Oceanography*, 2, doi: 10.4319/lo.1977.22.2.0361.

Carsner, Henry. 1968. *Biological Aspects of Waughop Lake*. A Report Submitted to Tom Cross, Director of Pierce County Parks Department.

Chaichana R., R. Leah & B. Moss, 2010. Birds as eutrophicating agents: a nutrient budget for a small lake in a protected area. Hydrobiologia 646: 111-121.

City of Lakewood (City). 2012. *Draft Remedial Action Plan Waughop Lake Cleanup*. Citizen Remedial Action Plan. Prepared for the City of Lakewood. Point of Contact, Tom McClellan.

Collings, M.R., 1973, Data on selected lakes in Washington, Part 1: Open-File Report 72-72, 190 p.,

Collings, M.R., 1973, Data on selected lakes in Washington: Part 1: [s.n.], Open-File Report 73-373, 179 p.; 1 v. :ill., maps ;27 cm.

Dion, N.P., S.S. Sumioka, and T.C. Winter. 1983. General Hydrology and External Sources of Nutrients Affecting Pine Lake, King County, Washington. U.S. Geological Survey, Water-Resources Investigations Report No. 83-4057, Tacoma, WA, 29 pp.

Ecology, 1979. Chambers-Clover Basin Instream Resources Protection Program Including Proposed Administrative Rules (Water Resource Inventory Area 12). State of Washington Department of Ecology. State Water Program. November, 1979. 64 pp.

Ecology, 2004. Guidelines for Preparing Quality Assurance Project Plans for Environmental Studies, July. (Publication No. 04-03-030)

Ecology, 2009. Environmental Assessment Program Safety Manual. Environmental Assessment Program, Washington State Department of Ecology, Olympia, Washington, July. 184 pp.

Engstrom, D., and D. Wright. 2002. “Sedimentological effects of aeration-induced lake circulation.” *Lake and Reservoir Management*, 18: 201-214.

Entranco Engineers (Entranco). 1978. *A Proposal for Waughop Lake Restoration*. Pierce County Parks and Recreation.

Farnsworth, R. K., and Thompson, E.S., 1982. Mean, monthly, seasonal, and annual pan evaporation for the United States: National Oceanic and Atmospheric Administration Technical Report NWS 33, 26 p.

Gawel, J. and Mason, B. 2008. “Waughop lake sediment phosphorus study.” Unpublished paper. University of Washington Tacoma. Tacoma, Washington.

Gawel, J.E., J.A. Asplund, S. Burdick, M. Miller, S.M. Peterson, A. Tollefson, and K. Ziegler. 2013. “Arsenic and lead distribution and mobility in lake sediments in the south-central Puget Sound watershed: The long-term impact of a metal smelter in Ruston, Washington, USA.” *Science of the Total Environment*, 472: 530–537.

Grochowska, J., and H. Gawronska. 2004. “Restoration effectiveness of a degraded lake using multi-year artificial aeration.” *Polish Journal of Environmental Studies*, 13: 671-681.

Herrera. 2011. Toxics in Surface Runoff to Puget Sound: Phase 3 Data and Load Estimates. Washington State Department of Ecology. Olympia, Washington. Publication No. 11-03-010.

LaFontaine, M. 2012. *Assessment and Monitoring of Water Quality in Waughop Lake, a Small Kettle Lake in Lakewood, Washington, as a Service-Learning Project: A Case Study Approach*. M.A. Thesis, Interdisciplinary Arts and Sciences Program, University of Washington-Tacoma, Tacoma, Washington.

McGuire, William, B. Trafton, and M. Winden. 2016. Measuring Lakewood Residents’ Willingness to Pay for Improvements to Waughop Lake. Technical report submitted to the City of Lakewood.

MSA Professional Services. 2016. “Breneman Lake Dredging,” accessed at: http://www.msa-ps.com/What-We-Do/Projects-By-State/Breneman-Lake-Dredging.aspx

National Aeronautics and Space Administration (NASA) NEO. 2016.

Natural Resources Conservation Service (NRCS), United States Department of Agriculture (USDA). 2016. Soil Survey Geographic (SSURGO) Database. Available online at http://sdmdataaccess.nrcs.usda.gov/. Accessed March 2016.

North American Lake Management Society (NALMS). 2001. *Managing Lakes and Reservoirs*. Prepared by the North American Lake Management Society, Madison, Wisconsin and Terrene Institute, Alexandria, Virginia. In cooperation with U.S. Environmental Protection Agency. Office of Water, Assessment and Watershed Protection Division. Washington D.C. Third Edition. 2001.

NALMS. 2004. Alum position paper. https://www.nalms.org/home/our-mission/nalms-position-papers/.

Ottolenghi, F., J. Qin and L. Mittiga. 2002. “Enhancement of phosphorus release from lake sediments by aeration and crayfish activity.” *Journal of Freshwater Ecology*, 17: 635-640.

Priestly, C.H.B., Taylor, R.J. 1972. *On the Assessment of Surface Heat Flux and Evaporation Using Large-Scale Parameters*, Monthly Weather Review, Vol. 100, No. 2, pp 81-92.

Roberts, M. 2013. Lake Loma Phosphorus Screening-Level Assessment. Washington State Department of Ecology, Publication No. 13-03-031, Olympia, WA, 37 pp.

Roberts, M. 2015. *Standard Operating Procedure for Benthic Flux Chambers*. Washington Department of Ecology publication, available online at: www.ecy.wa.gov/programs/eap/qa/docs/ECY_EAP_SOP_BenthicFluxChambers_v1_2EAP036.pdf.

Royal IHC. Website accessed at: https://www.royalihc.com

Tacoma-Pierce County Health Department (TPCHD). 2016. Website, accessed at: http://www.tpchd.org/environment/surface-water-lakes-beaches-shellfish/current-surface-water-advisories/

Tepper, Jeffrey H. 2013. “Sediment cores reconstruct environmental history of South Puget Sound lakes.” Geology Department, University of Puget Sound. September.

U.S. Environmental Protection Agency (EPA). 1988. *Lake and Reservoir Restoration Guidance Manual*. EPA. EPA 440/5-88-002

Washington State Department of Ecology (Ecology). 2016. Washington State Toxic Algae website, accessed at: https://www.nwtoxicalgae.org/. October.

Wilson, R., H. Gibbons, and S. Brattebo. 2016. Understanding Nutrient Issues Affecting Ohio’s Inland Lakes. Webcast sponsored by EPA’s Watershed Academy, November 30, 2016.

Appendix A: Field Sheets

This appendix contains copies of the field sheets from the 2014–15 monitoring study.

Waughop Lake sampling log

Position UTM
easting: 0533145
northing: 5224069

Date: 10/29/14
Time: 12:00 AM/[✓ PM]

Secchi Depth (ft)
Down: 4' 0"
Up: 3' 10"
Mean 3.11'
Staff gauge: 5.25'
Time: 13:00

Waterfowl count:
ducks: 139 (w/o BINOCULARS)
geese: —
gulls: —
Other:

Hydrolab

Depth (m)	Temp (°C)	Cond (µS/cm)	pH	Chlor (mg/L)	DO (mg/L)
0.5	13.21	50.5	6.92	24.64	9.80
1	13.12	50.2	7.06	28.27	9.68
1.5	13.01	50.3	7.11	30.65	9.56
2	12.91	50.3	7.08	13.56	9.05
2.5	12.82	50.3	7.03	22.92	8.61

Water samples

	Depth on tape (ft)	Check box after collection	
Alkallinity	1, 6	✓	✓
Chlorophyll	1, 6	✓	✓
Nutrients (UF)	1, 6	✓	✓
Phytoplankton	5	✓	✓
Zooplankton	5	✓	✓

Replicate (circle one)
[✓ upper]/lower

Waughop Lake sampling log

Position UTM
easting: 0533145
northing: 5224069

Date: 11/1/14
Time: 1:30 AM/[✓ PM]

Secchi Depth (ft)
Down: ____'____"
Up: ____'____"
Mean ____.____'
Staff gauge: 5.38'
Time: 1:30 AM/[✓ PM]

Waterfowl count:
ducks: 103
geese: ____
gulls: 9
Other: CORMORANT (2)

Hydrolab

Depth (m)	Temp (°C)	Cond (µS/cm)	pH	Chlor (mg/L)	DO (mg/L)
0.5					
1					
1.5					
2					
2.5					

Water samples

	Depth on tape (ft)	Check box after collection	
Alkallinity	1, 6		
Chlorophyll	1, 6		
Nutrients (UF)	1, 6		
Phytoplankton	5		
Zooplankton	5		

Replicate
(circle one)
upper/lower

Waughop Lake sampling log

Position UTM
easting: 0533145
northing: 5224069

Date: 11/19/14
Time: 12:00 AM/[✓ PM]

Secchi Depth (ft)
Down: 4'4"
Up: 4'3"
Mean 4.35'
Staff gauge: 5.42'
Time: 11:30 AM/PM

Waterfowl count:
ducks: 961
geese: 157
gulls:
Other: CORMORANT (2)

Hydrolab

Depth (m)	Temp (°C)	Cond (µS/cm)	pH	Chlor (mg/L)	DO (mg/L)
0.5	4.89	54.0	6.65	31.84	13.07
1	4.78	54.0	6.75	33.24	13.06
1.5	4.62	54.0	6.79	29.52	12.73
2	4.63	54.0	6.79	27.87	12.66
2.5	4.56	53.9	6.80	30.95	12.60

Water samples

	Depth on tape (ft)	Check box after collection	
Alkallinity	1, 6	✓	✓
Chlorophyll	1, 6	✓	✓
Nutrients (UF)	1, 6	✓	✓
Phytoplankton	5	✓	✓
Zooplankton	5	✓	✓

Replicate
(circle one)
upper/[✓ lower]

Groundwater wells

Well	Head (ft @ top of well)	Time	Sample
GW1			
GW2			
GW3			
GW4			
GW5			

Comments: SWAPPED PRESSURE GAUGE @ 12:57

Waughop Lake sampling log

Date: 11/26/14
Time: ___:___AM/PM

Position	UTM
easting:	0533145
northing:	5224069

Secchi	Depth (ft)
Down:	___'___"
Up:	___'___"
Mean	___.___'
Staff gauge:	5.72'
Time:	1:30 AM/[✓ PM]

Waterfowl count:
ducks: 643
geese: ______
gulls: ______
Other: CORMORANT (4)

Hydrolab

Depth (m)	Temp (°C)	Cond (µS/cm)	pH	Chlor (mg/L)	DO (mg/L)
0.5					
1					
1.5					
2					
2.5					

Water samples

	Depth on tape (ft)	Check box after collection	
Alkallinity	1, 6		
Chlorophyll	1, 6		
Nutrients (UF)	1, 6		
Phytoplankton	5		
Zooplankton	5		

Replicate
(circle one)
upper/lower

Groundwater wells

Well	Head (ft @ top of well)	Time	Sample
GW1	8.78	9:19	
GW2	5.39	10:16	
GW3	5.47	10:10	
GW4	13.32	10:06	
GW5	13.76	9:54	

Comments: GW1 MEASUREMENT BEFORE BAILING

Waughop Lake sampling log

Position UTM
easting: 0533145
northing: 5224069

Date: 12/15/14
Time: 11:20 [✓ AM]/PM

Secchi Depth (ft)
Down: 4 ' 6 "
Up: 4 ' 6 "
Mean 4 . 6 '
Staff gauge: 6 . 09 '
Time: 11 : 00 [✓ AM]/PM

Waterfowl count:
ducks: 1244
geese: –
gulls: –
other: CORMORANT - 2

Hydrolab

Depth (m)	Temp (°C)	Cond (µS/cm)	pH	Chlor (mg/L)	DO (mg/L)
0.5	6.89	52.3	6.64	13.86	10.71
1	6.78	52.3	6.51	18.48	10.50
1.5	6.70	52.3	5.78	11.60	10.42
2	6.71	52.2	6.02	18.22	10.39
2.5	6.44	52.5	6.10	9.51	10.06

* DEPTHS REVERSED FOR ALL PARAMETER

Hobo retrieved: 11 : 08 [✓ AM]/PM
Hobo deployed: 11 : 09 [✓ AM]/PM

Water samples

	Depth on tape (ft)	Check box after collection	
Alkallinity	1, 6	X	X
Chlorophyll	1, 6	X	X
Nutrients (UF)	1, 6	X	X
Phytoplankton	5	X	X
Zooplankton	5	X	X

Replicate (circle one)
[✓ upper]/lower

Groundwater wells

ADD SCREEN DEPTH

Well	Level from top of well (ft)	Time	Sample
GW1			
GW2	5.00	1:16	
GW3	Dry	1:05	
GW4			
GW5			

< 1:22 PM PUMPING @ 10F.
< WATER OVER TOP

Comments: Piezometer 1 ~~Gage~~ by pierce : 4ft water to sediment; 6-7 6ft in sediment 30 yds from storm water drain

Piezometer 2 : Approx. where road lets out ; 6ft of sediment

*ADD TO INVENTORY ^ PLASTIC GRAD. CYLINDER
1L

GW2 ~~1:22~~	TEMP	SPC	pH	LDO
1:28	12.68	278.1	~~6.07~~ 5.96	~~2.4~~ 1.51
1:32	12.63	276.1	5.84	1.38
1:36	12.31	272.6	5.96	1.45
1:44	12.26	272.5	5.98	1.65

PUMPING @ ~ 0.5L/MIN

(PUMP SET @ 2)

VISIBLY CLEARER

1:54 TOW 5.01 Ft.

(back of field sheet 12/15/14)

Waughop Lake sampling log

Date: 12/18/14
Time: 9:30 AM/PM

Position	UTM
easting:	0533145
northing:	5224069

Secchi	Depth (ft)
Down:	____'____"
Up:	____'____"
Mean	____.____'
Staff gauge:	____.____'
Time:	___:___ AM/PM

Waterfowl count:
ducks: 1285
geese: ____________
gulls: ____________
other: ____________

Hydrolab

Depth (m)	Temp (°C)	Cond (µS/cm)	pH	Chlor (mg/L)	DO (mg/L)
0.5					
1					
1.5					
2					
2.5					

Hobo retrieved: ___:___ AM/PM

Hobo deployed: ___:___ AM/PM

Water samples

	Depth on tape (ft)	Check box after collection	
Alkallinity	1, 6		
Chlorophyll	1, 6		
Nutrients (UF)	1, 6		
Phytoplankton	5		
Zooplankton	5		

Replicate
(circle one)
upper/lower

Groundwater wells

Well	Level from top of well (ft)	Time	Sample
GW1	7.22	10:00 am	✓
GW2	measured 12/15/14		
GW3	5.61	9:16 am	✓
GW4	11.26	11:48 am	✓
GW5	16.02	10:47 am	✓

added by JG from field notebook
JG

Comments: ____
____
____

WAUGHOP 12-18-14

DUCKS-1285

GW3

9:16 5.61' 950 5.62'

STARTED PUMPING @ .3 L/MIN @ 9:25

	TEMP	SpC	pH	LDO
930	15.73	199.8	3.72	2.00
935	14.60	117.8	5.36	1.57
938	14.38	116.9	5.62	0.92
942	14.26	116.2	5.82	2.48
945	14.15	116.4	5.89	1.15

H_2S SMELL NOTED DURING SAMPLING

GW 1

10:10 7.27' Started pump @ 10:12

10:35 8.30'

	Temp	Spc	pH	LDO
10:17	11.40	117.5	5.71	6.82
10:21	11.34	117.7	6.16	6.20
10:24	11.31	113.8	6.21	5.93
10:27	11.29	103.9	6.23	5.92
10:30	11.23	97.6	6.03	5.99

GW5

10:47 16.02' 11:27 16.01'

STARTED PUMP @ 10:53

Water in Man hole started running @ 11:12

	TEMP	SPC	pH	LDO
11:02	10.11	38.1	7.16	8.79
11:06	10.52	35.2	7.52	8.04
11:09	10.98	33.5	7.11	7.95
11:12	11.09	32.6	7.67	7.91
11:16	11:20	31.6	7.56	7.76
11:20	11.28	30.8	7.66	7.73
11:22	11.30	30.5	7.56	7.69

GW 4 11.26' →11.31' 11:48 pumping @ 15 Oz

	Temp	SPC	pH	LDO
11:56	10.86	84.9	7.20	5.53
12:00	11.46	87.0	7.52	3.98
12:03	11.78	90.3	7.52	3.74
12.07	12.20	93.9	7.22	3.64
12:11	12.17	96.4	7.27	3.61

Waughop Lake sampling log

Position UTM
easting: 0533145
northing: 5224069

Date: 1/24/15
Time: 10:30 [✓ AM]/PM

Secchi Depth (ft)
Down: 3' 7"
Up: 3' 7"
Mean 3.7'
Staff gauge: ___.___' OVER MAX OF 6.65
Time: 11:47 [✓ AM]/PM

Waterfowl count:
ducks: 453
geese: 1
gulls: 0
other:

Hydrolab

Depth (m)	Temp (°C)	Cond (µS/cm)	pH	Chlor (mg/L)	DO (mg/L)
0.5	6.82	56.9	5.33	58.94	13.50
1	6.53	56.3	5.62	45.36	13.24
1.5	6.50	57.0	5.71	28.56	11.98
2	6.42	57.0	5.71	27.42	11.56
2.5	6.38	57.0	5.70	26.35	11.42

Hobo retrieved: 10:35 [✓ AM]/PM

Hobo deployed: 10:46 [✓ AM]/PM

Water samples

	Depth on tape (ft)	Check box after collection	
Alkallinity	1, 6	✓	✓
Chlorophyll	1, 6	✓	✓
Nutrients (UF)	1, 6	✓	✓
Phytoplankton	5	✓	
Zooplankton	5	✓	

Replicate
(circle one)
upper/[✓ lower]

Groundwater wells

Well	Level from top of well (ft)	Time	Sample
GW1	6.46	12:19	
GW2	4.46	12:14	
GW3	4.98	12:01	
GW4	9.82	12:31	
GW5	14.52	12:24	

* WATER OVER TOP

* WATER OVER TOP

Comments: PIEZOMETER (ADD 0.5" TO LEVEL TO MATCH SURVEY)

* INNER DIAM 0.7'

	INSIDE		OUTSIDE
1	1.58	11:30	1.60'
2	2.03'	11:45	1.98'

ADD 0.55" TO LEVEL ")

Waughop Lake sampling log

Position UTM
easting: 0533145
northing: 5224069

Date: 2/19/15
Time: 9:55 [✓ AM]/PM

Secchi Depth (ft)
Down: 2' 8"
Up: 2' 8"
Mean 2.8'
Staff gauge: .5' (ABOVE TOP OF GAUGE)
Time: 11:20 [✓ AM]/PM

Waterfowl count:
ducks: 571
geese: 1
gulls: 0
other:

Hydrolab

Depth (m)	Temp (°C)	Cond (µS/cm)	pH	Chlor (mg/L)	DO (mg/L)
0.5	9.84	53.4	6.49	54.8	11.55
1	9.71	53.3	6.59	44.85	11.18
1.5	9.64	53.3	6.63	46.04	10.93
2	9.62	53.2	6.66	43.51	10.81
2.5	9.61	53.2	6.68	35.48	10.63
3.0	9.60	53.3	6.70	31.88	10.48

Hobo retrieved: 10:20 [✓ AM]/PM

Hobo deployed: 11:41 AM/PM SAME HOBO

Water samples

	Depth on tape (ft)	Check box after collection	
Alkallinity	1, 6	✓	✓
Chlorophyll	1, 6	✓	✓
Nutrients (UF)	1, 6	✓	✓
Phytoplankton	5	✓	✓
Zooplankton	5	✓	✓

Replicate (circle one)
[✓ upper]/lower

Groundwater wells

Well	Level from top of well (ft)		Time	Sample	
GW1	5.91		10.3	✓	WATER VERY CLEAR
GW2	4.18		1230	✓	IRON IN WATER
GW3	4.75		11:44	✓	WATER OVER TOP
GW4	9.00		210	✓	
GW5	14.10		134	✓	WATER VERY CLEAR
Piezometer	Inside (ft)	Outside (ft)	Time	Sample	
1	1.17	1.25	11:11		
2	1.64	1.60	11:18		

Comments:

2/19

GW3 4.75' @ 1144

STARTED PUMP 1155 (PUMP AT SETTING #2)

	TEMP	SPC	pH	LDO
1156	11.69	70.0	5.93	4.11
1200	11.44	75.3	5.98	1.69
1203	11.19	76.5	5.72	1.10
1206	11.05	77.1	5.87	0.91
1208	10.97	77.7	5.81	0.90
1211	10.92	77.5	5.88	0.85

GW2 4.18' @ 1230

STARTED PUMP @ 1233

1235	10.96	357.1	6.34	6.90
1238	10.99	351.3	6.47	5.01
1241	10.99	337.5	6.48	4.10
1244	11.00	361.1	6.49	2.49
1248	10.92	383.0	6.48	1.94
1251	10.88	391.7	6.58	2.07

GW1 5.91 @ 103

STARTED PUMP @ 105

108	11.40	120.8	6.70	8.16
111	11.33	97.3	6.50	7.06
114	11.09	83.8	6.23	6.50
117	10.92	79.6	6.26	6.14
120	10.76	79.4	6.19	5.96
123	10.85	78.5	6.24	5.81

GW5	STARTED PUMP @ 142			14.10' @ 134
	TEMP	SPC	PH	LDO
145	11.94	44.1	6.36	9.77
148	11.80	38.5	6.20	9.86
151	11.60	32.8	6.18	10.60
154	11.51	32.3	6.18	10.25
157	11.53	32.4	6.19	10.10
200	11.46	31.8	6.14	11.22
GW4	STARTED PUMP @ 216			9.00' @ 210
217	11.92	182.7	5.55	7.07
220	11.78	198.3	5.52	6.09
223	11.83	204.8	5.45	5.79
226	11.85	209.4	5.45	5.66
229	11.86	213.0	5.44	5.80
232	11.85	211.1	5.39	6.08
235	11.81	211.5	5.40	6.09

Waughop Lake sampling log

Position	UTM	Date:	3/12/15
easting:	0533145	Time:	9:57 [✓ AM]/PM
northing:	5224069		

Secchi	Depth (ft)	Waterfowl count:	
Down:	3'10"	ducks:	669
Up:	3'8"	geese:	1
Mean	3.9'	gulls:	–
Staff gauge:	.' 14.0 cm ABOVE	other:	
Time:	11:21 [✓ AM]/PM		

Hydrolab

Depth (m)	Temp (°C)	Cond (µS/cm)	pH	Chlor (mg/L)	DO (mg/L)
0.5	11.50	54.4	6.23	16.44	11.62
1	11.34	54.3	6.45	21.55	11.54
1.5	11.16	54.2	6.58	21.53	11.08
2	10.78	54.9	6.53	13.71	8.73
2.5	10.08	57.1	6.44	13.32	6.36

Hobo retrieved: 10:20 [✓ AM]/PM Hobo deployed: 10:25 [✓ AM]/PM

3.0	9.49	57.7	6.35	12.81	4.25

Water samples

	Depth on tape (ft)	Check box after collection		
Alkallinity	1, 6	✓	✓	Replicate
Chlorophyll	1, 6	✓	✓	(circle one)
Nutrients (UF)	1, 6	✓	✓	upper/[✓ lower]
Phytoplankton	5	✓	✓	
Zooplankton	5	✓	✓	

Groundwater wells

Well	Level from top of well (ft)	Time	Sample
GW1	6.36	11:48	
GW2	4.30	11:42	
GW3	4.81	11:35 am	
GW4	~~15.02~~ 9.21	12:03	
GW5	15.02	1155	

Comments: WIND GENERATED WAVES MADE STAFF GAUGE MEASUREMENT DIFFICULT

	INSIDE	OUTSIDE	TIME
PIEZ1	1.16"	1.22"	1108
PIEZ2	1.66"	1.59"	1117

Waughop Lake sampling log

Position UTM
easting: 0533145
northing: 5224069

Date: 4 / 20 / 15
Time: 10 : 37 AM/PM

Secchi Depth (ft)
Down: 5 ' 8 "
Up: 5 ' 7 "
Mean ___.___'
Staff gauge: ___.___' 6" from top
Time: 12 : 04 AM/PM

Waterfowl count: 26
ducks:
geese: Na
gulls: Na
other: Na

top of staff gauge 6.66 ft

Hydrolab

Depth (m)	Temp (°C)	Cond (µS/cm)	pH	Chlor ~~(mg/L)~~ µg/L?	DO (mg/L)
0.5	16.17	45.3	8.97	12.87	14.87
1	16.01	45.0	9.21	14.07	15.02
1.5	15.86	44.9	9.26	13.36	15.03
2	15.72	44.7	9.23	19.27	14.89
2.5	14.62	44.7	9.14	29.18	13.94

Hobo retrieved: 10:45 [✓ AM]/PM
Hobo deployed: 10:59 [✓ AM]/PM

3.0 13.82 47.1 8.33 33.05 9.31

Water samples

	Depth on tape (ft)	Check box after collection	
Alkallinity	1, 6	✓	✓
Chlorophyll	1, 6	✓	✓
Nutrients (UF)	1, 6	✓	✓
Phytoplankton	5	✓	✓
Zooplankton	5	✓	✓

Replicate (circle one)
[✓ upper]/lower

Groundwater wells

Well	Level from top of well (ft)	Time	Sample
GW1			
GW2			
GW3			
GW4			
GW5			

Piezometer	Inside (ft)	Outside (ft)	Time	Sample
1	1.13	1.20	11:53 am	
2	1.65	1.57	12:01 pm	

Comments:

Waughop Lake sampling log

Position	UTM
easting:	0533145
northing:	5224069

Date: 4/28/15
Time: ___:___AM/PM

Secchi	Depth (ft)
Down:	____'____"
Up:	____'____"
Mean	____.____'
Staff gauge:	____.____'
Time:	___:___ AM/PM

Waterfowl count:
ducks: ____________
geese: ____________
gulls: ____________
other: ____________________

Hydrolab

Depth (m)	Temp (°C)	Cond (µS/cm)	pH	Chlor (µg/L)	DO (mg/L)
0.5					
1					
1.5					
2					
2.5					

Hobo retrieved: ___:___ AM/PM

Hobo deployed: ___:___ AM/PM

Water samples

	Depth on tape (ft)	Check box after collection	
Alkallinity	1, 6		
Chlorophyll	1, 6		
Nutrients (UF)	1, 6		
Phytoplankton	5		
Zooplankton	5		

Replicate
(circle one)
upper/lower

Groundwater wells

Well	Level from top of well (ft)		Time	Sample
GW1	6.60		1608	
GW2	4.39		1600	
GW3	4.94		1645	
GW4	9.37		1625	
GW5	15.64		1616	
Piezometer	Inside (ft)	Outside (ft)	Time	Sample
1				
2				

ELEVATION CORRECTIONS
SURVEYED TO WBL (cm)

11.4
11.8
16.0
14.0
15.4

Comments: ______________________________

4/28/15

WELLS (FT.)		TIME	CORRECTION (MM)	
			LIP TO BOLT	LIP TO WELL *
GW1	6.60	1608	15	94
GW2	4.39	1600	15	98
GW3	4.94	1545	15	140
GW4	9.37	1625	15	120
GW5	15.64	1616	15	134

* ALSO SUBTRACT 5 MM FOR WIDTH OF RULER

L = LIP TO WELL - LIP TO BOLT - 5 MM

= CASE TO WELL

TOTAL CORRECTION (MM)

GW1	74
GW2	78
GW3	120
GW4	100
GW5	114

CORRECTION (FT)

GW1	0.243
GW2	0.256
GW3	0.394
GW4	0.328
GW5	0.374

Waughop Lake sampling log

Position	UTM
easting:	0533145
northing:	5224069

Date: 5 / 13 / 15
Time: 9 : 40 [✓ AM]/PM

Secchi	Depth (ft)
Down:	3 ' 1 "
Up:	3 ' 1 "
Mean	3 . 1 '
Staff gauge:	___ . ___ ' 2.3" ABOVE MAX
Time:	10 : 10 [✓ AM]/PM

Waterfowl count:
ducks: 16
geese: 1
gulls: ______
other: ______

Hydrolab

Depth (m)	Temp (°C)	Cond (μS/cm)	pH	Chlor (mg/L)	DO (mg/L)
0.5	17.31	57.1	6.85	10.10	10.98
1	17.32	56.8	7.07	11.18	11.03
1.5	17.29	57.0	7.28	8.96	11.03
2	17.29	56.7	7.43	10.94	11.07
2.5	17.25	57.0	7.38	10.68	7.51

Hobo retrieved: 9 : 57 [✓ AM]/PM   Hobo deployed: 10 : 26 [✓ AM]/PM

3.0	15.90	57.7	6.72	39.18	0.01

Water samples

	Depth on tape (ft)	Check box after collection	
Alkallinity	1, 6	✓	✓
Chlorophyll	1, 6	✓	✓
Nutrients (UF)	1, 6	11:10 ✓	11:16 ✓
Phytoplankton	5	✓	✓
Zooplankton	5	✓	✓

Replicate (circle one)
upper/[✓ lower]

- Used sampler pole instead of [illegible]

Groundwater wells

Well	Level from top of well (ft)	Time	Sample
GW1	7.00	1027	
GW2	4.66	1023	
GW3	5.22	1016	
GW4	9.71	1104	
GW5	16.25	1033	

Piezometer	Inside (ft)	Outside (ft)	Time	Sample
1	1.50	1.51	10:01	
2	1.95	1.88	10:08	

Comments: ____________________

Waughop Lake sampling log

Date: 5/27/15
Time: 10:00 [✓ AM]/PM

Position	UTM
easting:	0533145
northing:	5224069

Secchi	Depth (ft)
Down:	2' 4"
Up:	2' 6"
Mean	2.5'
Staff gauge:	6.60'
Time:	11:30 [✓ AM]/PM

Waterfowl count:
ducks: 22
geese: 2
gulls:
other:

Hydrolab

Depth (m)	Temp (°C)	Cond (µS/cm)	pH	Chlor (mg/L)	DO (mg/L)
0.5	19.46	56.9	6.54	3.29	10.66
1	19.03	56.7	7.35	4.52	10.66
1.5	18.23	56.9	7.21	9.28	9.0
2	17.82	57.5	6.88	7.51	5.20
2.5	~~17.~~16.97	56.4	6.51	30.88	6.36

Hobo retrieved: 10:14 [✓ AM]/PM Hobo deployed: 10:16 [✓ AM]/PM

3.0	16.01	79.4	6.32	13.14	0.00

Water samples

10ft max

	Depth on tape (ft)	Check box after collection	
Alkallinity	1, ~~6~~ 7	✓	✓
Chlorophyll	1, ~~6~~ 7	✓	✓
Nutrients (UF)	1, ~~6~~ 7	✓	✓
Phytoplankton	5	✓	✓
Zooplankton	5	✓	✓

Replicate (circle one)
[✓ upper]/lower
→ 153 µm NET

Groundwater wells

Well	Level from top of well (ft)		Time	Sample
GW1	7.42		1300	✓
GW2	4.97		12:28	✓
GW3	5.51		1149	✓
GW4	10.07		14:45	
GW5	16.74		1:35	✓
Piezometer	Inside (ft)	Outside (ft)	Time	Sample
1	1.67	1.76	1122	—
2	2.21	2.13	1129	—

Comments: WATER VERY GREEN. RED/BROWN SCUM ALONG SHORELINE.

Waughop 5/27/15

Well 3 (GW3) 5.51' 0.282 /min

Time	Temp (°C)	Cond (SPC)	pH ~~LDO~~	LDO
11:51				
11:54	20.06	336.2	2.95	8.85
11:57	19.72	532.8	3.17	41.84
12.00	17.12	101.6	5.78	4.10
12.03	16.59	100.9	5.97	2.82
12.06	16.50	101.2	5.92	2.87
12:10	16.36	101.2	6.02	1.43
12:13	16.35	1025	5.91	1.33

Well diameter .175 ft
Depth water 10 ft
Vol. = $r^2\pi h$
= 0.242 ft³
= 6098.92 cm³

2 on parastaltic pump

GW-2 4.97'

0.33 L/min
Pp @ 3

Time	Temp (°C)	Cond	pH	LDO
12.29				
12:32	17.14	102.8	6.01	3.07
12:35	15.56	407.8	6.25	1.52
12:38	13.97	404.2	6.24	1.13
12.41	13.53	402.4	6.20	0.88
12.44	13.57	402.3	6.19	0.85
12.47	13.70	399.0	6.22	0.63

GW1 7.42'

Time	Temp	Cond	pH	DO
1303	–	–	–	–
1307	18.26	257.1	6.21	5.67
1310	17.97	235.0	6.08	4.67
1313	17.33	131.1	5.95	5.10
1316	17.51	120.4	5.90	5.06
1319	17.70	108.8	5.95	5.00
1323	17.68	100.9	5.85	4.60

GW5 - 16.74

~~13[illegible]~~

TIME	TEMP	SPC	pH	DO
~~1338~~				
1354	25.57	75.2	6.10	6.80
~~1411~~				
1421	18.80	34.3	6.11	8.73
1425	17.47	34.1	6.05	9.25
1429	18.23	33.9	6.05	9.11
1432	17.42	33.1	6.03	9.07
1435	16.92	33.7	6.03	9.07

~~TOOK~~
MULTIPLE ATTEMPTS
TO MAINTAIN SUCTION

GW-4 10.07'

Time	Temp (°C)	SpC	pH	LDO
2:46				
2:49	22.85	64.3	5.85	7.83
2:52	16.63	140.6	5.45	4.62
2:55	16.02	150.8	5.36	4.65
2:58	15.73	154.3	5.40	4.53
3:01	15.47	155.0	5.40	4.34
3:04	15.28	153.7	5.39	4.47
3:05	15.13	155.7	5.42	4.43

Waughop Lake sampling log

Position UTM
easting: 0533145
northing: 5224069

Date: 6/9/15
Time: 11:00 [✓ AM]/PM

Secchi Depth (ft)
Down: 4' 6"
Up: 4' 3"
Mean ___.___'
Staff gauge: 6.38'
Time: 12:00 [✓ AM]/PM

Waterfowl count:
ducks: 12
geese: 16
gulls: 0
other: 0

Hydrolab

Depth (m)	Temp (°C)	Cond (µS/cm)	pH	Chlor (µg/L)	DO (mg/L)
0.5	24.86	56.9	7.26	1.71	9.32
1	24.20	56.8	7.24	1.88	9.00
1.5	20.71	56.2	7.28	3.08	9.54
2	19.08	57.9	7.01	5.38	3.42
2.5	17.52	58.1	6.60	4.62	0.62

Hobo retrieved: 11:05 [✓ AM]/PM
Hobo deployed: 11:01 [✓ AM]/PM

3.0 15.95 114.8 6.33 11.21 0.04

Water samples

	Depth on tape (ft)	Check box after collection	
Alkalinity	1, ~~6~~ 7	✓	✓
Chlorophyll	1, ~~6~~ 7	✓	✓
Nutrients (UF)	1, ~~6~~ 7	✓	✓
Phytoplankton	5	✓	✓
Zooplankton	5	✓	✓

Replicate (circle one)
upper/[✓ lower]

L USED OWN BOTTLE

Groundwater wells

Well	Level from top of well (ft)		Time	Sample
GW1	7.95		1223	
GW2	5.31		1217	
GW3	5.81		1212	
GW4	10.49		1235	
GW5	17.20		1228	
Piezometer	Inside (ft)	Outside (ft)	Time	Sample
1	1.96	2.04	1152	
2	2.50	2.42	1158	

Comments: ____________________

Waughop Lake sampling log

Position UTM
easting: 0533145
northing: 5224069

Date: 6/23/15
Time: 9:30 [✓ AM]/PM

Secchi Depth (ft)
Down: 6'6"
Up: 6'6"
Mean 6.6'
Staff gauge: 5.94'
Time: ~~2~~: [✓ AM]/PM
10:40

Waterfowl count:
ducks: ~~24~~ 28
geese: ~~11~~ 23
gulls: – –
other:

Hydrolab

Depth (m)	Temp (°C)	Cond (µS/cm)	pH	Chlor (µg/L)	DO (mg/L)
0.5	23.22	57.7	6.26	5.66	8.35
1	23.18	57.7	6.60	6.52	8.38
1.5	23.06	57.4	6.75	7.32	8.29
2	22.96	57.3	6.79	8.20	8.20
2.5	21.76	62.8	6.58	13.45	3.53

Hobo retrieved: 9:41 [✓ AM]/PM Hobo deployed: 9:49 [✓ AM]/PM

3.0	18.70	105.5	6.35	7.06	0.26
2.8	20.13	79.4	6.41	37.44	1.06

Water samples

	Depth on tape (ft)	Check box after collection	
Alkalinity	1, 6	✓	✓
Chlorophyll	1, 6	✓	✓
Nutrients (UF)	1, 6	✓✓	✓
Phytoplankton	5	✓	✓
Zooplankton	5	✓	✓

Replicate
(circle one)
[✓ upper]/lower

Groundwater wells

Well	Level from top of well (ft)		Time	Sample
GW1				
GW2				
GW3				
GW4				
GW5				
Piezometer	Inside (ft)	Outside (ft)	Time	Sample
1	2.33	2.42	1030	
2	~~2.42~~ ck 2.92	2.80	1039	

Comments:

Waughop Lake sampling log

Position	UTM
easting:	0533145
northing:	5224069

Date: 7/6/15

Time: 1:10 AM/[✓ PM]

Secchi	Depth (ft)
Down:	4' 7"
Up:	4' 9"
Mean	4.8'
Staff gauge:	5.90'
Time:	2:21 AM/[✓ PM]

Waterfowl count:

ducks: 84

geese: 27

gulls:

other: 11 on shore

Hydrolab

Depth of lake 16.7 ft

Depth (m)	Temp (°C)	Cond (µS/cm)	pH	Chlor (µg/L)	DO (mg/L)
0.5	27.29	55.5	8.54	2.44	9.93
1	27.26	55.5	8.73	2.67	10.22
1.5	26.86	54.9	8.78	3.50	10.21
2	26.14	57.1	8.49	10.51	10.37
2.5	24.08	69.3	7.75	64.91	10.09

Hobo retrieved: ~~___:___~~ AM/PM

Hobo deployed: ~~___:___~~ AM/PM

3m	22.08	91.7	6.70	0.10	0.46
2.8m	22.90	79.2	6.59	6.41	3.60

Water samples

	Depth on tape (ft)	Check box after collection		
Alkalinity	1, ~~6~~ 8	✓	✓	Replicate
Chlorophyll	1, ~~6~~ 8	✓	✓	(circle one)
Nutrients (UF)	1, ~~6~~ 8	upper 1:35	Bott. 1:46	upper/[✓ lower]
Phytoplankton	5	✓	✓	
Zooplankton	5	✓	✓	

Groundwater wells

Well	Level from top of well (ft)	Time	Sample
GW1			
GW2			
GW3			
GW4			
GW5			

Piezometer	Inside (ft)	Outside (ft)	Time	Sample
1	2.68	2.76	2:11 pm	
2	3.29	3.13	2:16 pm	

Comments:

Waughop Lake sampling log

Position		UTM
	easting:	0533145
	northing:	5224069

Date: 7/20/15
Time: 10:30 AM/PM
WINDY

Secchi — Depth (ft)
Down: 3' 9"
Up: 3' 10"
Mean 3.10'
Staff gauge: 5.21'
Time: 11:37 [✓ AM]/PM

Waterfowl count:
ducks: 92
geese: –
gulls: –
other:

Hydrolab

Depth (m)	Temp (°C)	Cond (µS/cm)	pH	Chlor (µg/L)	DO (mg/L)
0.5	24.92	50.8	9.08	3.10	13.15
1	24.94	50.5	9.01	3.32	13.25
1.5	24.92	50.2	8.70	3.66	12.94
2	23.89	42.9	7.01	11.56	4.77
2.5	23.38	60.8	6.21	30.24	6.66

Hobo retrieved: 10:32 [✓ AM]/PM
Hobo deployed: 11:22 [✓ AM]/PM

3.0 22.30 73.7 5.83 0.03 0.00

Water samples

	Depth on tape (ft)	Check box after collection	
Alkalinity	1, 6	✓	✓
Chlorophyll	1, 6	✓	✓
Nutrients (UF)	1, 6	✓	✓
Phytoplankton	5 wrong on bottle	✓	✓
Zooplankton	5	✓	✓

Replicate (circle one)
upper/[✓ lower]

Groundwater wells

Well	Level from top of well (ft)		Time	Sample
GW1	9.90		2:37	
GW2	6.95		220	
GW3	7.40		1:02	
GW4	12.10		1:50	
GW5	18.50 -cover did this		1:18	
Piezometer	Inside (ft)	Outside (ft)	Time	Sample
1	3.06	3.14	1127	
2	3.69	3.51	1135	

-2 2:39
-2 2:22
-2 2:06
-2 1:52
-1 1:36; 1½/1:38 18.5

Comments: VERY WINDY

2.7 22.92 48.4 5.87 45.77 0.06

Waughop Lake sampling log

Position UTM
easting: 0533145
northing: 5224069

Date: 8/5/15
Time: 9:30 [✓ AM]/PM

Secchi Depth (ft)
Down: 2'6"
Up: 2'7"
Mean ____.____'
Staff gauge: 4.81'
Time: 10:48 AM/PM

Waterfowl count:
ducks: 64
geese: –
gulls: –
other: –

Hydrolab

Depth (m)	Temp (°C)	Cond (µS/cm)	pH	Chlor (µg/L)	DO (mg/L)
0.5	23.29	51.9	8.81	13.32	9.36
1	23.38	52.2	8.94	13.74	9.32
1.5	23.33	50.6	8.80	13.29	8.71
2	22.65	48.6	7.32	7.05	2.85
2.5	21.59	62.9	6.59	16.84	0.05
2.7	21.50	67.3	6.28	46.18	0.02

Hobo retrieved: 9:40 [✓ AM]/PM
Hobo deployed: 9:47 [✓ AM]/PM

Water samples

	Depth on tape (ft)	Check box after collection	
Alkalinity	1, ~~6~~ 7	✓	✓
Chlorophyll	1, ~~6~~ 7	✓	✓
Nutrients (UF)	1, ~~6~~ 7	✓	✓
Phytoplankton	5	✓	✓
Zooplankton	5	✓	✓

Replicate
(circle one)
upper/[✓ lower]

ALSO BOTTOM
TEST 1 & 2
PREFILTERED IN
FIELD w/ 0.45µ

Groundwater wells

Well	Level from top of well (ft)		Time	Sample
GW1	10.50		1204	✓
GW2	7.52		1136	✓
GW3	7.95		1100	✓
GW4	12.82		1254	✓
GW5	18.91		1235	✓
Piezometer	Inside (ft)	Outside (ft)	Time	Sample
1	3.46	3.53	1040	
2	4.13	3.93	1045	

→ USED BAILER
HIGH TURBIDITY

Comments: ____________________

8/5/15

GW3 7.95 1100 STARTED PUMP 1105

	TEMP	SpC	pH	LDO	
1107	18.12	142.0	5.64	2.07	
1110	17.47	108.5	5.62	0.86	SULFUR SMELL
1113	17.57	111.7	5.63	0.68	IN WATER
1116	17.76	108.1	5.63	0.65	
1119	17.83	107.3	5.66	0.59	
1122	17.88	107.2	5.67	0.56	
1125	17.88	107.5	5.66	0.49	

GW2 7.52 1136 STARTED PUMP 1137

~~1137~~

1140	18.12	243.5	5.75	1.84
1143	15.61	357.1	5.78	0.60
1146	15.08	357.4	5.72	0.43
1150	14.75	354.4	5.77	0.39
1153	14.72	344.6	5.72	0.36
1156	14.76	343.1	5.77	0.37

GW1 10.50 @ 1204 START PUMP 1205

	TEMP	SPC	PH	LDO
1209	17.64	216.2	5.87	3.89
1212	16.97	141.4	5.76	4.51
1215	17.42	129.2	5.67	4.87
1218	17.72	129.6	5.67	5.55
1221	17.80	127.3	5.54	5.63
1224	17.77	126.9	5.58	5.59

FINE SEDIMENT IN LINE

GW5 18.91 @ 1235

* USED BAILER

1.	1236	14.41	40.9	6.22	9.96
2.	1238	12.66	38.8	6.03	10.25
3	1239	12.32	38.5	6.00	10.34
4	1240	12.27	37.9	5.99	10.30
5	1242	12.12	37.5	5.98	10.36
6.	1243	12.03	37.2	5.94	10.42

LOTS OF TURBIDITY

GW4 12.82 @ 1254 START: 1255

1257	20.31	77.5	5.88	4.32
1300	16.80	69.3	5.68	1.89
1303	15.79	69.1	5.60	1.31
1306	15.63	69.4	5.64	1.23
1309	15.60	69.0	5.52	1.15
1312	15.50	69.3	5.54	0.95
1315	15.47	68.9	5.64	0.91

Waughop Lake sampling log

Position	UTM	Date: 8/19/15
easting:	0533145	Time: 10:30 [✓ AM]/PM
northing:	5224069	

Secchi	Depth (ft)	Waterfowl count:	
Down:	2'10"	ducks:	73
Up:	2'10"	geese:	0
Mean	2.10'	gulls:	0
Staff gauge:	4.56'	other:	
Time:	11:30 [✓ AM]/PM		

Hydrolab

(QUANTA)

9.54

Depth (m)	Temp (°C)	Cond (µS/cm)	pH	Chlor (µg/L)	DO (mg/L)
0.5	23.85	64	~~12.47~~	~~9.54~~	12.47
1	23.14	60	9.47	—	11.44
1.5	22.42	52	8.88	—	9.46
2	21.82	51	8.43	—	6.38
2.5	21.36	55	7.90	—	1.99

Hobo retrieved: 10:30 [✓ AM]/PM

Hobo deployed: 10:45 [✓ AM]/PM

2.7	21.27	56	7.45	—	0.31 AND DROPPING

Water samples

	Depth on tape (ft)	Check box after collection	
Alkalinity	1, 6	✓	✓
Chlorophyll	1, 6	✓	✓
Nutrients (UF)	1, 6	✓	✓
Phytoplankton	5	✓	✓
Zooplankton	5	✓	✓

Replicate (circle one)

upper/[✓ lower]

Groundwater wells

Well	Level from top of well (ft)		Time	Sample
GW1				
GW2				
GW3				
GW4				
GW5				
Piezometer	Inside (ft)	Outside (ft)	Time	Sample
1	3.73	3.79	1118	
2	4.42	4.18	1128	

Comments:

Waughop Lake sampling log

Position	UTM
easting:	0533145
northing:	5224069

Date: 9/14/15
Time: ___:___AM/PM

Secchi	Depth (ft)
Down:	1 ' 5 "
Up:	1 ' 5 "
Mean	1 . 5 '
Staff gauge:	4 . 30 '
Time:	14 : 10 AM/PM

Waterfowl count:
ducks: 107
geese: 9
gulls: ______
other: ______

ADD 27.2 cm TO DEPTH (NEW YSI PROBE)
↓

Hydrolab

Depth (m)	Temp ~~(°C)~~ °F	Cond (µS/cm)	pH	Chlor (µg/L)	DO (mg/L)
0.5	67.1	72.5	9.29	—	13.63
1	66.7	62.0	9.13	—	11.74
1.5	65.9	57.5	8.51	—	9.60
2	64.8	58.2	7.64	—	0.61
2.5	64.5	74.9	6.76	—	0.30

Hobo retrieved: 1:02 AM/[✓ PM]   Hobo deployed: 1:07 AM/[✓ PM]

– Depth on borrowed Hydrolab lags a bit

Water samples

	Depth on tape (ft)	Check box after collection	
Alkalinity	1.~~6~~ 7	✓	✓
Chlorophyll	1.~~6~~ 7	✓	✓
Nutrients (UF)	1.~~6~~ 7	✓	✓
Phytoplankton	5	✓	✓
Zooplankton	5	✓	✓

Replicate (circle one)
upper/[✓ lower]

Groundwater wells

Well	Level from top of well (ft)		Time	Sample
GW1	11.17		12:18 pm	X
GW2	8.28		12:10 pm	X
GW3	8.70		12:36 pm	X
GW4	13.78		12:30 pm	X
GW5	19.36		12:25 pm	X
Piezometer	Inside (ft)	Outside (ft)	Time	Sample
1	4.01	4.05	1:53 pm	X
2	~~[illegible]~~ 4.73	4.44	2:07 pm	X

NO SAMPLES COLLECTED

Comments: ____________________

Waughop - 9/14/15

Benthic 9-12 - (2hrs)

~~Benth ID~~	Temp °F	DO mg/L	Cond. µS/cm	pH	Time	GPS	
Benth 9	66.1	11.24	94.2	6.63	2:26 pm	marked	+ sediment coming up
Benth 10	66.2	10.71	56.8	8.53	2:44 pm	marked	
Benth 11	65.5	10.34	54.6	8.47	2:58 pm	marked	
Benth 12	66.95	3.63	720	7.25	3:10 pm	marked	+ some sedimen

24hrs

Benth 9	64.5	3.02	68.5	5.94	1:45 pm	
Benth 10	65.5	6.93	62.1	6.45	1:58 pm	
Benth 11	64.6	4.08	79.9	6.47	2:11 pm	+ little sediment after settling
Benth 12	65.6	1.87	83.0	6.38	2:24 pm	

48HRS

Benth 9	64.3	0.90	72.1	5.86	1:41 pm
Benth 10	64.9	1.92	70.6	6.18	1:55 pm
Benth 11	64.1	0.31	173.9	5.97	207 pm
Benth 12	65.0	0.84	84.9	6.46	2:18 pm

9/22 GW-5 STARTED PUMP 1320

TEMP	DO	SPC	pH	TIME
70.2	8.99	43.5	5.54	1330
66.1	9.35	41.2	5.71	1333
65.6	9.44	41.3	5.77	1336
65.4	9.49	41.3	5.79	1339
65.1	9.51	41.2	5.77	1342
65.1	9.54	41.1	5.77	1345
64.8	9.47	41.0	5.77	1348

Waughop Lake sampling log

Position UTM
easting: 0533145
northing: 5224069

Date: 9/28/15
Time: ___:___AM/PM

Secchi Depth (ft)
Down: 1'11"
Up: 1'9"
Mean 1.10'
Staff gauge: 4.16'
Time: 1:17 AM/[✓ PM]

Waterfowl count:
ducks: 166
geese: –
gulls: –
other:

Hydrolab

Depth (m)	Temp (°~~C~~ F)	Cond (µS/cm)	pH	Chlor (µg/L)	DO (mg/L)
0.5	62.0	55.1	8.10	–	11.66
1	61.6	54.4	8.15	–	11.31
1.5	61.5	53.8	8.02	–	10.89
2	61.2	54.4	8.16	–	11.32
2.5	59.9	53.5	7.73	–	9.88

Hobo retrieved: 11:30 [✓ AM]/PM

Hobo deployed: 11:42 [✓ AM]/PM

Water samples

	Depth on tape (ft)	Check box after collection	
Alkalinity	1, 6	✓	✓
Chlorophyll	1, 6	✓	✓
Nutrients (UF)	1, 6	✓	✓
Phytoplankton	5	✓	✓
Zooplankton	5	✓	✓

Replicate
(circle one)
upper/[✓ lower]

Groundwater wells

Well	Level from top of well (ft)		Time	Sample
GW1				
GW2				
GW3				
GW4				
GW5				
Piezometer	Inside (ft)	Outside (ft)	Time	Sample
1	4.18	4.21	1217	
2	4.89	4.59	12:53	

Comments: 8'10" TOTAL DEPTH

Waughop Lake sampling log

Position	UTM
easting:	0533145
northing:	5224069

Date: 10 / 13 / 15
Time: 12 : 53 AM/PM

Secchi	Depth (ft)
Down:	3 ' 0 "
Up:	2 ' 11 "
Mean	___ . ___ '
Staff gauge:	4 . 11 '
Time:	12 : 52 AM/[✓ PM]

Waterfowl count:
ducks: 131
geese:
gulls: 5
other: 1

Hydrolab

Depth (m)	Temp (°C)	Cond (mS µS/cm)	pH	Chlor (µg/L)	DO (mg/L)
0.5	16.09	0.050	7.2		10.56
1	15.97	0.050	7.19		9.38
1.5	15.83	0.050	7.15		8.25
2	15.59	0.051	7.08		6.25
2.5	15.45	0.236	~~6~~ 6.45		0.25

Hobo retrieved: 12 : 56 AM/[✓ PM]

Hobo deployed: ~~__ : __ AM/PM~~

Water samples

	Depth on tape (ft)	Check box after collection	
Alkalinity	1, 6	✓	✓
Chlorophyll	1, 6	✓	✓
Nutrients (UF)	1, 6	1:21 pm ✓	✓ 1:30
Phytoplankton	5	✓	✓
Zooplankton	5	✓	✓

Replicate (circle one)
upper/[✓ lower]

Groundwater wells

Well	Level from top of well (ft)		Time	Sample
GW1	~~9.31~~ or 11.56		~~2:11~~ 2:25	
GW2	8.72		2:17	
GW3	9.31		2:11	
GW4	14.53		2:40	
GW5	19.78		2:35	
Piezometer	Inside (ft)	Outside (ft)	Time	Sample
1	4.23	4.25	1238	
2	4.95	4.61	1249	

Comments: TOTAL DEPTH 8'11"

Appendix B: Laboratory Results

This appendix contains copies of the laboratory results from the 2014–15 monitoring study.

M15034-71

IEH - Aquatic Research
3927 Aurora Ave N • Seattle • WA • 98103
P: 206-632-2715 F: 206-632-2417

Chain of Custody Form

Page 1 of 1

REPORT TO:
Client: GAWEL - UWT
Address: 1900 Commerce St.
Box 358436, Tacoma, WA 98402
Contact: Jim Gawel
Email: jimgawel@uw.edu
Phone: 253-692-5815 Fax: 253-692-4639

INVOICE TO: (IF DIFFERENT FROM REPORT)
Client:
Address:
Contact:
Email:
Phone: Fax:

PROJECT INFORMATION
Quote No.:
Client PO:
Client Project:

Reporting/Invoicing Format
☐ Fax ☑ Email ☐ Mail

QC Data Reported
☑ Yes ☐ No

Sample Disposal
☐ Hold ☑ Dispose ☐ Return

Turn Around Time (TAT)*
☐ Next Day ☐ 2 Business Day
☐ 3 Business Day ☑ Standard

Specific Date:

*Advanced notice required for Rush Analysis

LAB USE ONLY
Case File Number

SAMPLING Date (mm-dd-yy)	Time	Matrix**	SAMPLE DESCRIPTION (This Will Appear On The Report)	Number of Containers	TP	SRP	TN									Field pH (if applicable)	Field Temp (if applicable)	Metals Field Filtered (Y/N)	Containers Received	Temp	Lab ID
10-29-14	1:42	SW	L1 - surf	1	✓	✓	✓												1	5.3°C	
10-29-14	1:42	SW	L1 - surf - dup	1	✓	✓	✓												1		
10-29-14	1:47	SW	L1 - bot	1	✓	✓	✓												1		
																				(3)	

**Matrix: B=Biota, DW=Drinking Water, GW=Ground Water, P=Paint, S=Soil, SD=Sediment, SL=Sludge, SW=Surface Water, WW=Wastewater

Sampled By Jim Gawel	Date 10-29-14	Time 3:20pm
Received By	Date	Time
Relinquished to Aquatic By (Signature)	Date	Time

Comments:

Shipped By Jim Gawel	Shipping Reference	
Received at Aquatic By	Date 10/29/14	Time 5:00

IEH - AQUATIC RESEARCH

LABORATORY & CONSULTING SERVICES
3927 AURORA AVENUE NORTH, SEATTLE, WA 98103
PHONE: (206) 632-2715 FAX: (206) 632-2417

CASE FILE NUMBER: MIS034-71 **PAGE 1**
REPORT DATE: 12/09/14
DATE SAMPLED: 10/29/14 **DATE RECEIVED:** 10/29/14

FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM GAWEL - UWT

CASE NARRATIVE

Three water samples were received by the laboratory in good condition and analyzed according to the chain of custody. No difficulties were encountered in the preparation or analysis of these samples. Sample data follows while QA/QC data is contained on the subsequent page.

SAMPLE DATA

SAMPLE ID	TOTAL-P (mg/L)	SRP (mg/L)	TOTAL-N (mg/L)
L1-SURF	0.071	0.004	1.21
L1-SURF-DUP	0.074	0.004	1.16
L1-BOT	0.092	0.004	1.40

CASE FILE NUMBER: MIS034-71 **PAGE 2**
REPORT DATE: 12/09/14
DATE SAMPLED: 10/29/14 **DATE RECEIVED:** 10/29/14
FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM GAWEL - UWT

QA/QC DATA

QC PARAMETER	TOTAL-P (mg/L)	SRP (mg/L)	TOTAL-N (mg/L)
METHOD	SM18 4500PF	SM18 4500PF	SM204500NC
DATE ANALYZED	11/24/14	10/30/14	11/10/14
REPORTING LIMIT	0.002	0.001	0.050
DUPLICATE			
SAMPLE ID	BATCH	L1-BOT	BATCH
ORIGINAL	0.063	0.004	0.369
DUPLICATE	0.060	0.004	0.378
RPD	5.47%	2.67%	2.60%
SPIKE SAMPLE			
SAMPLE ID	BATCH	L1-BOT	BATCH
ORIGINAL	0.063	0.004	0.369
SPIKED SAMPLE	0.115	0.025	1.45
SPIKE ADDED	0.050	0.020	1.00
% RECOVERY	104.60%	104.00%	108.42%
QC CHECK			
FOUND	0.091	0.034	0.481
TRUE	0.090	0.033	0.490
% RECOVERY	100.58%	103.34%	98.16%
BLANK	<0.002	<0.001	<0.050

RPD = RELATIVE PERCENT DIFFERENCE.
NA = NOT APPLICABLE OR NOT AVAILABLE.
NC = NOT CALCULABLE DUE TO ONE OR MORE VALUES BEING BELOW THE DETECTION LIMIT.
OR = RECOVERY NOT CALCULABLE DUE TO SPIKE SAMPLE OUT OF RANGE OR SPIKE TOO LOW RELATIVE TO SAMPLE CONCENTRATION.

SUBMITTED BY:

Damien Gadomski

Damien Gadomski
Project Manager

M15034-82

IEH - Aquatic Research
3927 Aurora Ave N • Seattle • WA • 98103
P: 206-632-2715 F: 206-632-2417

Chain of Custody Form

Page ____ of ____

REPORT TO:
Client: University of Washington Tacoma
Address: 1900 Commerce St Tacoma
WA
Contact: Jim Gawel
Email: ~~(253) 651-2573~~ jimgawel@uw.edu
Phone: (253)651-2573 Fax:

INVOICE TO: (IF DIFFERENT FROM REPORT)
Client:
Address:
Contact:
Email:
Phone: Fax:

PROJECT INFORMATION
Quote No.:
Client PO:
Client Project:

Reporting/Invoicing Format
☐ Fax ☐ Email ☐ Mail

QC Data Reported
☐ Yes ☐ No

Sample Disposal
☐ Hold ☐ Dispose ☐ Return

Turn Around Time (TAT)*
☐ Next Day ☐ 2 Business Day
☐ 3 Business Day ☐ Standard
Specific Date:
*Advanced notice required for Rush Analysis

LAB USE ONLY
Case File Number

SAMPLING Date (mm-dd-yy)	Time	Matrix**	SAMPLE DESCRIPTION (This Will Appear On The Report)	Number of Containers	TP	SRP	TN									Field pH (If applicable)	Field Temp (If applicable)	Metals Field Filtered (Y/N)	Containers Received	Temp	Lab ID
11/19/14	12:14		S1 Surface	1	X	X	X													5.8°C	
11/19/14	12:19		S2 Bottom	1	X	X	X													↓	
11/19/14	12:19		S3 Bottom Dup.	1	X	X	X													↓	

**Matrix: B=Biota, DW=Drinking Water, GW=Ground Water, P=Paint, S=Soil, SD=Sediment, SL=Sludge, SW=Surface Water, WW=Wastewater

Comments:

Sampled By	Date 11/19/14	Time 2:50pm
Received By	Date	Time
Relinquished to Aquatic By (Signature)	Date	Time

Shipped By	Shipping Reference	
Received at Aquatic By (3) total	Date 11/19/14	Time 430

IEH - AQUATIC RESEARCH

LABORATORY & CONSULTING SERVICES
3927 AURORA AVENUE NORTH, SEATTLE, WA 98103
PHONE: (206) 632-2715 FAX: (206) 632-2417

CASE FILE NUMBER: MIS034-82

REPORT DATE: 12/16/14

DATE SAMPLED: 11/19/14 **DATE RECEIVED:** 11/19/14

FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM GAWEL - UWT

CASE NARRATIVE

Three water samples were received by the laboratory in good condition and analyzed according to the chain of custody. No difficulties were encountered in the preparation or analysis of these samples. Sample data follows while QA/QC data is contained on the subsequent page.

SAMPLE DATA

SAMPLE ID	TOTAL-P (mg/L)	SRP (mg/L)	TOTAL-N (mg/L)
S1 SURFACE	0.060	0.007	1.49
S2 BOTTOM	0.061	0.007	1.45
S3 BOTTOM DUP	0.068	0.007	1.71

CASE FILE NUMBER: MIS034-82 **PAGE 2**
REPORT DATE: 12/16/14
DATE SAMPLED: 11/19/14 **DATE RECEIVED:** 11/19/14
FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM GAWEL - UWT

QA/QC DATA

QC PARAMETER	TOTAL-P (mg/L)	SRP (mg/L)	TOTAL-N (mg/L)
METHOD	SM18 4500PF	SM18 4500PF	SM204500NC
DATE ANALYZED	12/01/14	11/21/14	12/01/14
REPORTING LIMIT	0.002	0.001	0.050
DUPLICATE			
SAMPLE ID	BATCH	BATCH	BATCH
ORIGINAL	0.005	0.009	0.396
DUPLICATE	0.004	0.009	0.417
RPD	1.87%	3.37%	5.25%
SPIKE SAMPLE			
SAMPLE ID	BATCH	BATCH	BATCH
ORIGINAL	0.005	0.009	0.396
SPIKED SAMPLE	0.076	0.029	1.41
SPIKE ADDED	0.075	0.020	1.00
% RECOVERY	95.31%	102.73%	101.69%
QC CHECK			
FOUND	0.090	0.033	0.485
TRUE	0.090	0.033	0.490
% RECOVERY	100.00%	100.71%	99.02%
BLANK	<0.002	<0.001	<0.050

RPD = RELATIVE PERCENT DIFFERENCE.
NA = NOT APPLICABLE OR NOT AVAILABLE.
NC = NOT CALCULABLE DUE TO ONE OR MORE VALUES BEING BELOW THE DETECTION LIMIT.
OR = RECOVERY NOT CALCULABLE DUE TO SPIKE SAMPLE OUT OF RANGE OR SPIKE TOO LOW RELATIVE TO SAMPLE CONCENTRATION.

SUBMITTED BY:

Damien Gadomski

Damien Gadomski
Project Manager

MIS085-04

IEH - Aquatic Research
3927 Aurora Ave N • Seattle • WA • 98103
P: 206-632-2715 F: 206-632-2417

Chain of Custody Form

Page ____ of ____

REPORT TO:
Client: James Gawel / UW Tacoma
Address: 1900 Commerce St.
Campus Box 358436, Tacoma, WA 98402
Contact: James Gawel
Email: jimgawel@uw.edu
Phone: 253-692-5815 Fax: 253-692-4639

INVOICE TO: (IF DIFFERENT FROM REPORT)
Client:
Address:
Contact:
Email:
Phone: Fax:

PROJECT INFORMATION
Quote No.:
Client PO:
Client Project:

Reporting/Invoicing Format
☐ Fax ☑ Email ☐ Mail

QC Data Reported
☑ Yes ☐ No

Sample Disposal
☐ Hold ☑ Dispose ☐ Return

Turn Around Time (TAT)*
☐ Next Day ☐ 2 Business Day
☐ 3 Business Day ☐ Standard

Specific Date: ____
*Advanced notice required for Rush Analysis

LAB USE ONLY
Case File Number

Date (mm-dd-yy)	Time	Matrix**	SAMPLE DESCRIPTION (This Will Appear On The Report)	Number of Containers	TP	SRP	TN	Field pH (if applicable)	Field Temp (if applicable)	Metals Field Filtered (Y/N)	Containers Received	Temp	Lab ID
12/15/14	11:30am	SW	Waughop 1 SURF	1	↓	↓	↓				1	0.9°c	
	11:31am	SW	Waughop 2 SURF DUP	1							1		
	11:59am	SW	Waughop 3 BOTTOM	1							1		
↓	1:50pm	GW	Waughop GW-2	1							1	↓	
												(4) Total	

**Matrix: B=Biota, DW=Drinking Water, GW=Ground Water, P=Paint, S=Soil, SD=Sediment, SL=Sludge, SW=Surface Water, WW=Wastewater

Sampled By: James E Gawel Date: 12/15/14 Time: 3:00 pm

Received By: Date: Time:

Relinquished to Aquatic By (Signature): Date: Time:

Comments:

Shipped By:

Shipping Reference:

Received at Aquatic By:

Date: 12/15/14 Time: 4:30

IEH - AQUATIC RESEARCH

LABORATORY & CONSULTING SERVICES
3927 AURORA AVENUE NORTH, SEATTLE, WA 98103
PHONE: (206) 632-2715 FAX: (206) 632-2417

CASE FILE NUMBER: MIS035-04 **PAGE 1**

REPORT DATE: 12/24/14

DATE SAMPLED: 12/15/14 **DATE RECEIVED:** 12/15/14

FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM GAWEL - UWT

CASE NARRATIVE

Four water samples were received by the laboratory in good condition and analyzed according to the chain of custody. No difficulties were encountered in the preparation or analysis of these samples. Sample data follows while QA/QC data is contained on the subsequent page.

SAMPLE DATA

SAMPLE ID	TOTAL-P (mg/L)	SRP (mg/L)	TOTAL-N (mg/L)
WAUGHOP 1 SURF	0.112	0.012	1.77
WAUGHOP 2 SURF DUP	0.097	0.015	2.19
WAUGHOP 3 BOTTOM	0.116	0.014	1.86
WAUGHOP GW-2	0.046	0.003	0.993

CASE FILE NUMBER: MIS035-04 **PAGE 2**
REPORT DATE: 12/24/14
DATE SAMPLED: 12/15/14 **DATE RECEIVED:** 12/15/14
FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM GAWEL - UWT

QA/QC DATA

QC PARAMETER	TOTAL-P (mg/L)	SRP (mg/L)	TOTAL-N (mg/L)
METHOD	SM18 4500PF	SM18 4500PF	SM204500NC
DATE ANALYZED	12/22/14	12/16/14	12/23/14
REPORTING LIMIT	0.002	0.001	0.050
DUPLICATE			
SAMPLE ID	BATCH	BATCH	BATCH
ORIGINAL	0.006	0.005	0.110
DUPLICATE	0.006	0.005	0.104
RPD	0.00%	0.11%	5.57%
SPIKE SAMPLE			
SAMPLE ID	BATCH	BATCH	BATCH
ORIGINAL	0.006	0.005	0.110
SPIKED SAMPLE	0.058	0.025	1.24
SPIKE ADDED	0.050	0.020	1.00
% RECOVERY	104.00%	100.61%	112.95%
QC CHECK			
FOUND	0.087	0.033	0.499
TRUE	0.090	0.033	0.490
% RECOVERY	96.67%	100.00%	101.76%
BLANK	<0.002	<0.001	<0.050

RPD = RELATIVE PERCENT DIFFERENCE.
NA = NOT APPLICABLE OR NOT AVAILABLE.
NC = NOT CALCULABLE DUE TO ONE OR MORE VALUES BEING BELOW THE DETECTION LIMIT.
OR = RECOVERY NOT CALCULABLE DUE TO SPIKE SAMPLE OUT OF RANGE OR SPIKE TOO LOW RELATIVE TO SAMPLE CONCENTRATION.

SUBMITTED BY:

Damien Gadomski

Damien Gadomski
Project Manager

MIS035-08

IEH - Aquatic Research
3927 Aurora Ave N • Seattle • WA • 98103
P: 206-632-2715 F: 206-632-2417

Chain of Custody Form

Page ____ of ____

REPORT TO:
Client: UNIV OF WASHINGTON · TACOMA
Address:
TACOMA, WA
Contact: JIM GAWEL
Email:
Phone: (253) 651-2573 Fax:

INVOICE TO: (IF DIFFERENT FROM REPORT)
Client:
Address:
Contact:
Email:
Phone: Fax:

PROJECT INFORMATION
Quote No.:
Client PO:
Client Project:

Reporting/Invoicing Format
☐ Fax ☐ Email ☐ Mail

QC Data Reported
☐ Yes ☐ No

Sample Disposal
☐ Hold ☐ Dispose ☐ Return

Turn Around Time (TAT)*
☐ Next Day ☐ 2 Business Day
☐ 3 Business Day ☐ Standard

Specific Date:

*Advanced notice required for Rush Analysis

LAB USE ONLY
Case File Number

SAMPLING Date (mm-dd-yy)	Time	Matrix**	SAMPLE DESCRIPTION (This Will Appear On The Report)	Number of Containers	Analysis Requested TP	SRP	TN										Field pH (if applicable)	Field Temp (if applicable)	Metals Field Filtered (Y/N)	Containers Received	Temp	Lab ID
12-18-14	1033		GW1	1																1	3.4°C	
12-18-14	947		GW3	1																		
12-18-14	1213		GW4	1																		
12-18-14	1122		GW5	1																		
																					(4) wtr	

**Matrix: B=Biota, DW=Drinking Water, GW=Ground Water, P=Paint, S=Soil, SD=Sediment, SL=Sludge, SW=Surface Water, WW=Wastewater

Comments:

Sampled By	Date	Time
	12/18/14	12:30pm

Received By	Date	Time

Relinquished to Aquatic By (Signature)	Date	Time

Shipped By

Shipping Reference

Received at Aquatic By

Date 12/19/14 Time 9:30

IEH - AQUATIC RESEARCH
LABORATORY & CONSULTING SERVICES
3927 AURORA AVENUE NORTH, SEATTLE, WA 98103
PHONE: (206) 632-2715 FAX: (206) 632-2417

CASE FILE NUMBER: **MIS035-08** **PAGE 1**
REPORT DATE: **01/06/15**
DATE SAMPLED: **12/18/14** **DATE RECEIVED:** **12/19/14**
FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM GAWEL - UWT

CASE NARRATIVE

Four water samples were received by the laboratory in good condition and analyzed according to the chain of custody. No difficulties were encountered in the preparation or analysis of these samples. Sample data follows while QA/QC data is contained on the subsequent page.

SAMPLE DATA

SAMPLE ID	TOTAL-P (mg/L)	SRP (mg/L)	TOTAL-N (mg/L)
GW 1	0.032	0.010	1.68
GW 3	0.064	0.016	1.32
GW 4	<0.002	<0.001	14.2
GW 5	0.017	0.013	0.878

CASE FILE NUMBER: **MIS035-08** **PAGE 2**
REPORT DATE: **01/06/15**
DATE SAMPLED: **12/18/14** **DATE RECEIVED:** **12/19/14**
FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM GAWEL - UWT

QA/QC DATA

QC PARAMETER	TOTAL-P (mg/L)	SRP (mg/L)	TOTAL-N (mg/L)
METHOD	SM18 4500PF	SM18 4500PF	SM204500NC
DATE ANALYZED	12/29/14	12/19/14	01/06/15
REPORTING LIMIT	0.002	0.001	0.050
DUPLICATE			
SAMPLE ID	BATCH	GW 5	BATCH
ORIGINAL	0.009	0.013	0.347
DUPLICATE	0.009	0.013	0.341
RPD	1.29%	0.64%	1.85%
SPIKE SAMPLE			
SAMPLE ID	BATCH	GW 5	BATCH
ORIGINAL	0.009	0.013	0.347
SPIKED SAMPLE	0.061	0.033	1.37
SPIKE ADDED	0.050	0.020	1.00
% RECOVERY	102.72%	99.14%	102.59%
QC CHECK			
FOUND	0.090	0.033	0.490
TRUE	0.090	0.033	0.490
% RECOVERY	100.00%	100.00%	100.00%
BLANK	<0.002	<0.001	<0.050

RPD = RELATIVE PERCENT DIFFERENCE.
NA = NOT APPLICABLE OR NOT AVAILABLE.
NC = NOT CALCULABLE DUE TO ONE OR MORE VALUES BEING BELOW THE DETECTION LIMIT.
OR = RECOVERY NOT CALCULABLE DUE TO SPIKE SAMPLE OUT OF RANGE OR SPIKE TOO LOW RELATIVE TO SAMPLE CONCENTRATION.

SUBMITTED BY:

Damien Gadomski

Damien Gadomski
Project Manager

MIS035-19

IEH - Aquatic Research
3927 Aurora Ave N • Seattle • WA • 98103
P: 206-632-2715 F: 206-632-2417

Chain of Custody Form

Page 1 of 1

REPORT TO:
Client: UWT -
Address: 1900 Commerce St, Box 358436
Tacoma, WA 98402
Contact: James Gawel
Email: jimgawel@uw.edu
Phone: 253-698-5815 Fax:

INVOICE TO: (IF DIFFERENT FROM REPORT)
Client:
Address:
Contact:
Email:
Phone: Fax:

PROJECT INFORMATION
Quote No.:
Client PO:
Client Project:

Reporting/Invoicing Format
☐ Fax ☑ Email ☐ Mail

QC Data Reported
☑ Yes ☐ No

Sample Disposal
☐ Hold ☑ Dispose ☐ Return

Turn Around Time (TAT)*
☐ Next Day ☐ 2 Business Day
☐ 3 Business Day ☐ Standard

Specific Date:
*Advanced notice required for Rush Analysis

LAB USE ONLY
Case File Number

SAMPLING Date (mm-dd-yy)	Time	Matrix**	SAMPLE DESCRIPTION (This Will Appear On The Report)	Number of Containers	TP	SRP	TPN										Field pH (if applicable)	Field Temp (if applicable)	Metals Field Filtered (Y/N)	Containers Received	Temp	Lab ID
01-05-15	11:18am	SW	WAUGHOP STORM-1	1																1	10.0°C	

**Matrix: B=Biota, DW=Drinking Water, GW=Ground Water, P=Paint, S=Soil, SD=Sediment, SL=Sludge, SW=Surface Water, WW=Wastewater

Sampled By: James Gawel Date: 1/5/15 Time:
Received By: Date: Time:
Relinquished to Aquatic By (Signature): Date: Time:

Comments:

Shipped By:
Shipping Reference:
Received at Aquatic By: Date: 1/5/15 Time: 3:20

IEH - AQUATIC RESEARCH

LABORATORY & CONSULTING SERVICES
3927 AURORA AVENUE NORTH, SEATTLE, WA 98103
PHONE: (206) 632-2715 FAX: (206) 632-2417

CASE FILE NUMBER: MIS035-19 **PAGE 1**
REPORT DATE: 02/06/15
DATE SAMPLED: 01/05/15 **DATE RECEIVED:** 01/05/15

FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM GAWEL - UWT

CASE NARRATIVE

One water sample was received by the laboratory in good condition and analyzed according to the chain of custody. No difficulties were encountered in the preparation or analysis of this sample. Sample data follows while QA/QC data is contained on the subsequent page.

SAMPLE DATA

SAMPLE ID	TOTAL-P (mg/L)	SRP (mg/L)	TOTAL-N (mg/L)
WAUCHOP STORM-1	0.038	0.007	0.190

CASE FILE NUMBER: **MIS035-19**

REPORT DATE: **02/06/15**

DATE SAMPLED: **01/05/15** **DATE RECEIVED:** **01/05/15**

FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM GAWEL - UWT

QA/QC DATA

QC PARAMETER	TOTAL-P (mg/L)	SRP (mg/L)	TOTAL-N (mg/L)
METHOD	SM18 4500PF	SM18 4500PF	SM204500NC
DATE ANALYZED	01/12/15	01/06/15	01/15/15
REPORTING LIMIT	0.002	0.001	0.050
DUPLICATE			
SAMPLE ID	BATCH	BATCH	BATCH
ORIGINAL	0.003	0.016	2.85
DUPLICATE	0.003	0.016	2.94
RPD	5.11%	0.26%	3.03%
SPIKE SAMPLE			
SAMPLE ID	BATCH	BATCH	BATCH
ORIGINAL	0.003	0.016	2.85
SPIKED SAMPLE	0.051	0.036	3.87
SPIKE ADDED	0.050	0.020	1.00
% RECOVERY	96.51%	97.08%	101.75%
QC CHECK			
FOUND	0.094	0.033	0.495
TRUE	0.094	0.033	0.490
% RECOVERY	100.00%	100.00%	101.02%
BLANK	<0.002	<0.001	<0.050

RPD = RELATIVE PERCENT DIFFERENCE.
NA = NOT APPLICABLE OR NOT AVAILABLE.
NC = NOT CALCULABLE DUE TO ONE OR MORE VALUES BEING BELOW THE DETECTION LIMIT.
OR = RECOVERY NOT CALCULABLE DUE TO SPIKE SAMPLE OUT OF RANGE OR SPIKE TOO LOW RELATIVE TO SAMPLE CONCENTRATION.

SUBMITTED BY:

Damien Gadomski

Damien Gadomski
Project Manager

~~M15035-04~~

Page ____ of ____

IEH - Aquatic Research
3927 Aurora Ave N • Seattle • WA • 98103
P: 206-632-2715 F: 206-632-2417

Chain of Custody Form

REPORT TO:
Client: JAMES GAWEL / UW TACOMA
Address: 1900 COMMERCE ST
CAMPUS BOX 358436, TACOMA, WA 98402
Contact: JAMES GAWEL
Email: jimgawel@uw.edu
Phone: (253) 692-5815 Fax: (253) 692-4639

INVOICE TO: (IF DIFFERENT FROM REPORT)
Client:
Address:
Contact:
Email:
Phone: Fax:

PROJECT INFORMATION
Quote No.:
Client PO:
Client Project:

Reporting/Invoicing Format
☐ Fax ☑ Email ☐ Mail

QC Data Reported
☑ Yes ☐ No

Sample Disposal
☐ Hold ☑ Dispose ☐ Return

Turn Around Time (TAT)*
☐ Next Day ☐ 2 Business Day
☐ 3 Business Day ☐ Standard

Specific Date: ______
*Advanced notice required for Rush Analysis

SAMPLING					Analysis Requested																LAB USE ONLY		
Date (mm-dd-yy)	**Time**	**Matrix****	**SAMPLE DESCRIPTION** (This Will Appear On The Report)	**Number of Containers**	TP	SRB	TN											Field pH (if applicable)	Field Temp (if applicable)	Metals Field Filtered (Y/N)	**Containers Received**	Temp	Lab ID
01-22-15	1100 AM	SW	WAUGHOP SURFACE	1	|	|	|													1	3.9°C	
01-22-15	1103 AM	SW	WAUGHOP BOTTOMA	1	|	|	|													1	|	
01-22-15	1103 AM	SW	WAUGHOP BOTTOMB	1	|	|	|													1	|	
																						(3) TOM	

Case File Number

**Matrix: B=Biota, DW=Drinking Water, GW=Ground Water, P=Paint, S=Soil, SD=Sediment, ~~SL=Sludge~~, SW=Surface Water, WW=Wastewater

Comments:

Sampled By	Date 1/22/15	Time 1:30 PM
Received By	Date	Time
Relinquished to Aquatic By (Signature)	Date	Time

Shipped By	Shipping Reference
Received at Aquatic By	Date 1/23/15 Time 9:00

IEH - AQUATIC RESEARCH

LABORATORY & CONSULTING SERVICES
3927 AURORA AVENUE NORTH, SEATTLE, WA 98103
PHONE: (206) 632-2715 FAX: (206) 632-2417

CASE FILE NUMBER: MIS035-34 **PAGE 1**

REPORT DATE: 02/06/15

DATE SAMPLED: 01/22/15 **DATE RECEIVED:** 01/23/15

FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM GAWEL - UWT

CASE NARRATIVE

Three water samples were received by the laboratory in good condition and analyzed according to the chain of custody. No difficulties were encountered in the preparation or analysis of these samples. Sample data follows while QA/QC data is contained on the subsequent page.

SAMPLE DATA

SAMPLE ID	TOTAL-P (mg/L)	SRP (mg/L)	TOTAL-N (mg/L)
WAUGHOP SURFACE	0.097	0.016	1.99
WAUGHOP BOTTOM A	0.081	0.013	1.72
WAUGHOP BOTTOM B	0.093	0.014	1.74

CASE FILE NUMBER: **MIS035-34** **PAGE 2**
REPORT DATE: **02/06/15**
DATE SAMPLED: **01/22/15** **DATE RECEIVED:** **01/23/15**
FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM GAWEL - UWT

QA/QC DATA

QC PARAMETER	TOTAL-P (mg/L)	SRP (mg/L)	TOTAL-N (mg/L)
METHOD	SM18 4500PF	SM18 4500PF	SM204500NC
DATE ANALYZED	02/02/15	01/23/15	01/27/15
REPORTING LIMIT	0.002	0.001	0.050
DUPLICATE			
SAMPLE ID	BATCH	WAUGHOP BOTTOM B	BATCH
ORIGINAL	0.006	0.014	3.49
DUPLICATE	0.007	0.014	3.44
RPD	9.41%	0.72%	1.45%
SPIKE SAMPLE			
SAMPLE ID	BATCH	WAUGHOP BOTTOM B	BATCH
ORIGINAL	0.006	0.014	3.49
SPIKED SAMPLE	0.058	0.034	4.59
SPIKE ADDED	0.050	0.020	1.00
% RECOVERY	102.63%	98.66%	109.80%
QC CHECK			
FOUND	0.094	0.041	0.484
TRUE	0.094	0.039	0.490
% RECOVERY	100.00%	105.13%	98.78%
BLANK	<0.002	<0.001	<0.050

RPD = RELATIVE PERCENT DIFFERENCE.
NA = NOT APPLICABLE OR NOT AVAILABLE.
NC = NOT CALCULABLE DUE TO ONE OR MORE VALUES BEING BELOW THE DETECTION LIMIT.
OR = RECOVERY NOT CALCULABLE DUE TO SPIKE SAMPLE OUT OF RANGE OR SPIKE TOO LOW RELATIVE TO SAMPLE CONCENTRATION.

SUBMITTED BY:

Damien Gadomski

Damien Gadomski
Project Manager

M15035-53

IEH - Aquatic Research
3927 Aurora Ave N • Seattle • WA • 98103
P: 206-632-2715 F: 206-632-2417

Chain of Custody Form

Page ____ of ____

REPORT TO:
Client: University of Washington Tacoma
Address: 1900 Commerce St, Box 358436
Tacoma, WA 98402
Contact: Jim Gawel
Email: jimgawel@uw.edu
Phone: 253-692-5815 Fax: 253-692-4639

INVOICE TO: (IF DIFFERENT FROM REPORT)
Client: Brown & Caldwell
Address:
Contact:
Email:
Phone: Fax:

PROJECT INFORMATION
Quote No.:
Client PO:
Client Project:

Reporting/Invoicing Format
☐ Fax ☑ Email ☐ Mail

QC Data Reported
☑ Yes ☐ No

Sample Disposal
☐ Hold ☑ Dispose ☐ Return

Turn Around Time (TAT)*
☐ Next Day ☐ 2 Business Day
☐ 3 Business Day ☑ Standard

Specific Date:
*Advanced notice required for Rush Analysis

SAMPLING Date (mm-dd-yy)	Time	Matrix**	SAMPLE DESCRIPTION (This Will Appear On The Report)	Number of Containers	TP	SRP	TN										Field pH (if applicable)	Field Temp (if applicable)	Metals Field Filtered (Y/N)	LAB USE ONLY Containers Received	Temp	Lab ID
02-05-15	3pm	SW	STORm-1	1	↓	↓	↓													1	4.9°C	
02-05-15	4pm	SW	STORm-2	1	↓	↓	↓													1	↓	
																					(2) 20TA	

LAB USE ONLY
Case File Number

**Matrix: B=Biota, DW=Drinking Water, GW=Ground Water, P=Paint, S=Soil, SD=Sediment, SL=Sludge, SW=Surface Water, WW=Wastewater

Comments:

Sampled By James Gawel	Date 2/5/15	Time 4pm
Received By	Date	Time
Relinquished to Aquatic By (Signature)	Date	Time

Shipped By
Shipping Reference
Received at Aquatic By
Date 2/6/15
Time 11:20

IEH - AQUATIC RESEARCH

LABORATORY & CONSULTING SERVICES
3927 AURORA AVENUE NORTH, SEATTLE, WA 98103
PHONE: (206) 632-2715 FAX: (206) 632-2417

CASE FILE NUMBER: MIS035-53 **PAGE 1**
REPORT DATE: 02/24/15
DATE SAMPLED: 02/05/15 **DATE RECEIVED:** 02/06/15
FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM GAWEL - UWT

CASE NARRATIVE

Two water samples were received by the laboratory in good condition and analyzed according to the chain of custody. No difficulties were encountered in the preparation or analysis of these samples. Sample data follows while QA/QC data is contained on the subsequent page.

SAMPLE DATA

SAMPLE ID	TOTAL-P (mg/L)	SRP (mg/L)	TOTAL-N (mg/L)
STORM-1	0.030	0.003	0.446
STORM-2	0.044	0.006	0.543

CASE FILE NUMBER: MIS035-53 **PAGE 2**
REPORT DATE: 02/24/15
DATE SAMPLED: 02/05/15 **DATE RECEIVED:** 02/06/15
FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM GAWEL - UWT

QA/QC DATA

QC PARAMETER	TOTAL-P (mg/L)	SRP (mg/L)	TOTAL-N (mg/L)
METHOD	SM18 4500PF	SM18 4500PF	SM204500NC
DATE ANALYZED	02/16/15	02/06/15	02/17/15
REPORTING LIMIT	0.002	0.001	0.050
DUPLICATE			
SAMPLE ID	BATCH	BATCH	BATCH
ORIGINAL	0.036	0.055	0.905
DUPLICATE	0.037	0.055	0.942
RPD	2.53%	0.83%	4.03%
SPIKE SAMPLE			
SAMPLE ID	BATCH	BATCH	BATCH
ORIGINAL	0.036	0.055	0.905
SPIKED SAMPLE	0.086	0.075	1.97
SPIKE ADDED	0.050	0.020	1.00
% RECOVERY	99.49%	98.95%	106.78%
QC CHECK			
FOUND	0.095	0.039	0.497
TRUE	0.094	0.039	0.490
% RECOVERY	101.06%	100.00%	101.43%
BLANK	<0.002	<0.001	<0.050

RPD = RELATIVE PERCENT DIFFERENCE.
NA = NOT APPLICABLE OR NOT AVAILABLE.
NC = NOT CALCULABLE DUE TO ONE OR MORE VALUES BEING BELOW THE DETECTION LIMIT.
OR = RECOVERY NOT CALCULABLE DUE TO SPIKE SAMPLE OUT OF RANGE OR SPIKE TOO LOW RELATIVE TO SAMPLE CONCENTRATION.

SUBMITTED BY:

Damien Gadomski

Damien Gadomski
Project Manager

IEH - Aquatic Research
3927 Aurora Ave N • Seattle • WA • 98103
P: 206-632-2715 F: 206-632-2417

Chain of Custody Form

MIS035-60

Page ____ of ____

REPORT TO:
Client: Jim Gawel - UWT
Address: 1900 Commerce St.
Campus Box 358436, Tacoma, WA 98402
Contact: Jim Gawel
Email: jimgawel@uw.edu
Phone: 253-692-5815 Fax:

INVOICE TO: (IF DIFFERENT FROM REPORT)
Client: Brown & Caldwell
Address:
Contact:
Email:
Phone: Fax:

PROJECT INFORMATION
Quote No.:
Client PO:
Client Project:

Reporting/Invoicing Format
☐ Fax ☑ Email ☐ Mail

QC Data Reported
☑ Yes ☐ No

Sample Disposal
☐ Hold ☑ Dispose ☐ Return

Turn Around Time (TAT)*
☐ Next Day ☐ 2 Business Day
☐ 3 Business Day ☑ Standard

Specific Date:

*Advanced notice required for Rush Analysis

LAB USE ONLY
Case File Number

SAMPLING Date (mm-dd-yy)	Time	Matrix**	SAMPLE DESCRIPTION (This Will Appear On The Report)	Number of Containers	Analysis Requested: SRP, TP, TN	Field pH (if applicable)	Field Temp (if applicable)	Metals Field Filtered (Y/N)	Containers Received	Temp	Lab ID
02-19-15	10:35	SW	LW1 SURFACE A	1	✓				1	4.6°C	
	10:35		LW1 SURFACE B	1							
	10:43	↓	LW1 BOTTOM	1							
	1:23	GW	GW-1	1							
	12:55		GW-2	1							
	12:15		GW-3	1							
	2:33		GW-4	1							
↓	2:06	↓	GW-5	1	✓						
									(8) WA		

**Matrix: B=Biota, DW=Drinking Water, GW=Ground Water, P=Paint, S=Soil, SD=Sediment, SL=Sludge, SW=Surface Water, WW=Wastewater

Comments:

Sampled By: Jim Gawel
Date: 2/19/15
Time: 10:35am

Received By:
Date:
Time:

Relinquished to Aquatic By (Signature):
Date:
Time:

Shipped By:

Shipping Reference:

Received at Aquatic By:
Date: 2/20/15
Time: 9:00

IEH ANALYTICAL LABORATORIES

LABORATORY & CONSULTING SERVICES
3927 AURORA AVENUE NORTH, SEATTLE, WA 98103
PHONE: (206) 632-2715 FAX: (206) 632-2417

CASE FILE NUMBER: MIS035-60 **PAGE 1**
REPORT DATE: 03/03/15
DATE SAMPLED: 02/19/15 **DATE RECEIVED:** 02/20/15

FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM GAWEL - UWT

CASE NARRATIVE

Eight water samples were received by the laboratory in good condition and analyzed according to the chain of custody. No difficulties were encountered in the preparation or analysis of these samples. Sample data follows while QA/QC data is contained on the subsequent page.

SAMPLE DATA

SAMPLE ID	TOTAL-P (mg/L)	SRP (mg/L)	TOTAL-N (mg/L)
LW1 SURFACE A	0.172	0.014	2.10
LW1 SURFACE B	0.133	0.020	2.35
LW1 BOTTOM	0.137	0.016	1.94
GW-1	0.009	0.004	1.73
GW-2	0.015	<0.001	3.82
GW-3	0.048	0.002	0.682
GW-4	0.004	<0.001	29.2
GW-5	0.022	0.008	0.660

CASE FILE NUMBER: **MIS035-60** **PAGE 2**
REPORT DATE: **03/03/15**
DATE SAMPLED: **02/19/15** **DATE RECEIVED:** **02/20/15**
FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM GAWEL - UWT

QA/QC DATA

QC PARAMETER	TOTAL-P (mg/L)	SRP (mg/L)	TOTAL-N (mg/L)
METHOD	SM18 4500PF	SM18 4500PF	SM204500NC
DATE ANALYZED	03/02/15	02/20/15	02/24/15
REPORTING LIMIT	0.002	0.001	0.050
DUPLICATE			
SAMPLE ID	GW-5	GW-5	GW-5
ORIGINAL	0.022	0.008	0.660
DUPLICATE	0.023	0.008	0.629
RPD	4.81%	5.42%	4.76%
SPIKE SAMPLE			
SAMPLE ID	GW-5	GW-5	GW-5
ORIGINAL	0.022	0.008	0.660
SPIKED SAMPLE	0.073	0.028	1.73
SPIKE ADDED	0.050	0.020	1.00
% RECOVERY	102.33%	99.04%	107.27%
QC CHECK			
FOUND	0.098	0.039	0.490
TRUE	0.094	0.039	0.490
% RECOVERY	104.26%	100.00%	100.00%
BLANK	<0.002	<0.001	<0.050

RPD = RELATIVE PERCENT DIFFERENCE.
NA = NOT APPLICABLE OR NOT AVAILABLE.
NC = NOT CALCULABLE DUE TO ONE OR MORE VALUES BEING BELOW THE DETECTION LIMIT.
OR = RECOVERY NOT CALCULABLE DUE TO SPIKE SAMPLE OUT OF RANGE OR SPIKE TOO LOW RELATIVE TO SAMPLE CONCENTRATION.

SUBMITTED BY:

Damien Gadomski

Damien Gadomski
Project Manager

MIS035-83

IEH - Aquatic Research
3927 Aurora Ave N • Seattle • WA • 98103
P: 206-632-2715 F: 206-632-2417

Chain of Custody Form

Page 1 of 1

REPORT TO:
Client: University of Washington Tacoma
Address: 1900 Commerce St.
Campus Box 358436, Tacoma, WA 98402
Contact: James Gawel
Email: jimgawel@uw.edu
Phone: 253-692-5815 Fax:

INVOICE TO: (IF DIFFERENT FROM REPORT)
Client: Brown and Caldwell
Address:
Seattle, WA
Contact: Sharonne Park
Email: spark@BrwnCald.com
Phone: 206.749.2892 Fax:

PROJECT INFORMATION
Quote No.:
Client PO:
Client Project:

Reporting/Invoicing Format
☐ Fax ☑ Email ☐ Mail

QC Data Reported
☑ Yes ☐ No

Sample Disposal
☐ Hold ☑ Dispose ☐ Return

Turn Around Time (TAT)*
☐ Next Day ☐ 2 Business Day
☐ 3 Business Day ☑ Standard

Specific Date:
*Advanced notice required for Rush Analysis

SAMPLING			SAMPLE DESCRIPTION		Analysis Requested															LAB USE ONLY Case File Number		
Date (mm-dd-yy)	Time	Matrix**	(This Will Appear On The Report)	Number of Containers	TP	TN	SRP										Field pH (if applicable)	Field Temp (if applicable)	Metals Field Filtered (Y/N)	Containers Received	Temp	Lab ID
03-12-15	10:25am	SW	LW1 top	1																1	7.3°C	
03-12-15			LW1 bottom A	1																1		
03-12-15			LW1 vottom B	1																1		
																					(S) 10A	

**Matrix: B=Biota, DW=Drinking Water, GW=Ground Water, P=Paint, S=Soil, SD=Sediment, SL=Sludge, SW=Surface Water, WW=Wastewater

Comments:

	Date	Time
Sampled By Jim Gawel	3/12/15 ~~1:08~~	1:08 pm
Received By		
Relinquished to Aquatic By (Signature)		

Shipped By
Shipping Reference

Received at Aquatic By	Date	Time
	3/12/15	4:25

IEH ANALYTICAL LABORATORIES

LABORATORY & CONSULTING SERVICES

3927 AURORA AVENUE NORTH, SEATTLE, WA 98103

PHONE: (206) 632-2715 FAX: (206) 632-2417

CASE FILE NUMBER: **MIS035-83** **PAGE 1**
REPORT DATE: **04/01/15**
DATE SAMPLED: **03/12/15** **DATE RECEIVED:** **03/12/15**
FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM GAWEL - UWT

CASE NARRATIVE

Three water samples were received by the laboratory in good condition and analyzed according to the chain of custody. No difficulties were encountered in the preparation or analysis of these samples. Sample data follows while QA/QC data is contained on the subsequent page.

SAMPLE DATA

SAMPLE ID	TOTAL-P (mg/L)	SRP (mg/L)	TOTAL-N (mg/L)
LW1 TOP	0.106	0.006	2.16
LW1 BOTTOM A	0.086	0.006	1.96
LW1 BOTTOM B	0.084	0.006	2.57

CASE FILE NUMBER: MIS035-83 **PAGE 2**
REPORT DATE: 04/01/15
DATE SAMPLED: 03/12/15 **DATE RECEIVED:** 03/12/15
FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM GAWEL - UWT

QA/QC DATA

QC PARAMETER	TOTAL-P (mg/L)	SRP (mg/L)	TOTAL-N (mg/L)
METHOD	EPA 365.1	EPA 365.1	SM204500NC
DATE ANALYZED	03/24/15	03/13/15	03/20/15
REPORTING LIMIT	0.002	0.001	0.050
DUPLICATE			
SAMPLE ID	BATCH	LW1 BOTTOM B	BATCH
ORIGINAL	0.045	0.006	0.984
DUPLICATE	0.044	0.006	0.931
RPD	1.19%	0.11%	5.44%
SPIKE SAMPLE			
SAMPLE ID	BATCH	LW1 BOTTOM B	BATCH
ORIGINAL	0.045	0.006	0.984
SPIKED SAMPLE	0.099	0.027	1.94
SPIKE ADDED	0.050	0.020	1.00
% RECOVERY	109.46%	104.62%	95.52%
QC CHECK			
FOUND	0.099	0.039	0.486
TRUE	0.094	0.039	0.490
% RECOVERY	105.32%	100.00%	99.09%
BLANK	<0.002	<0.001	<0.050

RPD = RELATIVE PERCENT DIFFERENCE.
NA = NOT APPLICABLE OR NOT AVAILABLE.
NC = NOT CALCULABLE DUE TO ONE OR MORE VALUES BEING BELOW THE DETECTION LIMIT.
OR = RECOVERY NOT CALCULABLE DUE TO SPIKE SAMPLE OUT OF RANGE OR SPIKE TOO LOW RELATIVE TO SAMPLE CONCENTRATION.

SUBMITTED BY:

Damien Gadomski

Damien Gadomski
Project Manager

MIS036-27

IEH - Aquatic Research
3927 Aurora Ave N • Seattle • WA • 98103
P: 206-632-2715 F: 206-632-2417

Chain of Custody Form

Page 1 of 1

REPORT TO:
Client: University of Washington Tacoma
Address: 1900 Commerce St.
Campus Box 358436, Tacoma, WA 98402
Contact: James Gawel
Email: jimgawel@uw.edu
Phone: 253-692-5815 Fax:

INVOICE TO: (IF DIFFERENT FROM REPORT)
Client: Brown and Caldwell
Address:
Seattle, WA
Contact: Sharonne Park
Email: spark@BrwnCald.com
Phone: 206.749.2892 Fax:

PROJECT INFORMATION
Quote No.:
Client PO:
Client Project:

Reporting/Invoicing Format
☐ Fax ☒ Email ☐ Mail

QC Data Reported
☒ Yes ☐ No

Sample Disposal
☐ Hold ☒ Dispose ☐ Return

Turn Around Time (TAT)*
☐ Next Day ☐ 2 Business Day
☐ 3 Business Day ☒ Standard

Specific Date:
*Advanced notice required for Rush Analysis

LAB USE ONLY
Case File Number

SAMPLING Date (mm-dd-yy)	SAMPLING Time	SAMPLING Matrix**	SAMPLE DESCRIPTION (This Will Appear On The Report)	Number of Containers	TP	TN	SRP	Field pH (if applicable)	Field Temp (if applicable)	Metals Field Filtered (Y/N)	Containers Received	Temp	Lab ID
04-22-15	11:15	SW	Waughop Surf A	1	1	1	1				1	2.9°C	
04-22-15	11:15	SW	Waughop Surf B	1	1	1	1						
04-22-15	11:20	SW	Waughop Bottom	1	1	1	1						
												(3)	

**Matrix: B=Biota, DW=Drinking Water, GW=Ground Water, P=Paint, S=Soil, SD=Sediment, SL=Sludge, SW=Surface Water, WW=Wastewater

Comments:

	Date	Time
Sampled By Jim Gawel	04-22-15	1:03 pm
Received By		
Relinquished to Aquatic By (Signature)		

Shipped By:
Shipping Reference
Received at Aquatic By:
Date 4/22/15 Time 4:00

IEH ANALYTICAL LABORATORIES

LABORATORY & CONSULTING SERVICES

3927 AURORA AVENUE NORTH, SEATTLE, WA 98103

PHONE: (206) 632-2715 FAX: (206) 632-2417

CASE FILE NUMBER: **MIS036-27** **PAGE 1**
REPORT DATE: **05/05/15**
DATE SAMPLED: **04/22/15** **DATE RECEIVED:** **04/22/15**

FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM GAWEL - UWT

CASE NARRATIVE

Three water samples were received by the laboratory in good condition and analyzed according to the chain of custody. No difficulties were encountered in the preparation or analysis of these samples. Sample data follows while QA/QC data is contained on the subsequent page.

SAMPLE DATA

SAMPLE ID	TOTAL-P (mg/L)	SRP (mg/L)	TOTAL-N (mg/L)
WAUGHOP SUFT A	0.081	0.003	1.18
WAUGHOP SURF B	0.069	0.002	1.19
WAUGHOP BOTTOM	0.056	0.002	1.16

CASE FILE NUMBER: **MIS036-27** **PAGE 2**
REPORT DATE: **05/05/15**
DATE SAMPLED: **04/22/15** **DATE RECEIVED:** **04/22/15**
FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM GAWEL - UWT

QA/QC DATA

QC PARAMETER	TOTAL-P (mg/L)	SRP (mg/L)	TOTAL-N (mg/L)
METHOD	EPA 365.1	EPA 365.1	SM204500NC
DATE ANALYZED	05/04/15	04/23/15	05/01/15
REPORTING LIMIT	0.002	0.001	0.050
DUPLICATE			
SAMPLE ID	BATCH	BATCH	BATCH
ORIGINAL	0.035	0.078	0.309
DUPLICATE	0.035	0.078	0.321
RPD	0.52%	0.33%	4.02%
SPIKE SAMPLE			
SAMPLE ID	BATCH	BATCH	BATCH
ORIGINAL	0.035	0.078	0.309
SPIKED SAMPLE	0.087	0.097	1.45
SPIKE ADDED	0.050	0.020	1.00
% RECOVERY	103.39%	97.04%	114.52%
QC CHECK			
FOUND	0.095	0.039	0.513
TRUE	0.094	0.039	0.490
% RECOVERY	101.06%	100.00%	104.69%
BLANK	<0.002	<0.001	<0.050

RPD = RELATIVE PERCENT DIFFERENCE.
NA = NOT APPLICABLE OR NOT AVAILABLE.
NC = NOT CALCULABLE DUE TO ONE OR MORE VALUES BEING BELOW THE DETECTION LIMIT.
OR = RECOVERY NOT CALCULABLE DUE TO SPIKE SAMPLE OUT OF RANGE OR SPIKE TOO LOW RELATIVE TO SAMPLE CONCENTRATION.

SUBMITTED BY:

Damien Gadomski

Damien Gadomski
Project Manager

IEH - Aquatic Research
3927 Aurora Ave N • Seattle • WA • 98103
P: 206-632-2715 F: 206-632-2417

Chain of Custody Form

M15036-52

Page 1 of 1

REPORT TO:
Client: University of Washington Tacoma
Address: 1900 Commerce St.
Campus Box 358436, Tacoma, WA 98402
Contact: James Gawel
Email: jimgawel@uw.edu
Phone: 253-692-5815 Fax: 253-692-4639

INVOICE TO: (IF DIFFERENT FROM REPORT)
Client: Brown and Caldwell
Address:
Seattle, WA
Contact: Sharonne Park
Email: spark@BrwnCald.com
Phone: 206.749.2892 Fax:

PROJECT INFORMATION
Quote No.:
Client PO:
Client Project:

Reporting/Invoicing Format
☐ Fax ☑ Email ☐ Mail

QC Data Reported
☑ Yes ☐ No

Sample Disposal
☐ Hold ☑ Dispose ☐ Return

Turn Around Time (TAT)*
☐ Next Day ☐ 2 Business Day
☐ 3 Business Day ☑ Standard

Specific Date:
*Advanced notice required for Rush Analysis

LAB USE ONLY
Case File Number

SAMPLING			SAMPLE DESCRIPTION		Analysis Requested							LAB USE ONLY	
Date (mm-dd-yy)	Time	Matrix**	(This Will Appear On The Report)	Number of Containers	TP	TN	SRP	Field pH (if applicable)	Field Temp (if applicable)	Metals Field Filtered (Y/N)	Containers Received	Temp	Lab ID
5/13/15	10:40	SW	Surf LW-1 Waughop	1	|	|	|				1	7.7°C	
5/13/15	11:00	SW	Bottom-A Waughop	1	|	|	|				|	|	
5/13/15	11:00	SW	Bottom-B Waughop	1	|	|	|				|	|	
												(3)	

**Matrix: B=Biota, DW=Drinking Water, GW=Ground Water, P=Paint, S=Soil, SD=Sediment, SL=Sludge, SW=Surface Water, WW=Wastewater

Comments:

Sampled By	Date	Time
Jim Gawel	5/13/15	12:42 pm
Received By	Date	Time
Relinquished to Aquatic By (Signature)	Date	Time

Shipped By	Shipping Reference

Received at Aquatic By	Date	Time
	5/13/15	3:00

IEH ANALYTICAL LABORATORIES

LABORATORY & CONSULTING SERVICES
3927 AURORA AVENUE NORTH, SEATTLE, WA 98103
PHONE: (206) 632-2715 FAX: (206) 632-2417

CASE FILE NUMBER: MIS036-52 **PAGE 1**
REPORT DATE: 05/26/15
DATE SAMPLED: 05/13/15 **DATE RECEIVED:** 05/13/15
FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM GAWEL - UWT

CASE NARRATIVE

Three water samples were received by the laboratory in good condition and analyzed according to the chain of custody. No difficulties were encountered in the preparation or analysis of these samples. Sample data follows while QA/QC data is contained on the subsequent page.

SAMPLE DATA

SAMPLE ID	TOTAL-P (mg/L)	SRP (mg/L)	TOTAL-N (mg/L)
SURF LW-1 WAUGHOP	0.077	0.003	1.51
BOTTOM-A WAUGHOP	0.079	0.003	1.61
BOTTOM-B WAUGHOP	0.078	0.003	1.80

CASE FILE NUMBER: MIS036-52 **PAGE 2**
REPORT DATE: 05/26/15
DATE SAMPLED: 05/13/15 **DATE RECEIVED:** 05/13/15
FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM GAWEL - UWT

QA/QC DATA

QC PARAMETER	TOTAL-P (mg/L)	SRP (mg/L)	TOTAL-N (mg/L)
METHOD	SM18 4500PF	SM18 4500PF	SM204500NC
DATE ANALYZED	05/18/15	05/15/15	05/20/15
REPORTING LIMIT	0.002	0.001	0.050
DUPLICATE			
SAMPLE ID	BATCH	BATCH	BATCH
ORIGINAL	0.036	0.010	0.661
DUPLICATE	0.037	0.009	0.695
RPD	3.97%	2.99%	4.94%
SPIKE SAMPLE			
SAMPLE ID	BATCH	BATCH	BATCH
ORIGINAL	0.036	0.010	0.661
SPIKED SAMPLE	0.087	0.030	1.81
SPIKE ADDED	0.050	0.020	1.00
% RECOVERY	101.21%	102.84%	115.07%
QC CHECK			
FOUND	0.100	0.040	0.496
TRUE	0.094	0.039	0.490
% RECOVERY	106.38%	102.56%	101.22%
BLANK	<0.002	<0.001	<0.050

RPD = RELATIVE PERCENT DIFFERENCE.
NA = NOT APPLICABLE OR NOT AVAILABLE.
NC = NOT CALCULABLE DUE TO ONE OR MORE VALUES BEING BELOW THE DETECTION LIMIT.
OR = RECOVERY NOT CALCULABLE DUE TO SPIKE SAMPLE OUT OF RANGE OR SPIKE TOO LOW RELATIVE TO SAMPLE CONCENTRATION.

SUBMITTED BY:

Damien Gadomski

Damien Gadomski
Project Manager

MIS036-71

IEH - Aquatic Research
3927 Aurora Ave N • Seattle • WA • 98103
P: 206-632-2715 F: 206-632-2417

Chain of Custody Form

Page 1 of 1

REPORT TO:
Client: University of Washington Tacoma
Address: 1900 Commerce St.
Campus Box 358436, Tacoma, WA 98402
Contact: James Gawel
Email: jimgawel@uw.edu
Phone: 253-692-5815 Fax:

INVOICE TO: (IF DIFFERENT FROM REPORT)
Client: Brown and Caldwell
Address:
Seattle, WA
Contact: Sharonne Park
Email: spark@BrwnCald.com
Phone: 206.749.2892 Fax:

PROJECT INFORMATION
Quote No.:
Client PO:
Client Project:

Reporting/Invoicing Format
☐ Fax ☒ Email ☐ Mail

QC Data Reported
☒ Yes ☐ No

Sample Disposal
☐ Hold ☒ Dispose ☐ Return

Turn Around Time (TAT)*
☐ Next Day ☐ 2 Business Day
☐ 3 Business Day ☒ Standard

Specific Date:

*Advanced notice required for Rush Analysis

SAMPLING			SAMPLE DESCRIPTION		Analysis Requested															LAB USE ONLY	
Date (mm-dd-yy)	Time	Matrix**	(This Will Appear On The Report)	Number of Containers	TP	TN	SRP										Field pH (if applicable)	Field Temp (if applicable)	Metals Field Filtered (Y/N)	Containers Received	Case File Number Temp	Lab ID
5/27/15	1:30	GW	GW-1																		4.6°C	
↓	12:50	GW	GW-2		↓	↓	↓														↓	
↓	12:00	GW	GW-3		↓	↓	↓														↓	
↓	3:20	GW	GW-4		↓	↓	↓														↓	
↓	2:36	GW	GW-5		↓	↓	↓														↓	
[redacted]	[redacted]	[redacted]	[redacted]		[redacted]	[redacted]	[redacted]														(5) 204	
[redacted]	[redacted]	[redacted]	[redacted]		[redacted]	[redacted]	[redacted]															
[redacted]	[redacted]	[redacted]	[redacted]		[redacted]	[redacted]	[redacted]															

**Matrix: B=Biota, DW=Drinking Water, GW=Ground Water, P=Paint, S=Soil, SD=Sediment, SL=Sludge, SW=Surface Water, WW=Wastewater

Comments:

Sampled By: Jim Gawel Date: 5/27/15 Time: 4:00 pm
Received By: Date: Time:
Relinquished to Aquatic By (Signature): Date: Time:

Shipped By: Shipping Reference:
Received at Aquatic By: Date: 5/28/15 Time: 11:00

IEH ANALYTICAL LABORATORIES

LABORATORY & CONSULTING SERVICES

3927 AURORA AVENUE NORTH, SEATTLE, WA 98103

PHONE: (206) 632-2715   FAX: (206) 632-2417

CASE FILE NUMBER: MIS036-71   **PAGE 1**

REPORT DATE: 06/12/15

DATE SAMPLED: 05/27/15   **DATE RECEIVED:** 05/28/15

FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM GAWEL - UWT

CASE NARRATIVE

Five water samples were received by the laboratory in good condition and analyzed according to the chain of custody. No difficulties were encountered in the preparation or analysis of these samples. Sample data follows while QA/QC data is contained on the subsequent page.

SAMPLE DATA

SAMPLE ID	TOTAL-P (mg/L)	SRP (mg/L)	TOTAL-N (mg/L)
GW-1	0.013	0.007	3.89
GW-2	0.019	0.001	0.668
GW-3	0.054	0.003	0.661
GW-4	<0.002	<0.001	13.8
GW-5	0.019	0.015	0.650

IEH ANALYTICAL LABORATORIES

LABORATORY & CONSULTING SERVICES

3927 AURORA AVENUE NORTH, SEATTLE, WA 98103

PHONE: (206) 632-2715 FAX: (206) 632-2417

CASE FILE NUMBER: **MIS036-71** **PAGE 2**
REPORT DATE: **06/12/15**
DATE SAMPLED: **05/27/15** **DATE RECEIVED:** **05/28/15**
FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM GAWEL - UWT

QA/QC DATA

QC PARAMETER	TOTAL-P (mg/L)	SRP (mg/L)	TOTAL-N (mg/L)
METHOD	SM18 4500PF	SM18 4500PF	SM204500NC
DATE ANALYZED	06/08/15	05/28/15	06/02/15
REPORTING LIMIT	0.002	0.001	0.050
DUPLICATE			
SAMPLE ID	BATCH	GW-5	GW-5
ORIGINAL	0.053	0.015	0.650
DUPLICATE	0.053	0.015	0.624
RPD	0.35%	0.82%	4.13%
SPIKE SAMPLE			
SAMPLE ID	BATCH	GW-5	GW-5
ORIGINAL	0.053	0.015	0.650
SPIKED SAMPLE	0.105	0.035	1.68
SPIKE ADDED	0.050	0.020	1.00
% RECOVERY	103.97%	101.37%	102.88%
QC CHECK			
FOUND	0.092	0.039	0.475
TRUE	0.094	0.039	0.490
% RECOVERY	97.87%	100.46%	96.95%
BLANK	<0.002	<0.001	<0.050

RPD = RELATIVE PERCENT DIFFERENCE.
NA = NOT APPLICABLE OR NOT AVAILABLE.
NC = NOT CALCULABLE DUE TO ONE OR MORE VALUES BEING BELOW THE DETECTION LIMIT.
OR = RECOVERY NOT CALCULABLE DUE TO SPIKE SAMPLE OUT OF RANGE OR SPIKE TOO LOW RELATIVE TO SAMPLE CONCENTRATION.

SUBMITTED BY:

Damien Gadomski

Damien Gadomski
Project Manager

M15036-88

IEH - Aquatic Research
3927 Aurora Ave N • Seattle • WA • 98103
P: 206-632-2715 F: 206-632-2417

Chain of Custody Form

Page 1 of 1

REPORT TO:
Client: University of Washington Tacoma
Address: 1900 Commerce St.
Campus Box 358436, Tacoma, WA 98402
Contact: James Gawel
Email: jimgawel@uw.edu
Phone: 253-692-5815 Fax:

INVOICE TO: (IF DIFFERENT FROM REPORT)
Client: Brown and Caldwell
Address:
Seattle, WA
Contact: Sharonne Park
Email: spark@BrwnCald.com
Phone: 206.749.2892 Fax:

PROJECT INFORMATION
Quote No.:
Client PO:
Client Project:

Reporting/Invoicing Format
☐ Fax ☑ Email ☐ Mail

QC Data Reported
☑ Yes ☐ No

Sample Disposal
☐ Hold ☑ Dispose ☐ Return

Turn Around Time (TAT)*
☐ Next Day ☐ 2 Business Day
☐ 3 Business Day ☑ Standard

Specific Date:

*Advanced notice required for Rush Analysis

SAMPLING			SAMPLE DESCRIPTION		Analysis Requested															LAB USE ONLY		
Date (mm-dd-yy)	Time	Matrix**	(This Will Appear On The Report)	Number of Containers	TP	TN	SRP										Field pH (if applicable)	Field Temp (if applicable)	Metals Field Filtered (Y/N)	Containers Received	Temp	Lab ID
6/9/15	~~11:30~~ 11:33	SW	Surface Waughop	1	/	/	/															
↓	11:35	SW	BottomA Waughop	1	/	/	/															
↓	11:35	SW	Bottom dup-B Waughop	1	/	/	/															

Case File Number

**Matrix: B=Biota, DW=Drinking Water, GW=Ground Water, P=Paint, S=Soil, SD=Sediment, SL=Sludge, SW=Surface Water, WW=Wastewater

Sampled By Jim Gawel	Date 6/9/15	Time 1:14
Received By	Date	Time
Relinquished to Aquatic By (Signature)	Date	Time

Comments:

Shipped By	Shipping Reference	
Received at Aquatic By (8) total	Date 6/9/15	Time 5pm

IEH ANALYTICAL LABORATORIES

LABORATORY & CONSULTING SERVICES

3927 AURORA AVENUE NORTH, SEATTLE, WA 98103

PHONE: (206) 632-2715 FAX: (206) 632-2417

CASE FILE NUMBER: **MIS036-88** **PAGE 1**

REPORT DATE: **06/25/15**

DATE SAMPLED: **06/09/15** **DATE RECEIVED:** **06/09/15**

FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM GAWEL - UWT

CASE NARRATIVE

Three water samples were received by the laboratory in good condition and analyzed according to the chain of custody. No difficulties were encountered in the preparation or analysis of these samples. Sample data follows while QA/QC data is contained on the subsequent page.

SAMPLE DATA

SAMPLE ID	TOTAL-P (mg/L)	SRP (mg/L)	TOTAL-N (mg/L)
SURFACE WAUGHOP	0.050	0.001	2.02
BOTTOM A WAUGHOP	0.117	0.001	1.69
BOTTOM DUP-B WAUGHOP	0.116	0.002	1.96

IEH ANALYTICAL LABORATORIES

LABORATORY & CONSULTING SERVICES

3927 AURORA AVENUE NORTH, SEATTLE, WA 98103
PHONE: (206) 632-2715 FAX: (206) 632-2417

CASE FILE NUMBER: **MIS036-88** **PAGE 2**
REPORT DATE: **06/25/15**
DATE SAMPLED: **06/09/15** **DATE RECEIVED:** **06/09/15**
FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM GAWEL - UWT

QA/QC DATA

QC PARAMETER	TOTAL-P (mg/L)	SRP (mg/L)	TOTAL-N (mg/L)
METHOD	SM18 4500PF	SM18 4500PF	SM204500NC
DATE ANALYZED	06/15/15	06/10/15	06/16/15
REPORTING LIMIT	0.002	0.001	0.050
DUPLICATE			
SAMPLE ID	BATCH	BATCH	BATCH
ORIGINAL	0.043	0.037	0.670
DUPLICATE	0.042	0.036	0.649
RPD	2.83%	3.33%	3.15%
SPIKE SAMPLE			
SAMPLE ID	BATCH	BATCH	BATCH
ORIGINAL	0.043	0.037	0.670
SPIKED SAMPLE	0.096	0.057	1.59
SPIKE ADDED	0.050	0.020	1.00
% RECOVERY	106.01%	99.02%	91.63%
QC CHECK			
FOUND	0.093	0.040	0.494
TRUE	0.094	0.039	0.490
% RECOVERY	98.94%	103.50%	100.82%
BLANK	<0.002	<0.001	<0.050

RPD = RELATIVE PERCENT DIFFERENCE.
NA = NOT APPLICABLE OR NOT AVAILABLE.
NC = NOT CALCULABLE DUE TO ONE OR MORE VALUES BEING BELOW THE DETECTION LIMIT.
OR = RECOVERY NOT CALCULABLE DUE TO SPIKE SAMPLE OUT OF RANGE OR SPIKE TOO LOW RELATIVE TO SAMPLE CONCENTRATION.

SUBMITTED BY:

Damien Gadomski

Damien Gadomski
Project Manager

M15036-98

IEH - Aquatic Research
3927 Aurora Ave N • Seattle • WA • 98103
P: 206-632-2715 F: 206-632-2417

Chain of Custody Form

Page 1 of 1

REPORT TO:
Client: University of Washington Tacoma
Address: 1900 Commerce St.
Campus Box 358436, Tacoma, WA 98402
Contact: James Gawel
Email: jimgawel@uw.edu
Phone: 253-692-5815 Fax:

INVOICE TO: (IF DIFFERENT FROM REPORT)
Client: Brown and Caldwell
Address:
Seattle, WA
Contact: Sharonne Park
Email: spark@BrwnCald.com
Phone: 206.749.2892 Fax:

PROJECT INFORMATION
Quote No.:
Client PO:
Client Project:

Reporting/Invoicing Format
☐ Fax ☒ Email ☐ Mail

QC Data Reported
☒ Yes ☐ No

Sample Disposal
☐ Hold ☒ Dispose ☐ Return

Turn Around Time (TAT)*
☐ Next Day ☐ 2 Business Day
☐ 3 Business Day ☒ Standard

Specific Date:

*Advanced notice required for Rush Analysis

LAB USE ONLY
Case File Number

SAMPLING Date (mm-dd-yy)	Time	Matrix**	SAMPLE DESCRIPTION (This Will Appear On The Report)	Number of Containers	TP	TN	SRP										Field pH (if applicable)	Field Temp (if applicable)	Metals Field Filtered (Y/N)	Containers Received	Temp	Lab ID
06-23-15	10:03	SW	WAUGHOP SURF-A	1	↓	↓	↓															
↓	10:03	↓	WAUGHOP SURF-B	1																		
	10:07		WAUGHOP BOTTOM	1																		

**Matrix: B=Biota, DW=Drinking Water, GW=Ground Water, P=Paint, S=Soil, SD=Sediment, SL=Sludge, SW=Surface Water, WW=Wastewater

Comments:

Sampled By	Date	Time
Jim Gawel	6/23/15	11:43 am
Received By	Date	Time
Relinquished to Aquatic By (Signature)	Date	Time

Shipped By

Shipping Reference

Received at Aquatic By	Date	Time
	6/23/15	5:30 pm

(3) total 7.8 °c

IEH ANALYTICAL LABORATORIES

LABORATORY & CONSULTING SERVICES

3927 AURORA AVENUE NORTH, SEATTLE, WA 98103

PHONE: (206) 632-2715   FAX: (206) 632-2417

CASE FILE NUMBER: **MIS036-98** **PAGE 1**

REPORT DATE: **07/03/15**

DATE SAMPLED: **06/23/15** **DATE RECEIVED:** **06/23/15**

FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM GAWEL - UWT

CASE NARRATIVE

Three water samples were received by the laboratory in good condition and analyzed according to the chain of custody. No difficulties were encountered in the preparation or analysis of these samples. Sample data follows while QA/QC data is contained on the subsequent page.

SAMPLE DATA

SAMPLE ID	TOTAL-P (mg/L)	SRP (mg/L)	TOTAL-N (mg/L)
WAUGHOP SURF-A	0.053	0.003	1.46
WAUGHOP SURF-B	0.056	0.002	1.25
WAUGHOP BOTTOM	0.100	0.005	1.63

IEH ANALYTICAL LABORATORIES

LABORATORY & CONSULTING SERVICES
3927 AURORA AVENUE NORTH, SEATTLE, WA 98103
PHONE: (206) 632-2715 FAX: (206) 632-2417

CASE FILE NUMBER: **MIS036-98** **PAGE 2**
REPORT DATE: **07/03/15**
DATE SAMPLED: **06/23/15** **DATE RECEIVED:** **06/23/15**

FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM GAWEL - UWT

QA/QC DATA

QC PARAMETER	TOTAL-P (mg/L)	SRP (mg/L)	TOTAL-N (mg/L)
METHOD	SM18 4500PF	SM18 4500PF	SM204500NC
DATE ANALYZED	06/27/15	06/24/15	06/28/15
REPORTING LIMIT	0.002	0.001	0.050
DUPLICATE			
SAMPLE ID	BATCH	BATCH	BATCH
ORIGINAL	0.050	0.013	0.329
DUPLICATE	0.046	0.012	0.328
RPD	7.35%	3.98%	0.45%
SPIKE SAMPLE			
SAMPLE ID	BATCH	BATCH	BATCH
ORIGINAL	0.050	0.013	0.329
SPIKED SAMPLE	0.099	0.033	1.44
SPIKE ADDED	0.050	0.020	1.00
% RECOVERY	97.91%	98.05%	110.99%
QC CHECK			
FOUND	0.096	0.039	0.480
TRUE	0.094	0.039	0.490
% RECOVERY	102.13%	100.00%	97.93%
BLANK	<0.002	<0.001	<0.050

RPD = RELATIVE PERCENT DIFFERENCE.
NA = NOT APPLICABLE OR NOT AVAILABLE.
NC = NOT CALCULABLE DUE TO ONE OR MORE VALUES BEING BELOW THE DETECTION LIMIT.
OR = RECOVERY NOT CALCULABLE DUE TO SPIKE SAMPLE OUT OF RANGE OR SPIKE TOO LOW RELATIVE TO SAMPLE CONCENTRATION.

SUBMITTED BY:

Damien Gadomski

Damien Gadomski
Project Manager

IEH - Aquatic Research
3927 Aurora Ave N • Seattle • WA • 98103
P: 206-632-2715 F: 206-632-2417

Chain of Custody Form

MIS037-14

Page 1 of 1

REPORT TO:
Client: University of Washington Tacoma
Address: 1900 Commerce St.
Campus Box 358436, Tacoma, WA 98402
Contact: James Gawel
Email: jimgawel@uw.edu
Phone: 253-692-5815 Fax:

INVOICE TO: (IF DIFFERENT FROM REPORT)
Client: Brown and Caldwell
Address:
Seattle, WA
Contact: Sharonne Park
Email: spark@BrwnCald.com
Phone: 206.749.2892 Fax:

PROJECT INFORMATION
Quote No.:
Client PO:
Client Project:

Reporting/Invoicing Format
☐ Fax ☒ Email ☐ Mail

QC Data Reported
☒ Yes ☐ No

Sample Disposal
☐ Hold ☒ Dispose ☐ Return

Turn Around Time (TAT)*
☐ Next Day ☐ 2 Business Day
☐ 3 Business Day ☒ Standard

Specific Date:
*Advanced notice required for Rush Analysis

LAB USE ONLY
Case File Number:

SAMPLING Date (mm-dd-yy)	SAMPLING Time	SAMPLING Matrix**	SAMPLE DESCRIPTION (This Will Appear On The Report)	Number of Containers	TP	TN	SRP									Field pH (if applicable)	Field Temp (if applicable)	Metals Field Filtered (Y/N)	Containers Received	Temp	Lab ID
07-06-15	1:35	SW	WAUGHOP -SURF	1	↓	↓	↓														
↓	1:46	↓	WAUGHOP - BOTT	1	↓	↓	↓														
↓	1:46	↓	WAUGHOP-BOTT DUP	1	↓	↓	↓														

**Matrix: B=Biota, DW=Drinking Water, GW=Ground Water, P=Paint, S=Soil, SD=Sediment, SL=Sludge, SW=Surface Water, WW=Wastewater

Comments:

Sampled By Jim Gawel	Date 7/6/15	Time 3:43pm
Received By	Date	Time
Relinquished to Aquatic By (Signature)	Date	Time

Shipped By:
Shipping Reference:
Received at Aquatic By: [illegible] Date: 7/7/15 Time: 10:30

(3) total

IEH ANALYTICAL LABORATORIES
LABORATORY & CONSULTING SERVICES
3927 AURORA AVENUE NORTH, SEATTLE, WA 98103
PHONE: (206) 632-2715 FAX: (206) 632-2417

CASE FILE NUMBER: **MIS037-14** **PAGE 1**
REPORT DATE: **07/27/15**
DATE SAMPLED: **07/06/15** **DATE RECEIVED:** **07/07/15**
FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM GAWEL - UWT

CASE NARRATIVE

Three water samples were received by the laboratory in good condition and analyzed according to the chain of custody. No difficulties were encountered in the preparation or analysis of these samples. Sample data follows while QA/QC data is contained on the subsequent page.

SAMPLE DATA

SAMPLE ID	TOTAL-P (mg/L)	SRP (mg/L)	TOTAL-N (mg/L)
WAUGHOP-SURF	0.034	0.002	0.986
WAUGHOP-BOTT	0.048	0.002	1.04
WAUGHOP-BOTT DUP	0.047	0.002	0.958

CASE FILE NUMBER: **MIS037-14** **PAGE 2**
REPORT DATE: **07/27/15**
DATE SAMPLED: **07/06/15** **DATE RECEIVED:** **07/07/15**
FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM GAWEL - UWT

QA/QC DATA

QC PARAMETER	TOTAL-P (mg/L)	SRP (mg/L)	TOTAL-N (mg/L)
METHOD	SM18 4500PF	SM18 4500PF	SM204500NC
DATE ANALYZED	07/20/15	07/08/15	07/27/15
REPORTING LIMIT	0.002	0.001	0.050
DUPLICATE			
SAMPLE ID	BATCH	BATCH	BATCH
ORIGINAL	0.009	<0.001	0.082
DUPLICATE	0.008	<0.001	0.096
RPD	11.50%	NC	15.44%
SPIKE SAMPLE			
SAMPLE ID	BATCH	BATCH	BATCH
ORIGINAL	0.009	<0.001	0.082
SPIKED SAMPLE	0.059	0.021	1.19
SPIKE ADDED	0.050	0.020	1.00
% RECOVERY	100.25%	105.00%	110.94%
QC CHECK			
FOUND	0.094	0.040	0.463
TRUE	0.094	0.039	0.490
% RECOVERY	100.00%	102.56%	94.49%
BLANK	<0.002	<0.001	<0.050

RPD = RELATIVE PERCENT DIFFERENCE.
NA = NOT APPLICABLE OR NOT AVAILABLE.
NC = NOT CALCULABLE DUE TO ONE OR MORE VALUES BEING BELOW THE DETECTION LIMIT.
OR = RECOVERY NOT CALCULABLE DUE TO SPIKE SAMPLE OUT OF RANGE OR SPIKE TOO LOW RELATIVE TO SAMPLE CONCENTRATION.

SUBMITTED BY:

Damien Gadomski

Damien Gadomski
Project Manager

MI5037-31

IEH - Aquatic Research
3927 Aurora Ave N • Seattle • WA • 98103
P: 206-632-2715 F: 206-632-2417

Chain of Custody Form

Page 1 of 1

REPORT TO:
Client: University of Washington Tacoma
Address: 1900 Commerce St.
Campus Box 358436, Tacoma, WA 98402
Contact: James Gawel
Email: jimgawel@uw.edu
Phone: 253-692-5815 Fax:

INVOICE TO: (IF DIFFERENT FROM REPORT)
Client: Brown and Caldwell
Address:
Seattle, WA
Contact: Sharonne Park
Email: spark@BrwnCald.com
Phone: 206.749.2892 Fax:

PROJECT INFORMATION
Quote No.:
Client PO:
Client Project:

Reporting/Invoicing Format
☐ Fax ☑ Email ☐ Mail

QC Data Reported
☑ Yes ☐ No

Sample Disposal
☐ Hold ☑ Dispose ☐ Return

Turn Around Time (TAT)*
☐ Next Day ☐ 2 Business Day
☐ 3 Business Day ☑ Standard

Specific Date:
*Advanced notice required for Rush Analysis

LAB USE ONLY
Case File Number

SAMPLING			SAMPLE DESCRIPTION	Number of Containers	Analysis Requested			Field pH (if applicable)	Field Temp (if applicable)	Metals Field Filtered (Y/N)	Containers Received	Temp	Lab ID
Date (mm-dd-yy)	Time	Matrix**	(This Will Appear On The Report)		TP	TN	SRP						
07-20-15	10:45	SW	WAUGHOP LW-1 surface	1	↓	↓	↓						
↓	10:50	↓	WAUGHOP LW-~~1~~ bottom-A	1	↓	↓	↓						
↓	10:50	↓	WAUGHOP LW-1 bottom-B	1	↓	↓	↓						
↓	12:15	↓	WAUGHOP BENTHIC 1	1	↓	↓	↓						

**Matrix: B=Biota, DW=Drinking Water, GW=Ground Water, P=Paint, S=Soil, SD=Sediment, SL=Sludge, SW=Surface Water, WW=Wastewater

Comments: deliver before 6pm

Sampled By	Date	Time
Jim Gawel	7/20/15	2:25pm
Received By	Date 7/21/15	Time 6:00
Relinquished to Aquatic By (Signature)	Date	Time

Shipped By
Shipping Reference
Received at Aquatic By
Date
Time

(4) total
4.3°

IEH ANALYTICAL LABORATORIES
LABORATORY & CONSULTING SERVICES
3927 AURORA AVENUE NORTH, SEATTLE, WA 98103
PHONE: (206) 632-2715 FAX: (206) 632-2417

CASE FILE NUMBER: MIS037-31 **PAGE 1**
REPORT DATE: 08/12/15
DATE SAMPLED: 07/20/15 **DATE RECEIVED:** 07/21/15
FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM GAWEL - UWT

CASE NARRATIVE

Four water samples were received by the laboratory in good condition and analyzed according to the chain of custody. No difficulties were encountered in the preparation or analysis of these samples. Sample data follows while QA/QC data is contained on the subsequent page.

SAMPLE DATA

SAMPLE ID	TOTAL-P (mg/L)	SRP (mg/L)	TOTAL-N (mg/L)
LW-1 SURFACE	0.062	0.004	1.45
LW-1 BOTTOM - A	0.100	0.001	1.60
LW-1 BOTTOM - B	0.102	<0.001	1.35
BENTH IC 1	0.090	<0.001	1.92

CASE FILE NUMBER: MIS037-31

REPORT DATE: 08/12/15

DATE SAMPLED: 07/20/15 **DATE RECEIVED:** 07/21/15

FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM GAWEL - UWT

QA/QC DATA

QC PARAMETER	TOTAL-P (mg/L)	SRP (mg/L)	TOTAL-N (mg/L)
METHOD	SM18 4500PF	SM18 4500PF	SM204500NC
DATE ANALYZED	08/08/15	07/22/15	08/04/15
REPORTING LIMIT	0.002	0.001	0.050
DUPLICATE			
SAMPLE ID	BATCH	BATCH	BATCH
ORIGINAL	0.007	<0.001	0.276
DUPLICATE	0.007	<0.001	0.283
RPD	1.81%	NC	2.40%
SPIKE SAMPLE			
SAMPLE ID	BATCH	BATCH	BATCH
ORIGINAL	0.007	<0.001	0.276
SPIKED SAMPLE	0.059	0.021	1.38
SPIKE ADDED	0.050	0.020	1.00
% RECOVERY	103.97%	105.00%	110.08%
QC CHECK			
FOUND	0.094	0.041	0.520
TRUE	0.094	0.039	0.490
% RECOVERY	100.00%	105.13%	106.12%
BLANK	<0.002	<0.001	<0.050

RPD = RELATIVE PERCENT DIFFERENCE.
NA = NOT APPLICABLE OR NOT AVAILABLE.
NC = NOT CALCULABLE DUE TO ONE OR MORE VALUES BEING BELOW THE DETECTION LIMIT.
OR = RECOVERY NOT CALCULABLE DUE TO SPIKE SAMPLE OUT OF RANGE OR SPIKE TOO LOW RELATIVE TO SAMPLE CONCENTRATION.

SUBMITTED BY:

Damien Gadomski

Damien Gadomski
Project Manager

MIS037-32

IEH - Aquatic Research
3927 Aurora Ave N • Seattle • WA • 98103
P: 206-632-2715 F: 206-632-2417

Chain of Custody Form

Page 1 of 1

REPORT TO:
Client: University of Washington Tacoma
Address: 1900 Commerce St.
Campus Box 358436, Tacoma, WA 98402
Contact: James Gawel
Email: jimgawel@uw.edu
Phone: 253-692-5815 Fax:

INVOICE TO: (IF DIFFERENT FROM REPORT)
Client: Brown and Caldwell
Address:
Seattle, WA
Contact: Sharonne Park
Email: spark@BrwnCald.com
Phone: 206.749.2892 Fax:

PROJECT INFORMATION
Quote No.:
Client PO:
Client Project:

Reporting/Invoicing Format
☐ Fax ☑ Email ☐ Mail

QC Data Reported
☑ Yes ☐ No

Sample Disposal
☐ Hold ☑ Dispose ☐ Return

Turn Around Time (TAT)*
☐ Next Day ☐ 2 Business Day
☐ 3 Business Day ☑ Standard

Specific Date:

*Advanced notice required for Rush Analysis

Analysis Requested

LAB USE ONLY
Case File Number

SAMPLING Date (mm-dd-yy)	SAMPLING Time	SAMPLING Matrix**	SAMPLE DESCRIPTION (This Will Appear On The Report)	Number of Containers	TP	TN	SRP										Field pH (if applicable)	Field Temp (if applicable)	Metals Field Filtered (Y/N)	Containers Received	Temp	Lab ID
7/21/15	1:30	SW	Benthic 1 24hr	1	↓	↓	↓															

**Matrix: B=Biota, DW=Drinking Water, GW=Ground Water, P=Paint, S=Soil, SD=Sediment, SL=Sludge, SW=Surface Water, WW=Wastewater

Sampled By: Jim Gawel
Date: 7/21/15
Time: 2:38

Received By
Date
Time

Relinquished to Aquatic By (Signature)
Date
Time

Comments:

Shipped By

Shipping Reference

Received at Aquatic By (1) total 5.6°
Date: 7/22/15
Time: 10:45

IEH ANALYTICAL LABORATORIES
LABORATORY & CONSULTING SERVICES
3927 AURORA AVENUE NORTH, SEATTLE, WA 98103
PHONE: (206) 632-2715 FAX: (206) 632-2417

CASE FILE NUMBER: MIS037-32

REPORT DATE: 08/12/15
DATE SAMPLED: 07/21/15 **DATE RECEIVED:** 07/22/15

FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM GAWEL - UWT

CASE NARRATIVE

One water sample was received by the laboratory in good condition and analyzed according to the chain of custody. No difficulties were encountered in the preparation or analysis of this sample. Sample data follows while QA/QC data is contained on the subsequent page.

SAMPLE DATA

SAMPLE ID	TOTAL-P (mg/L)	SRP (mg/L)	TOTAL-N (mg/L)
BENTHIC 1	0.146	0.003	1.94

CASE FILE NUMBER: MIS037-32 **PAGE 2**
REPORT DATE: 08/12/15
DATE SAMPLED: 07/21/15 **DATE RECEIVED:** 07/22/15

FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM GAWEL - UWT

QA/QC DATA

QC PARAMETER	TOTAL-P (mg/L)	SRP (mg/L)	TOTAL-N (mg/L)
METHOD	SM18 4500PF	SM18 4500PF	SM204500NC
DATE ANALYZED	08/08/15	07/22/15	08/04/15
REPORTING LIMIT	0.002	0.001	0.050
DUPLICATE			
SAMPLE ID	BATCH	BATCH	BATCH
ORIGINAL	0.007	<0.001	0.276
DUPLICATE	0.007	<0.001	0.283
RPD	1.81%	NC	2.40%
SPIKE SAMPLE			
SAMPLE ID	BATCH	BATCH	BATCH
ORIGINAL	0.007	<0.001	0.276
SPIKED SAMPLE	0.059	0.021	1.38
SPIKE ADDED	0.050	0.020	1.00
% RECOVERY	103.97%	105.00%	110.08%
QC CHECK			
FOUND	0.094	0.041	0.520
TRUE	0.094	0.039	0.490
% RECOVERY	100.00%	105.13%	106.12%
BLANK	<0.002	<0.001	<0.050

RPD = RELATIVE PERCENT DIFFERENCE.
NA = NOT APPLICABLE OR NOT AVAILABLE.
NC = NOT CALCULABLE DUE TO ONE OR MORE VALUES BEING BELOW THE DETECTION LIMIT.
OR = RECOVERY NOT CALCULABLE DUE TO SPIKE SAMPLE OUT OF RANGE OR SPIKE TOO LOW RELATIVE TO SAMPLE CONCENTRATION.

SUBMITTED BY:

Damien Gadomski

Damien Gadomski
Project Manager

MI5037-34

IEH - Aquatic Research
3927 Aurora Ave N • Seattle • WA • 98103
P: 206-632-2715 F: 206-632-2417

Chain of Custody Form

Page 1 of 1

REPORT TO:
Client: University of Washington Tacoma
Address: 1900 Commerce St.
Campus Box 358436, Tacoma, WA 98402
Contact: James Gawel
Email: jimgawel@uw.edu
Phone: 253-692-5815 Fax:

INVOICE TO: (IF DIFFERENT FROM REPORT)
Client: Brown and Caldwell
Address:
Seattle, WA
Contact: Sharonne Park
Email: spark@BrwnCald.com
Phone: 206.749.2892 Fax:

PROJECT INFORMATION
Quote No.:
Client PO:
Client Project:

Reporting/Invoicing Format
☐ Fax ☑ Email ☐ Mail

QC Data Reported
☑ Yes ☐ No

Sample Disposal
☐ Hold ☑ Dispose ☐ Return

Turn Around Time (TAT)*
☐ Next Day ☐ 2 Business Day
☐ 3 Business Day ☑ Standard

Specific Date:

*Advanced notice required for Rush Analysis

LAB USE ONLY
Case File Number

SAMPLING Date (mm-dd-yy)	Time	Matrix**	SAMPLE DESCRIPTION (This Will Appear On The Report)	Number of Containers	TP	TN	SRP										Field pH (if applicable)	Field Temp (if applicable)	Metals Field Filtered (Y/N)	Containers Received	Temp	Lab ID
7/22/15	2:19	SW	Benthic 1 48hr	1	1	1	1															

**Matrix: B=Biota, DW=Drinking Water, GW=Ground Water, P=Paint, S=Soil, SD=Sediment, SL=Sludge, SW=Surface Water, WW=Wastewater

Comments:

	Date	Time
Sampled By Jim Gawel	7/22/15	4:25 pm
Received By		
Relinquished to Aquatic By (Signature)		

Shipped By:
Shipping Reference:

Received at Aquatic By	Date	Time
Catherine Le 5.5°C	07/23/15	12:00

IEH ANALYTICAL LABORATORIES

LABORATORY & CONSULTING SERVICES
3927 AURORA AVENUE NORTH, SEATTLE, WA 98103
PHONE: (206) 632-2715 FAX: (206) 632-2417

CASE FILE NUMBER: **MIS037-34** **PAGE 1**
REPORT DATE: **08/12/15**
DATE SAMPLED: **07/22/15** **DATE RECEIVED:** **07/23/15**

FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM GAWEL - UWT

CASE NARRATIVE

One water sample was received by the laboratory in good condition and analyzed according to the chain of custody. No difficulties were encountered in the preparation or analysis of this sample. Sample data follows while QA/QC data is contained on the subsequent page.

SAMPLE DATA

SAMPLE ID	TOTAL-P (mg/L)	SRP (mg/L)	TOTAL-N (mg/L)
BENTHIC 1 48 HR	0.436	0.064	7.49

CASE FILE NUMBER: **MIS037-34** **PAGE 2**
REPORT DATE: **08/12/15**
DATE SAMPLED: **07/22/15** **DATE RECEIVED:** **07/23/15**
FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM GAWEL - UWT

QA/QC DATA

QC PARAMETER	TOTAL-P (mg/L)	SRP (mg/L)	TOTAL-N (mg/L)
METHOD	SM18 4500PF	SM18 4500PF	SM204500NC
DATE ANALYZED	08/08/15	07/23/15	08/11/15
REPORTING LIMIT	0.002	0.001	0.050
DUPLICATE			
SAMPLE ID	BATCH	BATCH	BATCH
ORIGINAL	0.007	0.003	0.241
DUPLICATE	0.007	0.003	0.248
RPD	1.81%	5.03%	2.98%
SPIKE SAMPLE			
SAMPLE ID	BATCH	BATCH	BATCH
ORIGINAL	0.007	0.003	0.241
SPIKED SAMPLE	0.059	0.024	1.38
SPIKE ADDED	0.050	0.020	1.00
% RECOVERY	103.97%	104.06%	113.51%
QC CHECK			
FOUND	0.094	0.040	0.476
TRUE	0.094	0.039	0.490
% RECOVERY	100.00%	102.56%	97.14%
BLANK	<0.002	<0.001	<0.050

RPD = RELATIVE PERCENT DIFFERENCE.
NA = NOT APPLICABLE OR NOT AVAILABLE.
NC = NOT CALCULABLE DUE TO ONE OR MORE VALUES BEING BELOW THE DETECTION LIMIT.
OR = RECOVERY NOT CALCULABLE DUE TO SPIKE SAMPLE OUT OF RANGE OR SPIKE TOO LOW RELATIVE TO SAMPLE CONCENTRATION.

SUBMITTED BY:

Damien Gadomski

Damien Gadomski
Project Manager

MI5037-41

IEH - Aquatic Research
3927 Aurora Ave N • Seattle • WA • 98103
P: 206-632-2715 F: 206-632-2417

Chain of Custody Form

Page 1 of 1

REPORT TO:
Client: University of Washington Tacoma
Address: 1900 Commerce St.
Campus Box 358436, Tacoma, WA 98402
Contact: James Gawel
Email: jimgawel@uw.edu
Phone: 253-692-5815 Fax:

INVOICE TO: (IF DIFFERENT FROM REPORT)
Client: Brown and Caldwell
Address:
Seattle, WA
Contact: Sharonne Park
Email: spark@BrwnCald.com
Phone: 206.749.2892 Fax:

PROJECT INFORMATION
Quote No.:
Client PO:
Client Project:

Reporting/Invoicing Format
☐ Fax ☒ Email ☐ Mail

QC Data Reported
☒ Yes ☐ No

Sample Disposal
☐ Hold ☒ Dispose ☐ Return

Turn Around Time (TAT)*
☐ Next Day ☐ 2 Business Day
☐ 3 Business Day ☒ Standard

Specific Date:
*Advanced notice required for Rush Analysis

SAMPLING			SAMPLE DESCRIPTION	Number of Containers	Analysis Requested												Field pH (if applicable)	Field Temp (if applicable)	Metals Field Filtered (Y/N)	LAB USE ONLY		
Date (mm-dd-yy)	Time	Matrix**	(This Will Appear On The Report)		TP	TN	SRP													Containers Received	Case File Number Temp	Lab ID
7/27/15	4:10	SW	Beuth 2 (2hrs)	1	│	│	│															
7/27/15	4:15	SW	Beuth 3 (2hrs)	1	│	│	│															
7/27/15	4:54	SW	Beuth 4 (2hrs)	1	│	│	│															

**Matrix: B=Biota, DW=Drinking Water, GW=Ground Water, P=Paint, S=Soil, SD=Sediment, SL=Sludge, SW=Surface Water, WW=Wastewater

	Date	Time
Sampled By Jim Gawel	7/27/15	5:52pm
Received By		
Relinquished to Aquatic By (Signature)		

Comments:

Shipped By:
Shipping Reference
Received at Aquatic By: 13.1°
Date 7/28/15
Time 15:30

IEH ANALYTICAL LABORATORIES

LABORATORY & CONSULTING SERVICES

3927 AURORA AVENUE NORTH, SEATTLE, WA 98103

PHONE: (206) 632-2715 FAX: (206) 632-2417

CASE FILE NUMBER: **MIS037-41** **PAGE 1**
REPORT DATE: **08/26/15**
DATE SAMPLED: **07/27/15** **DATE RECEIVED:** **07/28/15**
FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM GAWEL - UWT

CASE NARRATIVE

Three water samples were received by the laboratory in good condition and analyzed according to the chain of custody. No difficulties were encountered in the preparation or analysis of these samples. Sample data follows while QA/QC data is contained on the subsequent page.

SAMPLE DATA

SAMPLE ID	TOTAL-P (mg/L)	SRP (mg/L)	TOTAL-N (mg/L)
BEUTH 2 (2 HRS)	0.157	<0.001	2.29
BEUTH 3 (2 HRS)	0.114	<0.001	1.91
BEUTH 4 (2 HRS)	0.321	0.117	7.57

CASE FILE NUMBER: **MIS037-41** **PAGE 2**
REPORT DATE: **08/26/15**
DATE SAMPLED: **07/27/15** **DATE RECEIVED:** **07/28/15**
FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM GAWEL - UWT

QA/QC DATA

QC PARAMETER	TOTAL-P (mg/L)	SRP (mg/L)	TOTAL-N (mg/L)
METHOD	SM18 4500PF	SM18 4500PF	SM204500NC
DATE ANALYZED	08/17/15	07/29/15	08/11/15
REPORTING LIMIT	0.002	0.001	0.050
DUPLICATE			
SAMPLE ID	BATCH	BEUTH 4 (2 HRS)	BATCH
ORIGINAL	0.013	0.117	0.241
DUPLICATE	0.013	0.116	0.248
RPD	3.17%	0.76%	2.98%
SPIKE SAMPLE			
SAMPLE ID	BATCH	BEUTH 4 (2 HRS)	BATCH
ORIGINAL	0.013	0.117	0.241
SPIKED SAMPLE	0.066	0.136	1.38
SPIKE ADDED	0.050	0.020	1.00
% RECOVERY	105.59%	94.86%	113.51%
QC CHECK			
FOUND	0.092	0.038	0.476
TRUE	0.094	0.039	0.490
% RECOVERY	97.87%	97.44%	97.14%
BLANK	<0.002	<0.001	<0.050

RPD = RELATIVE PERCENT DIFFERENCE.
NA = NOT APPLICABLE OR NOT AVAILABLE.
NC = NOT CALCULABLE DUE TO ONE OR MORE VALUES BEING BELOW THE DETECTION LIMIT.
OR = RECOVERY NOT CALCULABLE DUE TO SPIKE SAMPLE OUT OF RANGE OR SPIKE TOO LOW RELATIVE TO SAMPLE CONCENTRATION.

SUBMITTED BY:

Damien Gadomski

Damien Gadomski
Project Manager

MIS037.42

IEH - Aquatic Research
3927 Aurora Ave N • Seattle • WA • 98103
P: 206-632-2715 F: 206-632-2417

Chain of Custody Form

Page 1 of 1

REPORT TO:
Client: University of Washington Tacoma
Address: 1900 Commerce St.
Campus Box 358436, Tacoma, WA 98402
Contact: James Gawel
Email: jimgawel@uw.edu
Phone: 253-692-5815 Fax:

INVOICE TO: (IF DIFFERENT FROM REPORT)
Client: Brown and Caldwell
Address:
Seattle, WA
Contact: Sharonne Park
Email: spark@BrwnCald.com
Phone: 206.749.2892 Fax:

PROJECT INFORMATION
Quote No.:
Client PO:
Client Project:

Reporting/Invoicing Format
☐ Fax ☑ Email ☐ Mail

QC Data Reported
☑ Yes ☐ No

Sample Disposal
☐ Hold ☑ Dispose ☐ Return

Turn Around Time (TAT)*
☐ Next Day ☐ 2 Business Day
☐ 3 Business Day ☑ Standard
Specific Date:
*Advanced notice required for Rush Analysis

LAB USE ONLY
Case File Number

SAMPLING Date (mm-dd-yy)	Time	Matrix**	SAMPLE DESCRIPTION (This Will Appear On The Report)	Number of Containers	TP	TN	SRP										Field pH (if applicable)	Field Temp (if applicable)	Metals Field Filtered (Y/N)	Containers Received	Temp	Lab ID
7/28/15	1:38	SW	Benth 2 (24hrs)	1	|	|	|															
7/28/15	1:25	SW	Benth 3 (24hrs)	1	|	|	|															
7/28/15	1:35	SW	Benth 4 (24hrs)	1	|	|	|															

**Matrix: B=Biota, DW=Drinking Water, GW=Ground Water, P=Paint, S=Soil, SD=Sediment, SL=Sludge, SW=Surface Water, WW=Wastewater

Comments:

Sampled By	Date	Time
Jim Gawel	7/28/15	3:06
Received By	Date	Time
Relinquished to Aquatic By (Signature)	Date	Time

Shipped By
Shipping Reference
Received at Aquatic By 7/29/15 11:00 (3)
Date
Time

12.8°

IEH ANALYTICAL LABORATORIES

LABORATORY & CONSULTING SERVICES

3927 AURORA AVENUE NORTH, SEATTLE, WA 98103

PHONE: (206) 632-2715 FAX: (206) 632-2417

CASE FILE NUMBER: **MIS037-42** **PAGE 1**
REPORT DATE: **08/26/15**
DATE SAMPLED: **07/28/15** **DATE RECEIVED:** **07/29/15**

FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM GAWEL - UWT

CASE NARRATIVE

Three water samples were received by the laboratory in good condition and analyzed according to the chain of custody. No difficulties were encountered in the preparation or analysis of these samples. Sample data follows while QA/QC data is contained on the subsequent page.

SAMPLE DATA

SAMPLE ID	TOTAL-P (mg/L)	SRP (mg/L)	TOTAL-N (mg/L)
BENTH 2 (24 HRS)	10.0	0.014	51.8
BENTH 3 (24 HRS)	6.24	0.024	31.4
BENTH 4 (24 HRS)	0.286	0.113	7.47

CASE FILE NUMBER: MIS037-42

REPORT DATE: 08/26/15

DATE SAMPLED: 07/28/15 **DATE RECEIVED:** 07/29/15

FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM GAWEL - UWT

QA/QC DATA

QC PARAMETER	TOTAL-P (mg/L)	SRP (mg/L)	TOTAL-N (mg/L)
METHOD	SM18 4500PF	SM18 4500PF	SM204500NC
DATE ANALYZED	08/17/15	07/29/15	08/18/15
REPORTING LIMIT	0.002	0.001	0.050
DUPLICATE			
SAMPLE ID	BATCH	BATCH	BATCH
ORIGINAL	0.013	0.117	0.076
DUPLICATE	0.013	0.116	0.073
RPD	3.17%	0.76%	3.30%
SPIKE SAMPLE			
SAMPLE ID	BATCH	BATCH	BATCH
ORIGINAL	0.013	0.117	0.076
SPIKED SAMPLE	0.066	0.136	1.03
SPIKE ADDED	0.050	0.020	1.00
% RECOVERY	105.59%	94.86%	95.72%
QC CHECK			
FOUND	0.092	0.038	0.491
TRUE	0.094	0.039	0.490
% RECOVERY	97.87%	97.44%	100.20%
BLANK	<0.002	<0.001	<0.050

RPD = RELATIVE PERCENT DIFFERENCE.
NA = NOT APPLICABLE OR NOT AVAILABLE.
NC = NOT CALCULABLE DUE TO ONE OR MORE VALUES BEING BELOW THE DETECTION LIMIT.
OR = RECOVERY NOT CALCULABLE DUE TO SPIKE SAMPLE OUT OF RANGE OR SPIKE TOO LOW RELATIVE TO SAMPLE CONCENTRATION.

SUBMITTED BY:

Damien Gadomski

Damien Gadomski
Project Manager

MIS037-44

IEH - Aquatic Research
3927 Aurora Ave N • Seattle • WA • 98103
P: 206-632-2715 F: 206-632-2417

Chain of Custody Form

Page 1 of 1

REPORT TO:
Client: University of Washington Tacoma
Address: 1900 Commerce St.
Campus Box 358436, Tacoma, WA 98402
Contact: James Gawel
Email: jimgawel@uw.edu
Phone: 253-692-5815 Fax:

INVOICE TO: (IF DIFFERENT FROM REPORT)
Client: Brown and Caldwell
Address:
Seattle, WA
Contact: Sharonne Park
Email: spark@BrwnCald.com
Phone: 206.749.2892 Fax:

PROJECT INFORMATION
Quote No.:
Client PO:
Client Project:

Reporting/Invoicing Format
☐ Fax ☑ Email ☐ Mail

QC Data Reported
☑ Yes ☐ No

Sample Disposal
☐ Hold ☑ Dispose ☐ Return

Turn Around Time (TAT)*
☐ Next Day ☐ 2 Business Day
☐ 3 Business Day ☑ Standard

Specific Date:

*Advanced notice required for Rush Analysis

LAB USE ONLY
Case File Number

SAMPLING / **SAMPLE DESCRIPTION** (This Will Appear On The Report) / **Analysis Requested**

Date (mm-dd-yy)	Time	Matrix**	Sample Description	Number of Containers	TP	TN	SRP										Field pH (if applicable)	Field Temp (if applicable)	Metals Field Filtered (Y/N)	Containers Received	Temp	Lab ID
7/29/15	1:52	SW	Benth 2 (48hrs)	1	1	1	1															
7/29/15	2:02	SW	Benth 3 (48hrs)	1	1	1	1															
7/29/15	2:18	SW	Benth 4 (48hrs)	1	1	1	1															

**Matrix: B=Biota, DW=Drinking Water, GW=Ground Water, P=Paint, S=Soil, SD=Sediment, SL=Sludge, SW=Surface Water, WW=Wastewater

Comments:

Sampled By Jim Gawel	Date 7/29/15	Time 3:38
Received By	Date	Time
Relinquished to Aquatic By (Signature)	Date	Time

Shipped By

Shipping Reference

Received at Aquatic By (3) GH1 1720

Date 7/30/15

Time 12:00

IEH ANALYTICAL LABORATORIES
LABORATORY & CONSULTING SERVICES
3927 AURORA AVENUE NORTH, SEATTLE, WA 98103
PHONE: (206) 632-2715 FAX: (206) 632-2417

CASE FILE NUMBER: **MIS037-44** **PAGE 1**
REPORT DATE: **08/26/15**
DATE SAMPLED: **07/29/15** **DATE RECEIVED:** **07/30/15**

FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM GAWEL - UWT

CASE NARRATIVE

Three water samples were received by the laboratory in good condition and analyzed according to the chain of custody. No difficulties were encountered in the preparation or analysis of these samples. Sample data follows while QA/QC data is contained on the subsequent page.

SAMPLE DATA

SAMPLE ID	TOTAL-P (mg/L)	SRP (mg/L)	TOTAL-N (mg/L)
BENTH 2 (48 HRS)	43.4	0.013	77.0
BENTH 3 (48 HRS)	17.0	0.012	0.518
BENTH 4 (48 HRS)	0.409	0.105	9.58

CASE FILE NUMBER: **MIS037-44** **PAGE 2**

REPORT DATE: **08/26/15**

DATE SAMPLED: **07/29/15** **DATE RECEIVED:** **07/30/15**

FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM GAWEL - UWT

QA/QC DATA

QC PARAMETER	TOTAL-P (mg/L)	SRP (mg/L)	TOTAL-N (mg/L)
METHOD	SM18 4500PF	SM18 4500PF	SM204500NC
DATE ANALYZED	08/22/15	07/30/15	08/18/15
REPORTING LIMIT	0.002	0.001	0.050
DUPLICATE			
SAMPLE ID	BATCH	BATCH	BATCH
ORIGINAL	0.057	<0.001	0.076
DUPLICATE	0.061	<0.001	0.073
RPD	6.11%	NC	3.30%
SPIKE SAMPLE			
SAMPLE ID	BATCH	BATCH	BATCH
ORIGINAL	0.057	<0.001	0.076
SPIKED SAMPLE	0.107	0.019	1.03
SPIKE ADDED	0.050	0.020	1.00
% RECOVERY	99.73%	95.00%	95.72%
QC CHECK			
FOUND	0.092	0.039	0.491
TRUE	0.094	0.039	0.490
% RECOVERY	97.87%	100.00%	100.20%
BLANK	<0.002	<0.001	<0.050

RPD = RELATIVE PERCENT DIFFERENCE.
NA = NOT APPLICABLE OR NOT AVAILABLE.
NC = NOT CALCULABLE DUE TO ONE OR MORE VALUES BEING BELOW THE DETECTION LIMIT.
OR = RECOVERY NOT CALCULABLE DUE TO SPIKE SAMPLE OUT OF RANGE OR SPIKE TOO LOW RELATIVE TO SAMPLE CONCENTRATION.

SUBMITTED BY:

Damien Gadomski

Damien Gadomski
Project Manager

MIS037-52

IEH - Aquatic Research
3927 Aurora Ave N • Seattle • WA • 98103
P: 206-632-2715 F: 206-632-2417

Chain of Custody Form

Page 1 of 1

REPORT TO:
Client: University of Washington Tacoma
Address: 1900 Commerce St.
Campus Box 358436, Tacoma, WA 98402
Contact: James Gawel
Email: jimgawel@uw.edu
Phone: 253-692-5815 Fax:

INVOICE TO: (IF DIFFERENT FROM REPORT)
Client: Brown and Caldwell
Address:
Seattle, WA
Contact: Sharonne Park
Email: spark@BrwnCald.com
Phone: 206.749.2892 Fax:

PROJECT INFORMATION
Quote No.:
Client PO:
Client Project:

Reporting/Invoicing Format
☐ Fax ☒ Email ☐ Mail

QC Data Reported
☒ Yes ☐ No

Sample Disposal
☐ Hold ☒ Dispose ☐ Return

Turn Around Time (TAT)*
☐ Next Day ☐ 2 Business Day
☐ 3 Business Day ☒ Standard
Specific Date:
*Advanced notice required for Rush Analysis

LAB USE ONLY
Case File Number

SAMPLING			SAMPLE DESCRIPTION		Analysis Requested																LAB USE ONLY		
Date (mm-dd-yy)	Time	Matrix**	(This Will Appear On The Report)	Number of Containers	TP	TN	SRP										Field pH (if applicable)	Field Temp (if applicable)	Metals Field Filtered (Y/N)	Containers Received	Temp	Lab ID
08-05-15	10:02	SW	WAUGHOP SURF			✓																
	10:07		WAUGHOP BOTTOM-A			✓																
	10:07		WAUGHOP BOTTOM-B			✓																
	10:07		BOTTOM TEST 1																			
	10:07	↓	BOTTOM TEST 2																			
	11:25	GW	GW-3			✓																
	1:15		GW-4			✓																
	12:48		GW-5			✓																
	12:25		GW-1			✓																
↓	11:57	↓	GW-2		↓	✓	↓															

**Matrix: B=Biota, DW=Drinking Water, GW=Ground Water, P=Paint, S=Soil, SD=Sediment, SL=Sludge, SW=Surface Water, WW=Wastewater

Comments:

Sampled By	Date	Time
Jim Gawel	8/5/15	2:11 pm
Received By	Date	Time
Relinquished to Aquatic By (Signature)	Date	Time

Shipped By
Shipping Reference 8.9°
Received at Aquatic By (10) lab
Date 8/6/15
Time 0500

IEH ANALYTICAL LABORATORIES

LABORATORY & CONSULTING SERVICES

3927 AURORA AVENUE NORTH, SEATTLE, WA 98103

PHONE: (206) 632-2715 FAX: (206) 632-2417

CASE FILE NUMBER:	**MIS037-52**		**PAGE 1**
REPORT DATE:	**09/01/15**		
DATE SAMPLED:	**08/05/15**	**DATE RECEIVED:**	**08/06/15**

FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM GAWEL - UWT

CASE NARRATIVE

Ten water samples were received by the laboratory in good condition and analyzed according to the chain of custody. No difficulties were encountered in the preparation or analysis of these samples. Sample data follows while QA/QC data is contained on the subsequent page.

SAMPLE DATA

SAMPLE ID	TOTAL-P (mg/L)	SRP (mg/L)	TOTAL-N (mg/L)
WAUGHOP SURF	0.076	<0.001	1.86
WAUGHOP BOTTOM-A	0.073	<0.001	1.85
WAUGHOP BOTTOM-B	0.075	<0.001	1.86
BOTTOM TEST 1	0.017	<0.001	▨
BOTTOM TEST 2	0.018	<0.001	▨
GW-3	0.048	0.006	1.06
GW-4	0.003	<0.001	0.163
GW-5	2.95	0.021	0.845
GW-1	0.080	0.005	6.95
GW-2	0.075	0.002	1.09

CASE FILE NUMBER: **MIS037-52** **PAGE 2**
REPORT DATE: **09/01/15**
DATE SAMPLED: **08/05/15** **DATE RECEIVED:** **08/06/15**
FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM GAWEL - UWT

QA/QC DATA

QC PARAMETER	TOTAL-P (mg/L)	SRP (mg/L)	TOTAL-N (mg/L)
METHOD	SM18 4500PF	SM18 4500PF	SM204500NC
DATE ANALYZED	08/31/15	08/06/15	08/25/15
REPORTING LIMIT	0.002	0.001	0.050
DUPLICATE			
SAMPLE ID	GW-2	GW-2	GW-2
ORIGINAL	0.075	0.002	1.09
DUPLICATE	0.076	0.002	1.12
RPD	0.85%	3.80%	2.76%
SPIKE SAMPLE			
SAMPLE ID	GW-2	GW-2	GW-2
ORIGINAL	0.075	0.002	1.09
SPIKED SAMPLE	0.128	0.022	1.98
SPIKE ADDED	0.050	0.020	1.00
% RECOVERY	106.32%	101.71%	89.25%
QC CHECK			
FOUND	0.094	0.039	0.498
TRUE	0.094	0.039	0.490
% RECOVERY	100.00%	100.69%	101.63%
BLANK	<0.002	<0.001	<0.050

RPD = RELATIVE PERCENT DIFFERENCE.
NA = NOT APPLICABLE OR NOT AVAILABLE.
NC = NOT CALCULABLE DUE TO ONE OR MORE VALUES BEING BELOW THE DETECTION LIMIT.
OR = RECOVERY NOT CALCULABLE DUE TO SPIKE SAMPLE OUT OF RANGE OR SPIKE TOO LOW RELATIVE TO SAMPLE CONCENTRATION.

SUBMITTED BY:

Damien Gadomski

Damien Gadomski
Project Manager

~~MIS035-04~~

IEH - Aquatic Research
3927 Aurora Ave N • Seattle • WA • 98103
P: 206-632-2715 F: 206-632-2417

Chain of Custody Form

Page 1 of 1 MI5037-65

REPORT TO:
Client: University of Washington Tacoma
Address: 1900 Commerce St.
Campus Box 358436, Tacoma, WA 98402
Contact: James Gawel
Email: jimgawel@uw.edu
Phone: 253-692-5815 Fax:

INVOICE TO: (IF DIFFERENT FROM REPORT)
Client: Brown and Caldwell
Address:
Seattle, WA
Contact: Sharonne Park
Email: spark@BrwnCald.com
Phone: 206.749.2892 Fax:

PROJECT INFORMATION
Quote No.:
Client PO:
Client Project:

Reporting/Invoicing Format
☐ Fax ☑ Email ☐ Mail

QC Data Reported
☑ Yes ☐ No

Sample Disposal
☐ Hold ☑ Dispose ☐ Return

Turn Around Time (TAT)*
☐ Next Day ☐ 2 Business Day
☐ 3 Business Day ☑ Standard

Specific Date:

*Advanced notice required for Rush Analysis

Analysis Requested

LAB USE ONLY
Case File Number

SAMPLING Date (mm-dd-yy)	Time	Matrix**	SAMPLE DESCRIPTION (This Will Appear On The Report)	Number of Containers	TP	TN	SRP										Field pH (if applicable)	Field Temp (if applicable)	Metals Field Filtered (Y/N)	Containers Received	Temp	Lab ID
08-19-15	1054	SW	WAUGHOP SURFACE	1	|	|	|															
|	1057	SW	WAUGHOP BOTTOM-A	1	|	|	|															
|	1057	SW	WAUGHOP BOTTOM-B	1	|	|	|															

**Matrix: B=Biota, DW=Drinking Water, GW=Ground Water, P=Paint, S=Soil, SD=Sediment, SL=Sludge, SW=Surface Water, WW=Wastewater

Sampled By Jim Gawel	Date 08-19-15	Time 157 PM
Received By	Date	Time
Relinquished to Aquatic By (Signature)	Date	Time

Comments:

Shipped By	Shipping Reference
Received at Aquatic By	Date / Time

IEH ANALYTICAL LABORATORIES
LABORATORY & CONSULTING SERVICES
3927 AURORA AVENUE NORTH, SEATTLE, WA 98103
PHONE: (206) 632-2715 FAX: (206) 632-2417

CASE FILE NUMBER: **MIS037-65** **PAGE 1**
REPORT DATE: **10/12/15**
DATE SAMPLED: **08/19/15** **DATE RECEIVED:** **08/19/15**
FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM GAWEL - UWT

CASE NARRATIVE

Three water samples were received by the laboratory in good condition and analyzed according to the chain of custody. No difficulties were encountered in the preparation or analysis of these samples. Sample data follows while QA/QC data is contained on the subsequent page.

SAMPLE DATA

SAMPLE ID	TOTAL-P (mg/L)	SRP (mg/L)	TOTAL-N (mg/L)
WAUGHOP SURFACE	0.057	0.002	1.65
WAUGHOP BOTTOM-A	0.058	0.001	1.45
WAUGHOP BOTTOM-B	0.054	0.001	1.58

CASE FILE NUMBER: **MIS037-65**
REPORT DATE: **10/12/15**
DATE SAMPLED: **08/19/15** **DATE RECEIVED:** **08/19/15**
FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM GAWEL - UWT

QA/QC DATA

QC PARAMETER	TOTAL-P (mg/L)	SRP (mg/L)	TOTAL-N (mg/L)
METHOD	SM18 4500PF	SM18 4500PF	SM204500NC
DATE ANALYZED	09/17/15	08/20/15	09/01/15
REPORTING LIMIT	0.002	0.001	0.050
DUPLICATE			
SAMPLE ID	BATCH	BATCH	BATCH
ORIGINAL	0.051	0.064	0.269
DUPLICATE	0.052	0.064	0.258
RPD	1.39%	0.40%	4.02%
SPIKE SAMPLE			
SAMPLE ID	BATCH	BATCH	BATCH
ORIGINAL	0.051	0.064	0.269
SPIKED SAMPLE	0.096	0.085	1.33
SPIKE ADDED	0.050	0.020	1.00
% RECOVERY	88.96%	103.62%	106.42%
QC CHECK			
FOUND	0.092	0.039	0.490
TRUE	0.094	0.039	0.490
% RECOVERY	97.87%	100.00%	100.00%
BLANK	<0.002	<0.001	<0.050

RPD = RELATIVE PERCENT DIFFERENCE.
NA = NOT APPLICABLE OR NOT AVAILABLE.
NC = NOT CALCULABLE DUE TO ONE OR MORE VALUES BEING BELOW THE DETECTION LIMIT.
OR = RECOVERY NOT CALCULABLE DUE TO SPIKE SAMPLE OUT OF RANGE OR SPIKE TOO LOW RELATIVE TO SAMPLE CONCENTRATION.

SUBMITTED BY:

Damien Gadomski

Damien Gadomski
Project Manager

MIS037-69

IEH - Aquatic Research
3927 Aurora Ave N • Seattle • WA • 98103
P: 206-632-2715 F: 206-632-2417

Chain of Custody Form

Page 1 of 1

REPORT TO:
Client: University of Washington Tacoma
Address: 1900 Commerce St.
Campus Box 358436, Tacoma, WA 98402
Contact: James Gawel
Email: jimgawel@uw.edu
Phone: 253-692-5815 Fax:

INVOICE TO: (IF DIFFERENT FROM REPORT)
Client: Brown and Caldwell
Address:
Seattle, WA
Contact: Sharonne Park
Email: spark@BrwnCald.com
Phone: 206.749.2892 Fax:

PROJECT INFORMATION
Quote No.:
Client PO:
Client Project:

Reporting/Invoicing Format
☐ Fax ☑ Email ☐ Mail

QC Data Reported
☑ Yes ☐ No

Sample Disposal
☐ Hold ☑ Dispose ☐ Return

Turn Around Time (TAT)*
☐ Next Day ☐ 2 Business Day
☐ 3 Business Day ☑ Standard

Specific Date:

*Advanced notice required for Rush Analysis

SAMPLING			SAMPLE DESCRIPTION	Number of Containers	Analysis Requested			Field pH (if applicable)	Field Temp (if applicable)	Metals Field Filtered (Y/N)	LAB USE ONLY Case File Number		
Date (mm-dd-yy)	Time	Matrix**	(This Will Appear On The Report)		TP	TN	SRP				Containers Received	Temp	Lab ID
8/24/15	4:20pm	SW	Benth 5	1	1	1	1						
8/24/15	4:35pm	SW	Benth 6	1	1	1	1						
8/24/15	4:47pm	SW	Benth 7	1	1	1	1						
8/24/15	5:00	SW	Benth 8	1	1	1	1						

**Matrix: B=Biota, DW=Drinking Water, GW=Ground Water, P=Paint, S=Soil, SD=Sediment, SL=Sludge, SW=Surface Water, WW=Wastewater

Comments:

Sampled By Jim Gawel	Date 8/24/15	Time 5:57pm
Received By	Date	Time
Relinquished to Aquatic By (Signature)	Date	Time

Shipped By:
Shipping Reference:

Received at Aquatic By: 11.6° (4) lot
Date: 8/25/15
Time: 1130

IEH ANALYTICAL LABORATORIES

LABORATORY & CONSULTING SERVICES
3927 AURORA AVENUE NORTH, SEATTLE, WA 98103
PHONE: (206) 632-2715 FAX: (206) 632-2417

CASE FILE NUMBER: MIS037-69 **PAGE 1**
REPORT DATE: 10/12/15
DATE SAMPLED: 08/24/15 **DATE RECEIVED:** 08/25/15

FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM GAWEL - UWT

CASE NARRATIVE

Four water samples were received by the laboratory in good condition and analyzed according to the chain of custody. No difficulties were encountered in the preparation or analysis of these samples. Sample data follows while QA/QC data is contained on the subsequent page.

SAMPLE DATA

SAMPLE ID	TOTAL-P (mg/L)	SRP (mg/L)	TOTAL-N (mg/L)
BENTH 5	0.110	0.002	2.44
BENTH 6	0.188	<0.001	3.73
BENTH 7	0.074	0.002	2.04
BENTH 8	0.123	<0.001	2.77

CASE FILE NUMBER: **MIS037-69**

REPORT DATE: **10/12/15**

DATE SAMPLED: **08/24/15** **DATE RECEIVED:** **08/25/15**

FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM GAWEL - UWT

QA/QC DATA

QC PARAMETER	TOTAL-P (mg/L)	SRP (mg/L)	TOTAL-N (mg/L)
METHOD	SM18 4500PF	SM18 4500PF	SM204500NC
DATE ANALYZED	09/21/15	08/26/15	09/14/15
REPORTING LIMIT	0.002	0.001	0.050
DUPLICATE			
SAMPLE ID	BATCH	BATCH	BATCH
ORIGINAL	0.016	<0.001	0.243
DUPLICATE	0.015	<0.001	0.246
RPD	5.59%	NC	1.51%
SPIKE SAMPLE			
SAMPLE ID	BATCH	BATCH	BATCH
ORIGINAL	0.016	<0.001	0.243
SPIKED SAMPLE	0.065	0.022	1.26
SPIKE ADDED	0.050	0.020	1.00
% RECOVERY	98.83%	110.00%	101.27%
QC CHECK			
FOUND	0.094	0.040	0.475
TRUE	0.094	0.039	0.490
% RECOVERY	100.00%	102.56%	96.94%
BLANK	<0.002	<0.001	<0.050

RPD = RELATIVE PERCENT DIFFERENCE.
NA = NOT APPLICABLE OR NOT AVAILABLE.
NC = NOT CALCULABLE DUE TO ONE OR MORE VALUES BEING BELOW THE DETECTION LIMIT.
OR = RECOVERY NOT CALCULABLE DUE TO SPIKE SAMPLE OUT OF RANGE OR SPIKE TOO LOW RELATIVE TO SAMPLE CONCENTRATION.

SUBMITTED BY:

Damien Gadomski

Damien Gadomski
Project Manager

MIS037-71

IEH - Aquatic Research
3927 Aurora Ave N • Seattle • WA • 98103
P: 206-632-2715 F: 206-632-2417

Chain of Custody Form

Page 1 of 1

REPORT TO:
Client: University of Washington Tacoma
Address: 1900 Commerce St.
Campus Box 358436, Tacoma, WA 98402
Contact: James Gawel
Email: jimgawel@uw.edu
Phone: 253-692-5815 Fax:

INVOICE TO: (IF DIFFERENT FROM REPORT)
Client: Brown and Caldwell
Address:
Seattle, WA
Contact: Sharonne Park
Email: spark@BrwnCald.com
Phone: 206.749.2892 Fax:

PROJECT INFORMATION
Quote No.:
Client PO:
Client Project:

Reporting/Invoicing Format
☐ Fax ☑ Email ☐ Mail

QC Data Reported
☑ Yes ☐ No

Sample Disposal
☐ Hold ☑ Dispose ☐ Return

Turn Around Time (TAT)*
☐ Next Day ☐ 2 Business Day
☐ 3 Business Day ☑ Standard

Specific Date:

*Advanced notice required for Rush Analysis

LAB USE ONLY
Case File Number

SAMPLING Date (mm-dd-yy)	Time	Matrix**	SAMPLE DESCRIPTION (This Will Appear On The Report)	Number of Containers	TP	TN	SRP										Field pH (if applicable)	Field Temp (if applicable)	Metals Field Filtered (Y/N)	Containers Received	Temp	Lab ID
8/25/15	1:00	SW	Benth 5 (24 hrs)	1	✓	✓	✓															
8/25/15	1:10	SW	Benth 6 (24 hrs)	1	✓	✓	✓															
8/28/15	1:20	SW	Benth 7 (24 hrs)	1	✓	✓	✓															
8/28/15	1:30	SW	Benth 8 (24 hrs)	1	✓	✓	✓															

**Matrix: B=Biota, DW=Drinking Water, GW=Ground Water, P=Paint, S=Soil, SD=Sediment, SL=Sludge, SW=Surface Water, WW=Wastewater

Sampled By: Jim Gawel Date: 8/28/15 Time: 2:55
Received By: Date: Time:
Relinquished to Aquatic By (Signature): Date: Time:

Comments:

Shipped By:
Shipping Reference:
Received at Aquatic By: (4) LL 14.1° Date: 8/26/15 Time: 10:30

IEH ANALYTICAL LABORATORIES

LABORATORY & CONSULTING SERVICES
3927 AURORA AVENUE NORTH, SEATTLE, WA 98103
PHONE: (206) 632-2715 FAX: (206) 632-2417

CASE FILE NUMBER: MIS037-71 **PAGE 1**
REPORT DATE: 10/12/15
DATE SAMPLED: 08/25/15 **DATE RECEIVED:** 08/26/15

FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM GAWEL - UWT

CASE NARRATIVE

Four water samples were received by the laboratory in good condition and analyzed according to the chain of custody. No difficulties were encountered in the preparation or analysis of these samples. Sample data follows while QA/QC data is contained on the subsequent page.

SAMPLE DATA

SAMPLE ID	TOTAL-P (mg/L)	SRP (mg/L)	TOTAL-N (mg/L)
BENTH 5	5.43	0.007	45.3
BENTH 6	0.059	<0.001	2.52
BENTH 7	0.072	<0.001	2.68
BENTH 8	0.056	<0.001	1.77

CASE FILE NUMBER: MIS037-71 **PAGE 2**
REPORT DATE: 10/12/15
DATE SAMPLED: 08/25/15 **DATE RECEIVED:** 08/26/15
FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM GAWEL - UWT

QA/QC DATA

QC PARAMETER	TOTAL-P (mg/L)	SRP (mg/L)	TOTAL-N (mg/L)
METHOD	SM18 4500PF	SM18 4500PF	SM204500NC
DATE ANALYZED	09/21/15	08/26/15	09/14/15
REPORTING LIMIT	0.002	0.001	0.050
DUPLICATE			
SAMPLE ID	BATCH	BATCH	BATCH
ORIGINAL	0.016	<0.001	0.243
DUPLICATE	0.015	<0.001	0.246
RPD	5.59%	NC	1.51%
SPIKE SAMPLE			
SAMPLE ID	BATCH	BATCH	BATCH
ORIGINAL	0.016	<0.001	0.243
SPIKED SAMPLE	0.065	0.022	1.26
SPIKE ADDED	0.050	0.020	1.00
% RECOVERY	98.83%	110.00%	101.27%
QC CHECK			
FOUND	0.094	0.040	0.475
TRUE	0.094	0.039	0.490
% RECOVERY	100.00%	102.56%	96.94%
BLANK	<0.002	<0.001	<0.050

RPD = RELATIVE PERCENT DIFFERENCE.
NA = NOT APPLICABLE OR NOT AVAILABLE.
NC = NOT CALCULABLE DUE TO ONE OR MORE VALUES BEING BELOW THE DETECTION LIMIT.
OR = RECOVERY NOT CALCULABLE DUE TO SPIKE SAMPLE OUT OF RANGE OR SPIKE TOO LOW RELATIVE TO SAMPLE CONCENTRATION.

SUBMITTED BY:

Damien Gadomski

Damien Gadomski
Project Manager

M15037 72

~~M15035-64~~

IEH - Aquatic Research
3927 Aurora Ave N • Seattle • WA • 98103
P: 206-632-2715 F: 206-632-2417

Chain of Custody Form

Page 1 of 1

REPORT TO:
Client: University of Washington Tacoma
Address: 1900 Commerce St.
Campus Box 358436, Tacoma, WA 98402
Contact: James Gawel
Email: jimgawel@uw.edu
Phone: 253-692-5815 Fax:

INVOICE TO: (IF DIFFERENT FROM REPORT)
Client: Brown and Caldwell
Address:
Seattle, WA
Contact: Sharonne Park
Email: spark@BrwnCald.com
Phone: 206.749.2892 Fax:

PROJECT INFORMATION
Quote No.:
Client PO:
Client Project:

Reporting/Invoicing Format
☐ Fax ☒ Email ☐ Mail

QC Data Reported
☒ Yes ☐ No

Sample Disposal
☐ Hold ☒ Dispose ☐ Return

Turn Around Time (TAT)*
☐ Next Day ☐ 2 Business Day
☐ 3 Business Day ☒ Standard

Specific Date:

*Advanced notice required for Rush Analysis

LAB USE ONLY
Case File Number

SAMPLING			SAMPLE DESCRIPTION		Analysis Requested						LAB USE ONLY	
Date (mm-dd-yy)	Time	Matrix**	(This Will Appear On The Report)	Number of Containers	TP	TN	SRP	Field pH (if applicable)	Field Temp (if applicable)	Metals Field Filtered (Y/N)	Containers Received	Temp	Lab ID
08/26/15	1345	SW	BENTHIC 5	1									
08/26/15	1300	SW	BENTHIC 6	1									
08/26/15	1315	SW	BENTHIC 7	1									
08/26/15	1330	SW	BENTHIC 8	1									

**Matrix: B=Biota, DW=Drinking Water, GW=Ground Water, P=Paint, S=Soil, SD=Sediment, SL=Sludge, SW=Surface Water, WW=Wastewater

Comments:

Sampled By: ~~Jim Gawel~~ Date: 8/26/15 Time: 1600
Received By: Corey Kuk Date: Time:
Relinquished to Aquatic By (Signature) Date: Time:

Shipped By:
Shipping Reference:
Received at Aquatic By: (4) ice 7.8° Date: 8/27/15 Time: 10 30

IEH ANALYTICAL LABORATORIES

LABORATORY & CONSULTING SERVICES

3927 AURORA AVENUE NORTH, SEATTLE, WA 98103

PHONE: (206) 632-2715 FAX: (206) 632-2417

CASE FILE NUMBER: MIS037-72 **PAGE 1**

REPORT DATE: 10/12/15

DATE SAMPLED: 08/26/15 **DATE RECEIVED:** 08/27/15

FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM GAWEL - UWT

CASE NARRATIVE

Four water samples were received by the laboratory in good condition and analyzed according to the chain of custody. No difficulties were encountered in the preparation or analysis of these samples. Sample data follows while QA/QC data is contained on the subsequent page.

SAMPLE DATA

SAMPLE ID	TOTAL-P (mg/L)	SRP (mg/L)	TOTAL-N (mg/L)
BENTHIC 5	76.8	0.043	512
BENTHIC 6	0.098	0.004	2.87
BENTHIC 7	0.079	0.004	4.87
BENTHIC 8	0.066	0.003	2.12

CASE FILE NUMBER: **MIS037-72** **PAGE 2**
REPORT DATE: **10/12/15**
DATE SAMPLED: **08/26/15** **DATE RECEIVED:** **08/27/15**
FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM GAWEL - UWT

QA/QC DATA

QC PARAMETER	TOTAL-P (mg/L)	SRP (mg/L)	TOTAL-N (mg/L)
METHOD	SM18 4500PF	SM18 4500PF	SM204500NC
DATE ANALYZED	09/21/15	08/27/15	09/21/15
REPORTING LIMIT	0.002	0.001	0.050
DUPLICATE			
SAMPLE ID	BENTHIC 8	BATCH	BATCH
ORIGINAL	0.066	<0.001	0.331
DUPLICATE	0.065	<0.001	0.339
RPD	1.94%	NC	2.27%
SPIKE SAMPLE			
SAMPLE ID	BENTHIC 8	BATCH	BATCH
ORIGINAL	0.066	<0.001	0.331
SPIKED SAMPLE	0.116	0.022	1.52
SPIKE ADDED	0.050	0.020	1.00
% RECOVERY	100.24%	110.00%	118.91%
QC CHECK			
FOUND	0.094	0.040	0.455
TRUE	0.094	0.039	0.490
% RECOVERY	100.00%	102.56%	92.86%
BLANK	<0.002	<0.001	<0.050

RPD = RELATIVE PERCENT DIFFERENCE.
NA = NOT APPLICABLE OR NOT AVAILABLE.
NC = NOT CALCULABLE DUE TO ONE OR MORE VALUES BEING BELOW THE DETECTION LIMIT.
OR = RECOVERY NOT CALCULABLE DUE TO SPIKE SAMPLE OUT OF RANGE OR SPIKE TOO LOW RELATIVE TO SAMPLE CONCENTRATION.

SUBMITTED BY:

Damien Gadomski

Damien Gadomski
Project Manager

M15038-88

IEH - Aquatic Research
3927 Aurora Ave N • Seattle • WA • 98103
P: 206-632-2715 F: 206-632-2417

IEH

Chain of Custody Form

Page 1 of 1

REPORT TO:
Client: UW TACOMA
Address: 1900 COMMERCE ST.
CAMPUS BOX 358436, TACOMA, WA 98402
Contact: JAMES GAWEL
Email: jimgawel@uw.edu
Phone (253) 692-5815 Fax: (253) 692-4639

INVOICE TO: (IF DIFFERENT FROM REPORT)
Client:
Address:
Contact:
Email:
Phone: Fax:

PROJECT INFORMATION
Quote No.:
Client PO:
Client Project:

Reporting/Invoicing Format
☐ Fax ☒ Email ☐ Mail

QC Data Reported
☒ Yes ☐ No

Sample Disposal
☐ Hold ☒ Dispose ☐ Return

Turn Around Time (TAT)*
☐ Next Day ☐ 2 Business Day
☐ 3 Business Day ☐ Standard

Specific Date:
*Advanced notice required for Rush Analysis

LAB USE ONLY
Case File Number

SAMPLING Date (mm-dd-yy)	Time	Matrix**	SAMPLE DESCRIPTION (This Will Appear On The Report)	Number of Containers	TP	TN											Field pH (if applicable)	Field Temp (if applicable)	Metals Field Filtered (Y/N)	Containers Received	Temp	Lab ID
09-04-15		SD	WAUGHOP SEDIMENT 1	1																		
		B	WAUGHOP PLANT 1	1																		
		B	WAUGHOP PLANT 2	1																		
		B	WAUGHOP PLANT 3	1																		

**Matrix: B=Biota, DW=Drinking Water, GW=Ground Water, P=Paint, S=Soil, SD=Sediment, SL=Sludge, SW=Surface Water, WW=Wastewater

	Date	Time
Sampled By COREY KING	11-17-15	1:09 PM
Received By		
Relinquished to Aquatic By (Signature)		

Comments:

Shipped By

Shipping Reference

Received at Aquatic By

Date 11/18/15 Time 3:30pm

(4) total RT

IEH ANALYTICAL LABORATORIES

LABORATORY & CONSULTING SERVICES
3927 AURORA AVENUE NORTH, SEATTLE, WA 98103
PHONE: (206) 632-2715 FAX: (206) 632-2417

CASE FILE NUMBER: **MIS038-88** **PAGE 1**
REPORT DATE: **01/29/16**
DATE SAMPLED: **09/04/15** **DATE RECEIVED:** **11/18/15**

FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON SOIL AND PLANT SAMPLES FROM UW TACOMA

CASE NARRATIVE

Four solid samples were received by the laboratory in good condition. The water samples were analyzed according to the chain of custody. No difficulties were encountered in the preparation or analysis of these samples. QA/QC data is retained by the laboratory.

SAMPLE DATA

SAMPLE ID	TOTAL-P (mg/kg)	TOTAL-N (mg/kg)
WAUGHOP SEDIMENT 1	1820	10800
WAUGHOP PLANT 1	4420	31800
WAUGHOP PLANT 2	5115	8100
WAUGHOP PLANT 3	4280	5490

SUBMITTED BY:

Damien Gadomski

Damien Gadomski
Project Manager

MI5037-89
MI5035-04

IEH - Aquatic Research
3927 Aurora Ave N • Seattle • WA • 98103
P: 206-632-2715 F: 206-632-2417

Chain of Custody Form

Page 1 of 1

REPORT TO:
Client: University of Washington Tacoma
Address: 1900 Commerce St.
Campus Box 358436, Tacoma, WA 98402
Contact: James Gawel
Email: jimgawel@uw.edu
Phone: 253-692-5815 Fax:

INVOICE TO: (IF DIFFERENT FROM REPORT)
Client: Brown and Caldwell
Address:
Seattle, WA
Contact: Sharonne Park
Email: spark@BrwnCald.com
Phone: 206.749.2892 Fax:

PROJECT INFORMATION
Quote No.:
Client PO:
Client Project:

Reporting/invoicing Format
☐ Fax ☑ Email ☐ Mail

QC Data Reported
☑ Yes ☐ No

Sample Disposal
☐ Hold ☑ Dispose ☐ Return

Turn Around Time (TAT)*
☐ Next Day ☐ 2 Business Day
☐ 3 Business Day ☑ Standard

Specific Date:
*Advanced notice required for Rush Analysis

SAMPLING			SAMPLE DESCRIPTION		Analysis Requested						LAB USE ONLY		
Date (mm-dd-yy)	Time	Matrix**	(This Will Appear On The Report)	Number of Containers	TP	TN	SRP	Field pH (if applicable)	Field Temp (if applicable)	Metals Field Filtered (Y/N)	Containers Received	Temp	Lab ID
09-14-15	127	SW	SURF.										
09-14-15	128	SW	BOTTOM										
09-14-15	128	SW	BOTTOM DUP										
09-14-15	226	SW	BENTH 9 (2HRS)										
09-14-15	244	SW	BENTH 10 (2HRS)										
09-14-15	258	SW	BENTH 11 (2HRS)										
09-14-15	310	SW	BENTH 12 (2HRS)										

Case File Number

**Matrix: B=Biota, DW=Drinking Water, GW=Ground Water, P=Paint, S=Soil, SD=Sediment, SL=Sludge, SW=Surface Water, WW=Wastewater

Sampled By: Jim Gawel
Date: 9/14/15
Time: 4:15 PM
Received By:
Date:
Time:
Relinquished to Aquatic By (Signature):
Date:
Time:

Comments:

Shipped By:
Shipping Reference:
Received at Aquatic By: (2) of 16.8°
Date: 9/15/15
Time: 11:55

IEH ANALYTICAL LABORATORIES

LABORATORY & CONSULTING SERVICES

3927 AURORA AVENUE NORTH, SEATTLE, WA 98103

PHONE: (206) 632-2715 FAX: (206) 632-2417

CASE FILE NUMBER: **MIS037-89** **PAGE 1**

REPORT DATE: **10/22/15**

DATE SAMPLED: **09/14/15** **DATE RECEIVED:** **09/15/15**

FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM GAWEL - UWT

CASE NARRATIVE

Seven water samples were received by the laboratory in good condition and analyzed according to the chain of custody. No difficulties were encountered in the preparation or analysis of these samples. Sample data follows while QA/QC data is contained on the subsequent page.

SAMPLE DATA

SAMPLE ID	TOTAL-P (mg/L)	SRP (mg/L)	TOTAL-N (mg/L)
SURF	0.103	0.008	2.42
BOTTOM	0.077	0.002	1.64
BOTTOM DUP	0.078	0.002	1.49
BENTH 9 (2 HRS)	1.17	0.002	8.89
BENTH 10 (2 HRS)	0.070	0.002	1.44
BENTH 11 (2 HRS)	0.119	0.002	2.57
BENTH 12 (2 HRS)	1.99	0.001	13.3

CASE FILE NUMBER: MIS037-89 **PAGE 2**
REPORT DATE: 10/22/15
DATE SAMPLED: 09/14/15 **DATE RECEIVED:** 09/15/15
FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM GAWEL - UWT

QA/QC DATA

QC PARAMETER	TOTAL-P (mg/L)	SRP (mg/L)	TOTAL-N (mg/L)
METHOD	SM18 4500PF	SM18 4500PF	SM204500NC
DATE ANALYZED	10/08/15	09/16/15	10/09/15
REPORTING LIMIT	0.002	0.001	0.050
DUPLICATE			
SAMPLE ID	BATCH	BATCH	BATCH
ORIGINAL	0.015	<0.001	0.952
DUPLICATE	0.015	<0.001	0.993
RPD	0.36%	NC	4.23%
SPIKE SAMPLE			
SAMPLE ID	BATCH	BATCH	BATCH
ORIGINAL	0.015	<0.001	0.952
SPIKED SAMPLE	0.068	0.021	1.81
SPIKE ADDED	0.050	0.020	1.00
% RECOVERY	106.08%	105.00%	85.62%
QC CHECK			
FOUND	0.097	0.041	0.506
TRUE	0.094	0.039	0.490
% RECOVERY	103.19%	105.13%	103.27%
BLANK	<0.002	<0.001	<0.050

RPD = RELATIVE PERCENT DIFFERENCE.
NA = NOT APPLICABLE OR NOT AVAILABLE.
NC = NOT CALCULABLE DUE TO ONE OR MORE VALUES BEING BELOW THE DETECTION LIMIT.
OR = RECOVERY NOT CALCULABLE DUE TO SPIKE SAMPLE OUT OF RANGE OR SPIKE TOO LOW RELATIVE TO SAMPLE CONCENTRATION.

SUBMITTED BY:

Damien Gadomski

Damien Gadomski
Project Manager

MI5037-92

IEH - Aquatic Research
3927 Aurora Ave N • Seattle • WA • 98103
P: 206-632-2715 F: 206-632-2417

Chain of Custody Form

Page 1 of 1

REPORT TO:
Client: University of Washington Tacoma
Address: 1900 Commerce St.
Campus Box 358436, Tacoma, WA 98402
Contact: James Gawel
Email: jimgawel@uw.edu
Phone: 253-692-5815 Fax:

INVOICE TO: (IF DIFFERENT FROM REPORT)
Client: Brown and Caldwell
Address:
Seattle, WA
Contact: Sharonne Park
Email: spark@BrwnCald.com
Phone: 206.749.2892 Fax:

PROJECT INFORMATION
Quote No.:
Client PO:
Client Project:

Reporting/Invoicing Format
☐ Fax ☑ Email ☐ Mail

QC Data Reported
☑ Yes ☐ No

Sample Disposal
☐ Hold ☑ Dispose ☐ Return

Turn Around Time (TAT)*
☐ Next Day ☐ 2 Business Day
☐ 3 Business Day ☑ Standard

Specific Date:

*Advanced notice required for Rush Analysis

SAMPLING			SAMPLE DESCRIPTION	Number of Containers	Analysis Requested			Field pH (if applicable)	Field Temp (if applicable)	Metals Field Filtered (Y/N)	LAB USE ONLY		
Date (mm-dd-yy)	Time	Matrix**	(This Will Appear On The Report)		TP	TN	SRP				Containers Received	Temp	Lab ID
9/15/15	1:45	SW	Benth 9 (24hrs)	1	|	|	|						
9/15/15	1:58	SW	Benth 10 (24hrs)	1	|	|	|						
9/15/15	2:11	SW	Benth 11 (24 hrs)	1	|	|	|						
9/15/15	2:24	SW	Benth 12 (24 hrs)	1	|	|	|						

Case File Number:

**Matrix: B=Biota, DW=Drinking Water, GW=Ground Water, P=Paint, S=Soil, SD=Sediment, SL=Sludge, SW=Surface Water, WW=Wastewater

Comments:

Sampled By	Date	Time
Jim Gawel	9/15/15	3:15pm

Received By	Date	Time

Relinquished to Aquatic By (Signature)	Date	Time

Shipped By:
Shipping Reference:

Received at Aquatic By: 11.8° [illegible]
Date: 9/16/15
Time: 10:00

IEH ANALYTICAL LABORATORIES

LABORATORY & CONSULTING SERVICES
3927 AURORA AVENUE NORTH, SEATTLE, WA 98103
PHONE: (206) 632-2715 FAX: (206) 632-2417

CASE FILE NUMBER: MIS037-92 **PAGE 1**
REPORT DATE: 10/22/15
DATE SAMPLED: 09/15/15 **DATE RECEIVED:** 09/16/15

FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM GAWEL - UWT

CASE NARRATIVE

Four water samples were received by the laboratory in good condition and analyzed according to the chain of custody. No difficulties were encountered in the preparation or analysis of these samples. Sample data follows while QA/QC data is contained on the subsequent page.

SAMPLE DATA

SAMPLE ID	TOTAL-P (mg/L)	SRP (mg/L)	TOTAL-N (mg/L)
BENTH 9 (24 HRS)	0.066	0.002	3.27
BENTH 10 (24 HRS)	0.042	0.002	1.73
BENTH 11 (24 HRS)	0.477	0.003	6.25
BENTH 12 (24 HRS)	0.097	0.002	3.33

CASE FILE NUMBER: **MIS037-92** **PAGE 2**

REPORT DATE: **10/22/15**

DATE SAMPLED: **09/15/15** **DATE RECEIVED:** **09/16/15**

FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM GAWEL - UWT

QA/QC DATA

QC PARAMETER	TOTAL-P (mg/L)	SRP (mg/L)	TOTAL-N (mg/L)
METHOD	SM18 4500PF	SM18 4500PF	SM204500NC
DATE ANALYZED	10/08/15	09/16/15	10/09/15
REPORTING LIMIT	0.002	0.001	0.050
DUPLICATE			
SAMPLE ID	BATCH	BATCH	BATCH
ORIGINAL	0.015	<0.001	0.952
DUPLICATE	0.015	<0.001	0.993
RPD	0.36%	NC	4.23%
SPIKE SAMPLE			
SAMPLE ID	BATCH	BATCH	BATCH
ORIGINAL	0.015	<0.001	0.952
SPIKED SAMPLE	0.068	0.021	1.81
SPIKE ADDED	0.050	0.020	1.00
% RECOVERY	106.08%	105.00%	85.62%
QC CHECK			
FOUND	0.097	0.041	0.506
TRUE	0.094	0.039	0.490
% RECOVERY	103.19%	105.13%	103.27%
BLANK	<0.002	<0.001	<0.050

RPD = RELATIVE PERCENT DIFFERENCE.
NA = NOT APPLICABLE OR NOT AVAILABLE.
NC = NOT CALCULABLE DUE TO ONE OR MORE VALUES BEING BELOW THE DETECTION LIMIT.
OR = RECOVERY NOT CALCULABLE DUE TO SPIKE SAMPLE OUT OF RANGE OR SPIKE TOO LOW RELATIVE TO SAMPLE CONCENTRATION.

SUBMITTED BY:

Damien Gadomski

Damien Gadomski
Project Manager

~~M15035-014~~/ww

IEH - Aquatic Research
3927 Aurora Ave N • Seattle • WA • 98103
P: 206-632-2715 F: 206-632-2417

Chain of Custody Form

Page 1 of 1

REPORT TO:
Client: University of Washington Tacoma
Address: 1900 Commerce St.
Campus Box 358436, Tacoma, WA 98402
Contact: James Gawel
Email: jimgawel@uw.edu
Phone: 253-692-5815
Fax:

INVOICE TO: (IF DIFFERENT FROM REPORT)
Client: Brown and Caldwell
Address:
Seattle, WA
Contact: Sharonne Park
Email: spark@BrwnCald.com
Phone: 206.749.2892
Fax:

PROJECT INFORMATION
Quote No.:
Client PO:
Client Project:

Reporting/Invoicing Format
☐ Fax ☑ Email ☐ Mail

QC Data Reported
☑ Yes ☐ No

Sample Disposal
☐ Hold ☑ Dispose ☐ Return

Turn Around Time (TAT)*
☐ Next Day ☐ 2 Business Day
☐ 3 Business Day ☑ Standard

Specific Date:

*Advanced notice required for Rush Analysis

SAMPLING			SAMPLE DESCRIPTION	Number of Containers	Analysis Requested												Field pH (if applicable)	Field Temp (if applicable)	Metals Field Filtered (Y/N)	LAB USE ONLY		
Date (mm-dd-yy)	Time	Matrix**	(This Will Appear On The Report)		TP	TN	SRP													Containers Received	Temp	Lab ID
09-16-15	1:41PM	SW	BENTH 9 (48HRS)	1	│	│	│															
09-16-15	1:55PM	SW	BENTH 10 (48HRS)	1	│	│	│															
09-16-15	2:07PM	SW	BENTH 11 (48 HRS)	1	│	│	│															
09-16-15	2:18PM	SW	BENTH 12 (48 HRS)	1	│	│	│															

Case File Number

**Matrix: B=Biota, DW=Drinking Water, GW=Ground Water, P=Paint, S=Soil, SD=Sediment, SL=Sludge, SW=Surface Water, WW=Wastewater

Sampled By Jim Gawel Date 9/16/15 Time 4:24 PM
Received By Date Time
Relinquished to Aquatic By (Signature) Date Time

Comments:

Shipped By
Shipping Reference
Received at Aquatic By 0.3° (4) Ice Date 9/17/15 Time 11:30

IEH ANALYTICAL LABORATORIES
LABORATORY & CONSULTING SERVICES
3927 AURORA AVENUE NORTH, SEATTLE, WA 98103
PHONE: (206) 632-2715 FAX: (206) 632-2417

CASE FILE NUMBER: **MIS037-93** **PAGE 1**
REPORT DATE: **10/22/15**
DATE SAMPLED: **09/16/15** **DATE RECEIVED:** **09/17/15**
FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM GAWEL - UWT

CASE NARRATIVE

Four water samples were received by the laboratory in good condition and analyzed according to the chain of custody. No difficulties were encountered in the preparation or analysis of these samples. Sample data follows while QA/QC data is contained on the subsequent page.

SAMPLE DATA

SAMPLE ID	TOTAL-P (mg/L)	SRP (mg/L)	TOTAL-N (mg/L)
BENTH 9 (48 HRS)	0.126	0.003	3.34
BENTH 10 (48 HRS)	0.070	0.004	2.72
BENTH 11 (48 HRS)	1.29	0.191	16.0
BENTH 12 (48 HRS)	0.106	0.004	3.25

IEH ANALYTICAL LABORATORIES

LABORATORY & CONSULTING SERVICES

3927 AURORA AVENUE NORTH, SEATTLE, WA 98103

PHONE: (206) 632-2715 FAX: (206) 632-2417

CASE FILE NUMBER: MIS037-93 **PAGE 2**

REPORT DATE: 10/22/15

DATE SAMPLED: 09/16/15 **DATE RECEIVED:** 09/17/15

FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM GAWEL - UWT

QA/QC DATA

QC PARAMETER	TOTAL-P (mg/L)	SRP (mg/L)	TOTAL-N (mg/L)
METHOD	SM18 4500PF	SM18 4500PF	SM204500NC
DATE ANALYZED	10/08/15	09/18/15	10/09/15
REPORTING LIMIT	0.002	0.001	0.050
DUPLICATE			
SAMPLE ID	BATCH	BATCH	BATCH
ORIGINAL	0.015	0.008	0.952
DUPLICATE	0.015	0.008	0.993
RPD	0.36%	0.45%	4.23%
SPIKE SAMPLE			
SAMPLE ID	BATCH	BATCH	BATCH
ORIGINAL	0.015	0.008	0.952
SPIKED SAMPLE	0.068	0.027	1.81
SPIKE ADDED	0.050	0.020	1.00
% RECOVERY	106.08%	98.64%	85.62%
QC CHECK			
FOUND	0.097	0.040	0.506
TRUE	0.094	0.039	0.490
% RECOVERY	103.19%	102.56%	103.27%
BLANK	<0.002	<0.001	<0.050

RPD = RELATIVE PERCENT DIFFERENCE.
NA = NOT APPLICABLE OR NOT AVAILABLE.
NC = NOT CALCULABLE DUE TO ONE OR MORE VALUES BEING BELOW THE DETECTION LIMIT.
OR = RECOVERY NOT CALCULABLE DUE TO SPIKE SAMPLE OUT OF RANGE OR SPIKE TOO LOW RELATIVE TO SAMPLE CONCENTRATION.

SUBMITTED BY:

Damien Gadomski

Damien Gadomski
Project Manager

~~M15035-04~~

IEH - Aquatic Research
3927 Aurora Ave N • Seattle • WA • 98103
P: 206-632-2715 F: 206-632-2417

Chain of Custody Form

Page ____ of ____

REPORT TO:
Client: JAMES GAWEL / UW TACOMA
Address: 1900 COMMERCE ST.
CAMPUS BOX 358436, TACOMA, WA 98402
Contact: JAMES GAWEL
Email: JIMGAWEL@UW.EDU
Phone: 253 692-5815 Fax: 253 692 4639

INVOICE TO: (IF DIFFERENT FROM REPORT)
Client:
Address:
Contact:
Email:
Phone: Fax:

PROJECT INFORMATION
Quote No.:
Client PO:
Client Project:

Reporting/Invoicing Format
☐ Fax ☑ Email ☐ Mail

QC Data Reported
☑ Yes ☐ No

Sample Disposal
☐ Hold ☑ Dispose ☐ Return

Turn Around Time (TAT)*
☐ Next Day ☐ 2 Business Day
☐ 3 Business Day ☐ Standard

Specific Date:
*Advanced notice required for Rush Analysis

LAB USE ONLY
Case File Number

SAMPLING			**SAMPLE DESCRIPTION**	**Number of Containers**	**Analysis Requested**												**Field pH (if applicable)**	**Field Temp (if applicable)**	**Metals Field Filtered (Y/N)**	**Containers Received**	**Temp**	**Lab ID**
Date (mm-dd-yy)	**Time**	**Matrix****	(This Will Appear On The Report)		TP	SRP	TN															
09/17/15	1043	SW	STORMWATER	1	1	1	1															

**Matrix: B=Biota, DW=Drinking Water, GW=Ground Water, P=Paint, S=Soil, SD=Sediment, SL=Sludge, SW=Surface Water, WW=Wastewater

Sampled By Corey King Date 9/17/05 Time 1:45 PM

Received By Date Time

Relinquished to Aquatic By (Signature) Date Time

Comments:

Shipped By

Shipping Reference

Received at Aquatic By (1) 1OL 14.1° Date 9/17/15 Time 4:00

IEH ANALYTICAL LABORATORIES

LABORATORY & CONSULTING SERVICES
3927 AURORA AVENUE NORTH, SEATTLE, WA 98103
PHONE: (206) 632-2715 FAX: (206) 632-2417

CASE FILE NUMBER: MIS037-96

REPORT DATE: 10/22/15
DATE SAMPLED: 09/17/15 **DATE RECEIVED:** 09/17/15

FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM GAWEL - UWT

CASE NARRATIVE

One water sample was received by the laboratory in good condition and analyzed according to the chain of custody. No difficulties were encountered in the preparation or analysis of this sample. Sample data follows while QA/QC data is contained on the subsequent page.

SAMPLE DATA

SAMPLE ID	TOTAL-P (mg/L)	SRP (mg/L)	TOTAL-N (mg/L)
STORMWATER	0.094	0.032	0.860

CASE FILE NUMBER: **MIS037-96** **PAGE 2**
REPORT DATE: **10/22/15**
DATE SAMPLED: **09/17/15** **DATE RECEIVED:** **09/17/15**
FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM GAWEL - UWT

QA/QC DATA

QC PARAMETER	TOTAL-P (mg/L)	SRP (mg/L)	TOTAL-N (mg/L)
METHOD	SM18 4500PF	SM18 4500PF	SM204500NC
DATE ANALYZED	10/08/15	09/18/15	10/09/15
REPORTING LIMIT	0.002	0.001	0.050
DUPLICATE			
SAMPLE ID	BATCH	BATCH	BATCH
ORIGINAL	0.015	0.008	0.952
DUPLICATE	0.015	0.008	0.993
RPD	0.36%	0.45%	4.23%
SPIKE SAMPLE			
SAMPLE ID	BATCH	BATCH	BATCH
ORIGINAL	0.015	0.008	0.952
SPIKED SAMPLE	0.068	0.027	1.81
SPIKE ADDED	0.050	0.020	1.00
% RECOVERY	106.08%	98.64%	85.62%
QC CHECK			
FOUND	0.097	0.040	0.506
TRUE	0.094	0.039	0.490
% RECOVERY	103.19%	102.56%	103.27%
BLANK	<0.002	<0.001	<0.050

RPD = RELATIVE PERCENT DIFFERENCE.
NA = NOT APPLICABLE OR NOT AVAILABLE.
NC = NOT CALCULABLE DUE TO ONE OR MORE VALUES BEING BELOW THE DETECTION LIMIT.
OR = RECOVERY NOT CALCULABLE DUE TO SPIKE SAMPLE OUT OF RANGE OR SPIKE TOO LOW RELATIVE TO SAMPLE CONCENTRATION.

SUBMITTED BY:

Damien Gadomski

Damien Gadomski
Project Manager

IEH - Aquatic Research
3927 Aurora Ave N • Seattle • WA • 98103
P: 206-632-2715 F: 206-632-2417

Chain of Custody Form

Page ____ of ____

REPORT TO:
Client: UW TACOMA
Address: 1900 COMMERCE ST
CAMPUS BOX 358436, TACOMA WA 98402
Contact: JAMES GAWEL
Email: JIM GAWEL@UW.EDU
Phone: 253 692 5815 Fax: 253 692 4639

INVOICE TO: (IF DIFFERENT FROM REPORT)
Client: BROWN AND CALDWELL
Address:
SEATTLE, WA
Contact: SHARONNE PARK
Email: SPARK@BRWNCALD.COM
Phone: 206 749 2892 Fax:

PROJECT INFORMATION
Quote No.:
Client PO:
Client Project:

Reporting/Invoicing Format
☐ Fax ☑ Email ☐ Mail

QC Data Reported
☑ Yes ☐ No

Sample Disposal
☐ Hold ☑ Dispose ☐ Return

Turn Around Time (TAT)*
☐ Next Day ☐ 2 Business Day
☐ 3 Business Day ☐ Standard

Specific Date:
*Advanced notice required for Rush Analysis

LAB USE ONLY
Case File Number

SAMPLING Date (mm-dd-yy)	SAMPLING Time	SAMPLING Matrix**	SAMPLE DESCRIPTION (This Will Appear On The Report)	Number of Containers	Analysis Requested: TP	SRP	TN										Field pH (if applicable)	Field Temp (if applicable)	Metals Field Filtered (Y/N)	Containers Received	Temp	Lab ID
09-22-15	1348	GW	GW-5	1	✓	✓	✓															

**Matrix: B=Biota, DW=Drinking Water, GW=Ground Water, P=Paint, S=Soil, SD=Sediment, SL=Sludge, SW=Surface Water, WW=Wastewater

Comments:

Sampled By COREY KING	Date 9/22/15	Time 1430
Received By	Date	Time
Relinquished to Aquatic By (Signature)	Date	Time

Shipped By

Shipping Reference

Received at Aquatic By 9.0° (1) tot

Date 9/23/15 Time 10:00

IEH ANALYTICAL LABORATORIES

LABORATORY & CONSULTING SERVICES

3927 AURORA AVENUE NORTH, SEATTLE, WA 98103

PHONE: (206) 632-2715 FAX: (206) 632-2417

CASE FILE NUMBER: **MIS038-08** **PAGE 1**
REPORT DATE: **10/22/15**
DATE SAMPLED: **09/22/15** **DATE RECEIVED:** **09/23/15**

FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM GAWEL - UWT

CASE NARRATIVE

One water samples was received by the laboratory in good condition and analyzed according to the chain of custody. No difficulties were encountered in the preparation or analysis of this sample. Sample data follows while QA/QC data is contained on the subsequent page.

SAMPLE DATA

SAMPLE ID	TOTAL-P (mg/L)	SRP (mg/L)	TOTAL-N (mg/L)
GW-5	0.039	0.016	0.560

CASE FILE NUMBER: MIS038-08 **PAGE 2**
REPORT DATE: 10/22/15
DATE SAMPLED: 09/22/15 **DATE RECEIVED:** 09/23/15
FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM GAWEL - UWT

QA/QC DATA

QC PARAMETER	TOTAL-P (mg/L)	SRP (mg/L)	TOTAL-N (mg/L)
METHOD	SM18 4500PF	SM18 4500PF	SM204500NC
DATE ANALYZED	10/17/15	09/25/15	10/17/15
REPORTING LIMIT	0.002	0.001	0.050
DUPLICATE			
SAMPLE ID	BATCH	BATCH	GW-5
ORIGINAL	0.073	0.005	0.560
DUPLICATE	0.075	0.005	0.550
RPD	2.86%	2.20%	1.76%
SPIKE SAMPLE			
SAMPLE ID	BATCH	BATCH	GW-5
ORIGINAL	0.073	0.005	0.560
SPIKED SAMPLE	0.125	0.025	1.58
SPIKE ADDED	0.050	0.020	1.00
% RECOVERY	103.85%	97.19%	101.77%
QC CHECK			
FOUND	0.094	0.039	0.490
TRUE	0.094	0.039	0.490
% RECOVERY	100.11%	100.72%	100.00%
BLANK	<0.002	<0.001	<0.050

RPD = RELATIVE PERCENT DIFFERENCE.
NA = NOT APPLICABLE OR NOT AVAILABLE.
NC = NOT CALCULABLE DUE TO ONE OR MORE VALUES BEING BELOW THE DETECTION LIMIT.
OR = RECOVERY NOT CALCULABLE DUE TO SPIKE SAMPLE OUT OF RANGE OR SPIKE TOO LOW RELATIVE TO SAMPLE CONCENTRATION.

SUBMITTED BY:

Damien Gadomski

Damien Gadomski
Project Manager

MIS038-17

IEH - Aquatic Research
3927 Aurora Ave N • Seattle • WA • 98103
P: 206-632-2715 F: 206-632-2417

Chain of Custody Form

Page ____ of ____

REPORT TO:
Client: James Gawel / UW Tacoma
Address: 1900 commerce St.
Campus Box 358436, Tacoma, WA 98402
Contact: James Gawel
Email: jimgawel@uw.edu
Phone: 253-692-5815 Fax: 253-692-4639

INVOICE TO: (IF DIFFERENT FROM REPORT)
Client:
Address:
Contact:
Email:
Phone: Fax:

PROJECT INFORMATION
Quote No.:
Client PO:
Client Project:

Reporting/Invoicing Format
☐ Fax ☑ Email ☐ Mail

QC Data Reported
☑ Yes ☐ No

Sample Disposal
☐ Hold ☑ Dispose ☐ Return

Turn Around Time (TAT)*
☐ Next Day ☐ 2 Business Day
☐ 3 Business Day ☐ Standard

Specific Date:
*Advanced notice required for Rush Analysis

LAB USE ONLY
Case File Number

SAMPLING Date (mm-dd-yy)	Time	Matrix**	SAMPLE DESCRIPTION (This Will Appear On The Report)	Number of Containers	TP	SRP	TN										Field pH (if applicable)	Field Temp (if applicable)	Metals Field Filtered (Y/N)	Containers Received	Temp	Lab ID
9/28/15	12:07	SW	Surf	1	|	|	|															
9/28/15	12:08	SW	Bottom-A	1	|	|	|															
9/28/15	12:09	SW	Bottom - B	1	|	|	|															

**Matrix: B=Biota, DW=Drinking Water, GW=Ground Water, P=Paint, S=Soil, SD=Sediment, SL=Sludge, SW=Surface Water, WW=Wastewater

Comments:

Sampled By James Gawel	Date 9/28/15	Time 2:38pm
Received By	Date	Time
Relinquished to Aquatic By (Signature)	Date	Time

Shipped By

Shipping Reference

Received at Aquatic By (3) tot 6.9°

Date 9/28/15 Time 4:30

IEH ANALYTICAL LABORATORIES

LABORATORY & CONSULTING SERVICES

3927 AURORA AVENUE NORTH, SEATTLE, WA 98103

PHONE: (206) 632-2715 FAX: (206) 632-2417

CASE FILE NUMBER: **MIS038-17** **PAGE 1**

REPORT DATE: **11/05/15**

DATE SAMPLED: **09/28/15** **DATE RECEIVED:** **09/28/15**

FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM GAWEL - UWT

CASE NARRATIVE

Three water samples were received by the laboratory in good condition and analyzed according to the chain of custody. No difficulties were encountered in the preparation or analysis of these samples. Sample data follows while QA/QC data is contained on the subsequent page.

SAMPLE DATA

SAMPLE ID	TOTAL-P (mg/L)	SRP (mg/L)	TOTAL-N (mg/L)
SURF	0.085	0.004	1.92
BOTTOM-A	0.077	0.004	1.88
BOTTOM-B	0.076	0.003	1.82

CASE FILE NUMBER: **MIS038-17** **PAGE 2**
REPORT DATE: **11/05/15**
DATE SAMPLED: **09/28/15** **DATE RECEIVED:** **09/28/15**
FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM GAWEL - UWT

QA/QC DATA

QC PARAMETER	TOTAL-P (mg/L)	SRP (mg/L)	TOTAL-N (mg/L)
METHOD	SM18 4500PF	SM18 4500PF	SM204500NC
DATE ANALYZED	10/22/15	10/01/15	10/20/15
REPORTING LIMIT	0.002	0.001	0.050
DUPLICATE			
SAMPLE ID	BATCH	BATCH	BATCH
ORIGINAL	0.036	0.028	0.387
DUPLICATE	0.038	0.028	0.401
RPD	5.13%	0.31%	3.53%
SPIKE SAMPLE			
SAMPLE ID	BATCH	BATCH	BATCH
ORIGINAL	0.036	0.028	0.387
SPIKED SAMPLE	0.087	0.047	1.50
SPIKE ADDED	0.050	0.020	1.00
% RECOVERY	101.24%	96.29%	111.81%
QC CHECK			
FOUND	0.093	0.041	0.458
TRUE	0.094	0.039	0.490
% RECOVERY	98.94%	105.13%	93.47%
BLANK	<0.002	<0.001	<0.050

RPD = RELATIVE PERCENT DIFFERENCE.
NA = NOT APPLICABLE OR NOT AVAILABLE.
NC = NOT CALCULABLE DUE TO ONE OR MORE VALUES BEING BELOW THE DETECTION LIMIT.
OR = RECOVERY NOT CALCULABLE DUE TO SPIKE SAMPLE OUT OF RANGE OR SPIKE TOO LOW RELATIVE TO SAMPLE CONCENTRATION.

SUBMITTED BY:

Damien Gadomski

Damien Gadomski
Project Manager

IEH - Aquatic Research
3927 Aurora Ave N • Seattle • WA • 98103
P: 206-632-2715 F: 206-632-2417

IEH

Chain of Custody Form

MI8038-37

Page ____ of ____

REPORT TO:
Client: JAMES GAWEL / UW TACOMA
Address: 1900 COMMERCE ST.
CAMPUS BOX 358436, TACOMA, WA 98402
Contact: JAMES GAWEL
Email: JIM GAWEL @ UW.EDU
Phone: (253) 692-5815 Fax: (253) 692 - 4639

INVOICE TO: (IF DIFFERENT FROM REPORT)
Client:
Address:
Contact:
Email:
Phone: Fax:

PROJECT INFORMATION
Quote No.:
Client PO:
Client Project:

Reporting/Invoicing Format
☐ Fax ☑ Email ☐ Mail

QC Data Reported
☑ Yes ☐ No

Sample Disposal
☐ Hold ☑ Dispose ☐ Return

Turn Around Time (TAT)*
☐ Next Day ☐ 2 Business Day
☐ 3 Business Day ☐ Standard

Specific Date: ____
*Advanced notice required for Rush Analysis

SAMPLING			SAMPLE DESCRIPTION	Number of Containers	Analysis Requested												Field pH (if applicable)	Field Temp (if applicable)	Metals Field Filtered (Y/N)	Containers Received	LAB USE ONLY	
Date (mm-dd-yy)	Time	Matrix**	(This Will Appear On The Report)		TP	[redacted] Ow SRP	TN														Case File Number Temp	Lab ID
10-07-15	0910	SW	STORMWATER	1	✓	✓	✓														

**Matrix: B=Biota, DW=Drinking Water, GW=Ground Water, P=Paint, S=Soil, SD=Sediment, SL=Sludge, SW=Surface Water, WW=Wastewater

Comments:

Sampled By: COREY KING	Date: 10/7/15	Time: 1007
Received By:	Date:	Time:
Relinquished to Aquatic By (Signature)	Date	Time

Shipped By	Shipping Reference

Received at Aquatic By: ① tot 14.5°
Date: 10/7
Time: 4:55

IEH ANALYTICAL LABORATORIES

LABORATORY & CONSULTING SERVICES

3927 AURORA AVENUE NORTH, SEATTLE, WA 98103

PHONE: (206) 632-2715 FAX: (206) 632-2417

CASE FILE NUMBER: **MIS038-37** **PAGE 1**
REPORT DATE: **11/05/15**
DATE SAMPLED: **10/07/15** **DATE RECEIVED:** **10/07/15**
FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM GAWEL - UWT

CASE NARRATIVE

One water sample was received by the laboratory in good condition and analyzed according to the chain of custody. No difficulties were encountered in the preparation or analysis of this sample. Sample data follows while QA/QC data is contained on the subsequent page.

SAMPLE DATA

SAMPLE ID	TOTAL-P (mg/L)	SRP (mg/L)	TOTAL-N (mg/L)
STORMWATER	0.369	0.136	0.925

IEH ANALYTICAL LABORATORIES

LABORATORY & CONSULTING SERVICES

3927 AURORA AVENUE NORTH, SEATTLE, WA 98103

PHONE: (206) 632-2715 FAX: (206) 632-2417

CASE FILE NUMBER: **MIS038-37** **PAGE 2**

REPORT DATE: **11/05/15**

DATE SAMPLED: **10/07/15** **DATE RECEIVED:** **10/07/15**

FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM GAWEL - UWT

QA/QC DATA

QC PARAMETER	TOTAL-P (mg/L)	SRP (mg/L)	TOTAL-N (mg/L)
METHOD	SM18 4500PF	SM18 4500PF	SM204500NC
DATE ANALYZED	10/31/15	10/08/15	11/02/15
REPORTING LIMIT	0.002	0.001	0.050
DUPLICATE			
SAMPLE ID	BATCH	BATCH	BATCH
ORIGINAL	0.010	0.002	0.175
DUPLICATE	0.010	0.002	0.178
RPD	0.00%	0.00%	1.70%
SPIKE SAMPLE			
SAMPLE ID	BATCH	BATCH	BATCH
ORIGINAL	0.010	0.002	0.175
SPIKED SAMPLE	0.062	0.019	1.14
SPIKE ADDED	0.050	0.020	1.00
% RECOVERY	104.00%	85.00%	96.50%
QC CHECK			
FOUND	0.093	0.039	0.509
TRUE	0.094	0.039	0.490
% RECOVERY	98.94%	100.00%	103.88%
BLANK	<0.002	<0.001	<0.050

RPD = RELATIVE PERCENT DIFFERENCE.
NA = NOT APPLICABLE OR NOT AVAILABLE.
NC = NOT CALCULABLE DUE TO ONE OR MORE VALUES BEING BELOW THE DETECTION LIMIT.
OR = RECOVERY NOT CALCULABLE DUE TO SPIKE SAMPLE OUT OF RANGE OR SPIKE TOO LOW RELATIVE TO SAMPLE CONCENTRATION.

SUBMITTED BY:

Damien Gadomski

Damien Gadomski
Project Manager

IEH - Aquatic Research

3927 Aurora Ave N • Seattle • WA • 98103
P: 206-632-2715 F: 206-632-2417

Chain of Custody Form

MI5038-41

Page ____ of ____

REPORT TO:

Client: James Gawel / UW Tacoma

Address: 1900 commerce St
Campus Box 358436, Tacoma WA 98402

Contact: James Gawel

Email: jlmgawel@uw.edu

Phone: 253-692-5815 Fax: 253-692-4639

INVOICE TO: (IF DIFFERENT FROM REPORT)

Client:

Address:

Contact:

Email:

Phone: Fax:

PROJECT INFORMATION

Quote No.:

Client PO:

Client Project:

Reporting/Invoicing Format

☐ Fax ☑ Email ☐ Mail

QC Data Reported

☑ Yes ☐ No

Sample Disposal

☐ Hold ☑ Dispose ☐ Return

Turn Around Time (TAT)*

☐ Next Day ☐ 2 Business Day

☐ 3 Business Day ☐ Standard

Specific Date: ____

*Advanced notice required for Rush Analysis

LAB USE ONLY

Case File Number

SAMPLING			SAMPLE DESCRIPTION		Analysis Requested																	LAB USE ONLY	
Date (mm-dd-yy)	Time	Matrix**	(This Will Appear On The Report)	Number of Containers	TP	SRP	TN											Field pH (if applicable)	Field Temp (if applicable)	Metals Field Filtered (Y/N)	Containers Received	Temp	Lab ID
10/13/15	1:21	SW	Surface	1	|	|	|															
10/13/15	1:30	SW	Bottom-A	1	|	|	|															
10/13/15	1:30	SW	Bottom-B	1	|	|	|															

**Matrix: B=Biota, DW=Drinking Water, GW=Ground Water, P=Paint, S=Soil, SD=Sediment, SL=Sludge, SW=Surface Water, WW=Wastewater

Comments:

Sampled By	Date 10/13/15	Time 3:40 pm
Received By	Date	Time
Relinquished to Aquatic By (Signature)	Date	Time

Shipped By

Shipping Reference

Received at Aquatic By (3)tot 14.4°

Date 10/14

Time 12:20

IEH ANALYTICAL LABORATORIES
LABORATORY & CONSULTING SERVICES
3927 AURORA AVENUE NORTH, SEATTLE, WA 98103
PHONE: (206) 632-2715 FAX: (206) 632-2417

CASE FILE NUMBER: **MIS038-41** **PAGE 1**
REPORT DATE: **11/05/15**
DATE SAMPLED: **10/13/15** **DATE RECEIVED:** **10/14/15**

FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM GAWEL - UWT

CASE NARRATIVE

Three water samples were received by the laboratory in good condition and analyzed according to the chain of custody. No difficulties were encountered in the preparation or analysis of these samples. Sample data follows while QA/QC data is contained on the subsequent page.

SAMPLE DATA

SAMPLE ID	TOTAL-P (mg/L)	SRP (mg/L)	TOTAL-N (mg/L)
SURFACE	0.070	0.002	1.58
BOTTOM-A	0.058	0.002	1.43
BOTTOM-B	0.063	0.001	1.27

CASE FILE NUMBER: **MIS038-41** **PAGE 2**
REPORT DATE: **11/05/15**
DATE SAMPLED: **10/13/15** **DATE RECEIVED:** **10/14/15**
FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM GAWEL - UWT

QA/QC DATA

QC PARAMETER	TOTAL-P (mg/L)	SRP (mg/L)	TOTAL-N (mg/L)
METHOD	SM18 4500PF	SM18 4500PF	SM204500NC
DATE ANALYZED	11/04/15	10/14/15	11/02/15
REPORTING LIMIT	0.002	0.001	0.050
DUPLICATE			
SAMPLE ID	BATCH	BATCH	BATCH
ORIGINAL	0.093	0.028	0.175
DUPLICATE	0.092	0.027	0.178
RPD	1.29%	0.68%	1.70%
SPIKE SAMPLE			
SAMPLE ID	BATCH	BATCH	BATCH
ORIGINAL	0.093	0.028	0.175
SPIKED SAMPLE	0.149	0.048	1.14
SPIKE ADDED	0.050	0.020	1.00
% RECOVERY	112.10%	104.10%	96.50%
QC CHECK			
FOUND	0.094	0.042	0.509
TRUE	0.094	0.039	0.490
% RECOVERY	100.00%	107.69%	103.88%
BLANK	<0.002	<0.001	<0.050

RPD = RELATIVE PERCENT DIFFERENCE.
NA = NOT APPLICABLE OR NOT AVAILABLE.
NC = NOT CALCULABLE DUE TO ONE OR MORE VALUES BEING BELOW THE DETECTION LIMIT.
OR = RECOVERY NOT CALCULABLE DUE TO SPIKE SAMPLE OUT OF RANGE OR SPIKE TOO LOW RELATIVE TO SAMPLE CONCENTRATION.

SUBMITTED BY:

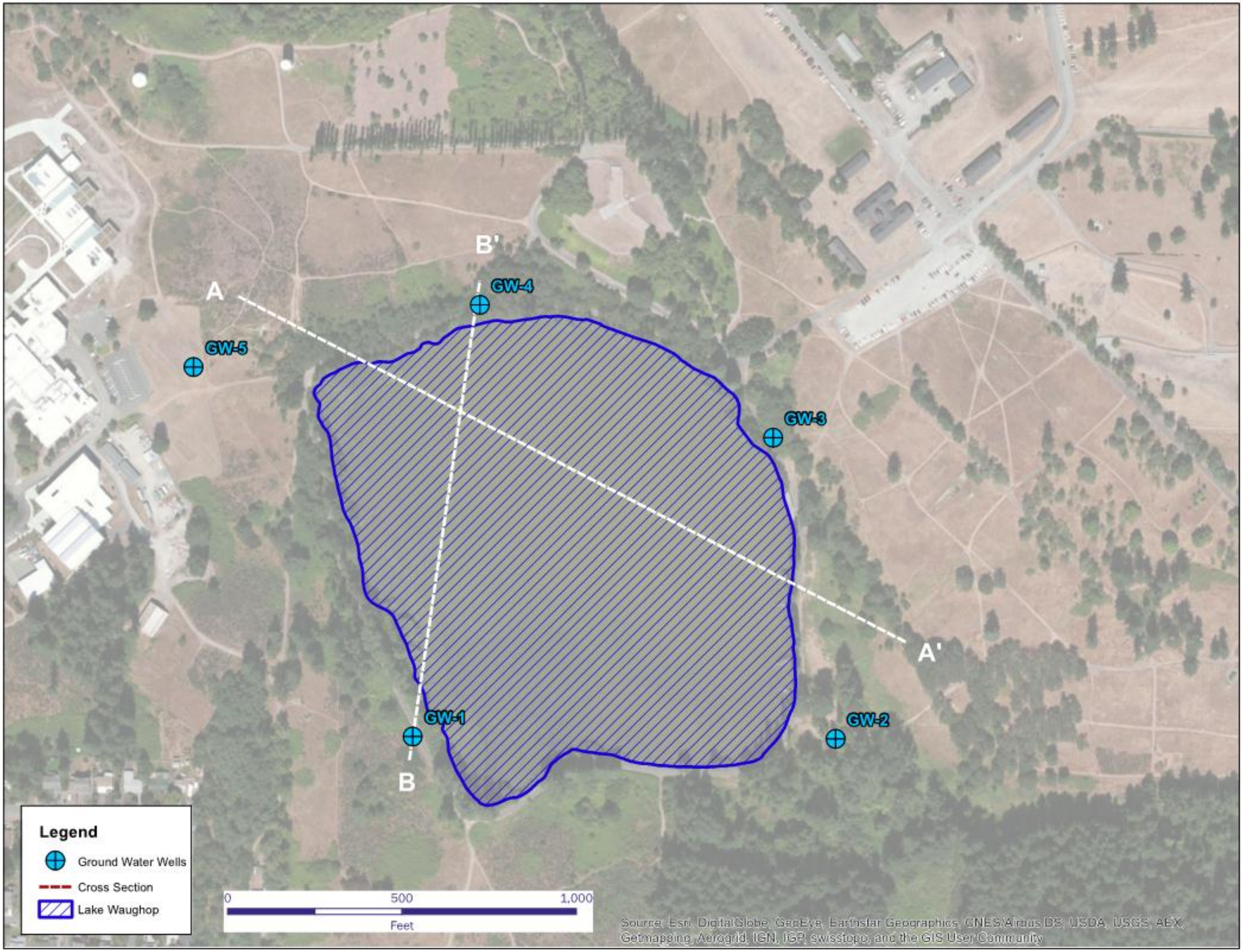
Damien Gadomski

Damien Gadomski
Project Manager

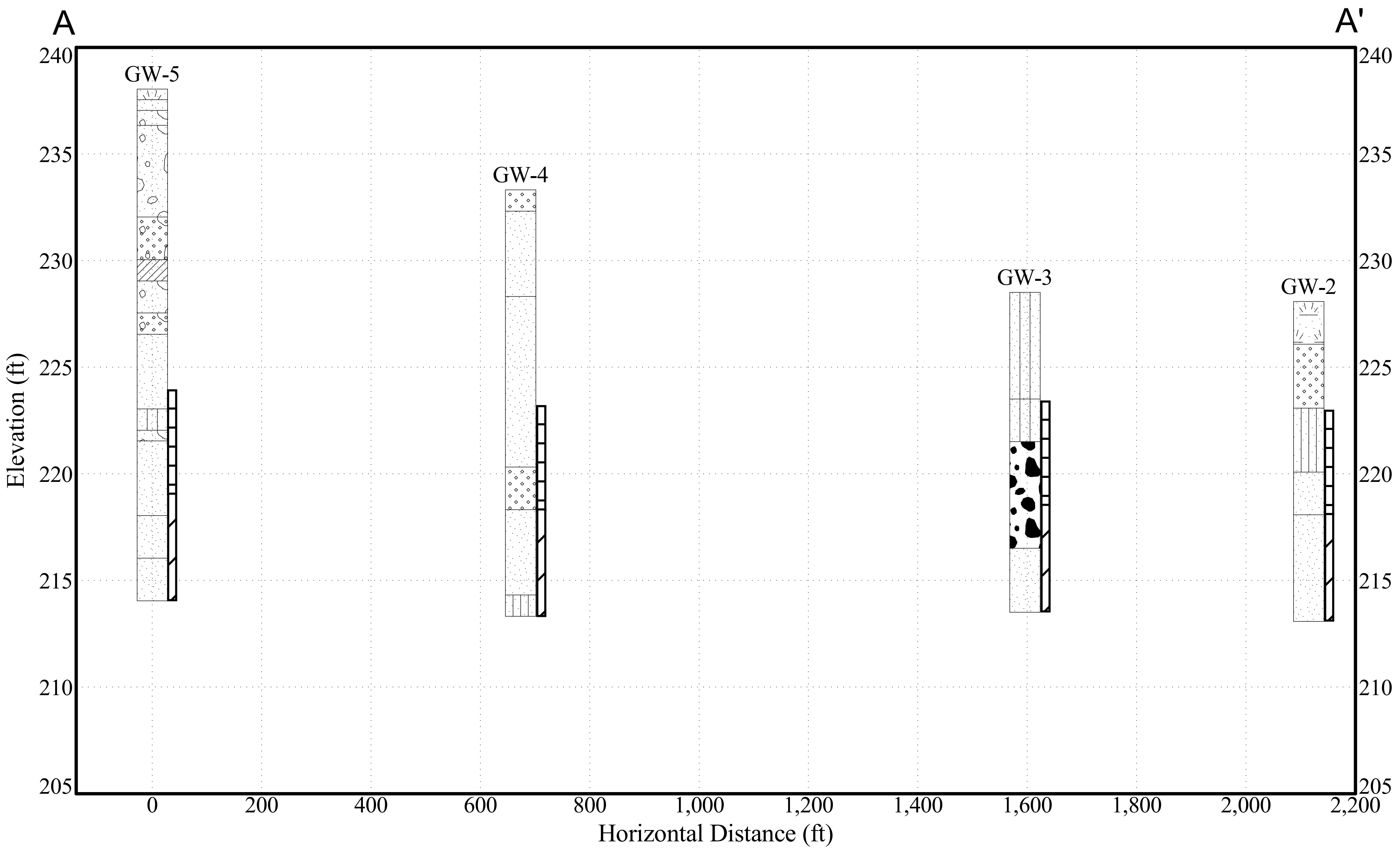
Appendix C: Monitoring Well Logs and Geologic Cross Section Diagrams

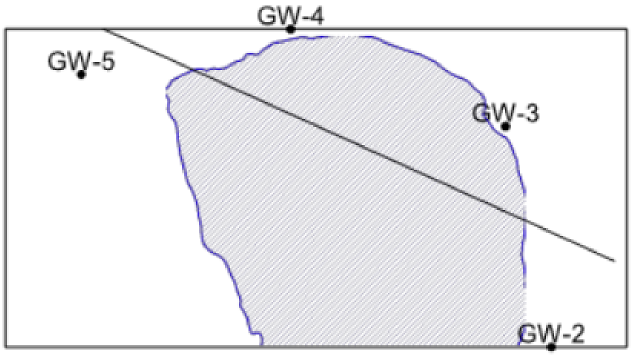
This appendix contains copies of the monitoring well logs from the 2014–15 monitoring study.

This page intentionally left blank.



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community





LEGEND

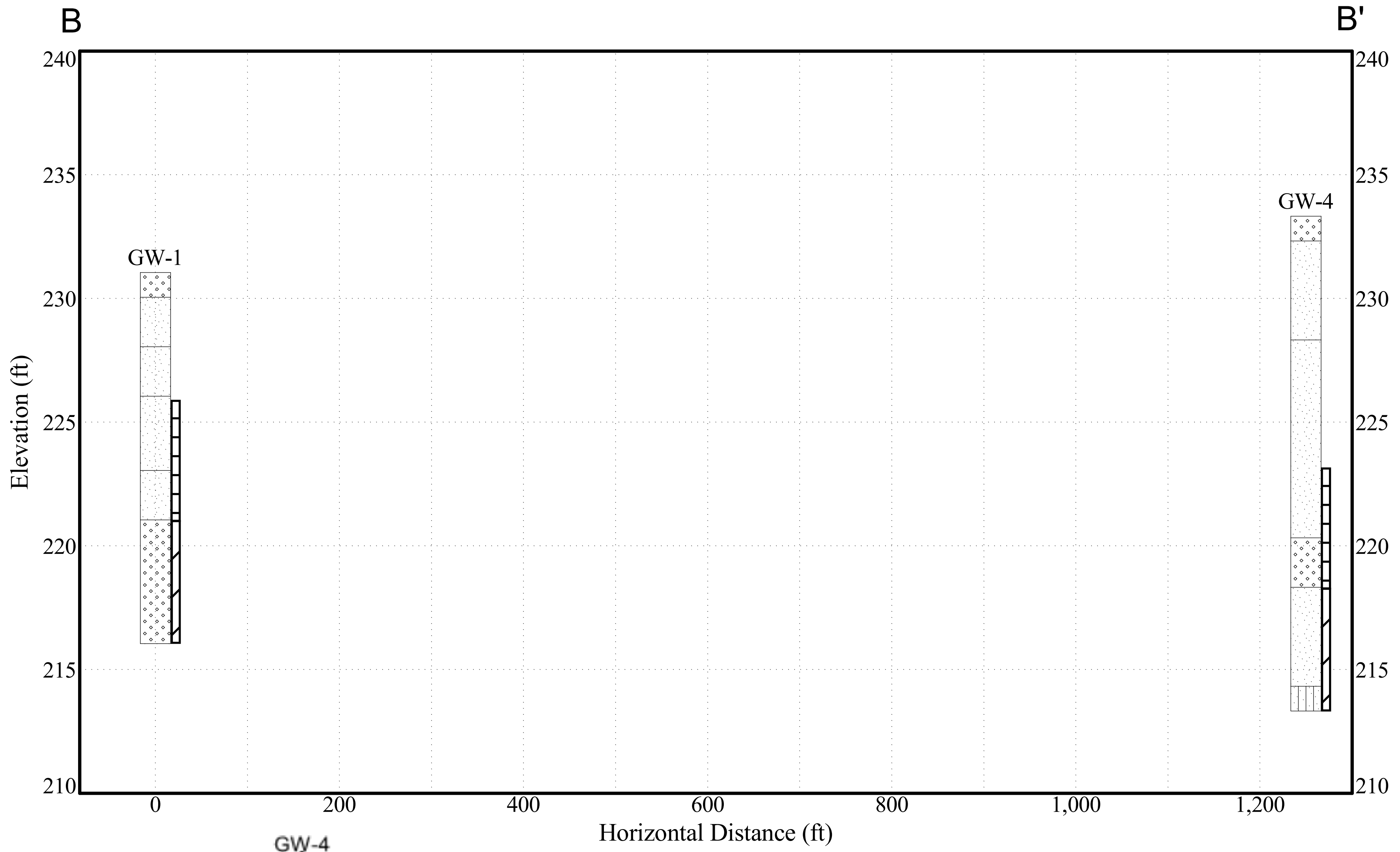
- Topsoil
- USCS Poorly-graded Sand
- USCS Poorly-graded Gravelly Sand
- 10 slot screen
- USCS Well-graded Sand
- USCS Silty Sand
- USCS Well-graded Gravelly Sand
- Prepacked screen
- USCS Sandy Silt
- USCS Well-graded Gravel
- USCS Low Plasticity Sandy Clay

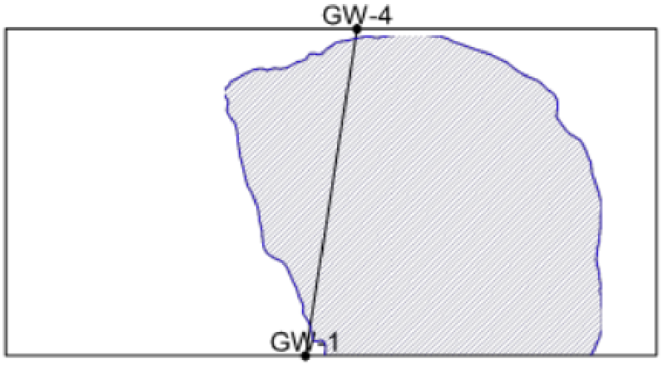
BROWN AND CALDWELL

Cross Section Diagram

Waughop Lake Management Plan
Waughop Lake

PROJECT NO.:	DATE:	FIGURE:
146081	March 10th, 2015	





LEGEND

- USCS Well-graded Sand
- USCS Poorly-graded Sand
- USCS Sandy Silt
- 10 slot screen
- Prepacked screen

BROWN AND CALDWELL

Cross Section Diagram

Waughop Lake Management Plan
Waughop Lake

PROJECT NO.:	DATE:	FIGURE:
146081	March 10th, 2015	

BROWN AND CALDWELL

GW-1

Project Name: **Waughop Lake Management Plan**

Project Number: **146081**

Sheet **1** of **1**

Project Location: **Waughop Lake**

Logged By: **S. Park**

Checked By:

Drilling Contractor: **ESN**

Date Started: **11/10/14**

Date Finished: **11/10/14**

Drilling Equipment:

Driller: **ESN**

Total Boring Depth: (feet) **15.0**

Depth to Static Water: (feet) **10.00**

Drilling Method: **Geoprobe**

Borehole Diameter: **4"**

TOC Elevation(ft): **231.05**

Ground Elevation(ft): **231.05**

Sampling Method:

Diameter and Type of Well Casing: **2" Schedule 40 PVC**

Comments:

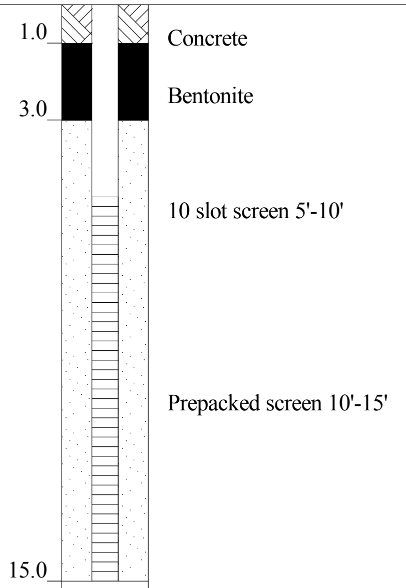
Slot Size: **0.010"**

Filter Material: **10/20 sand**

Development Method:

Depth (feet)	Depth to Water	USC Soil Type	Lithology	Description	PID Readings	Sampled Interval	Recovery (feet)	Sample ID
		SW		SAND. Fine to coarse sand with some silt; dark brown; moist.				
2		SP		SAND. Fine to medium sand with some silt, little gravel; red-brown.			2.5	
4		SP		SAND. Fine to medium sand with trace gravel; tan.				
6		SP		SAND. Fine to medium sand with some silt and trace gravel; tan.			3.8	
8		SP		SAND. Fine sand with little silt and trace gravel; moist.				
10 12 14	▽	SW		SAND. Fine to coarse sand with little silt and gravel; tan; wet at 10'.			5.0	

Remarks



This log should not be used separately from the original report.

GW-2

Project Name: **Waughop Lake Management Plan**

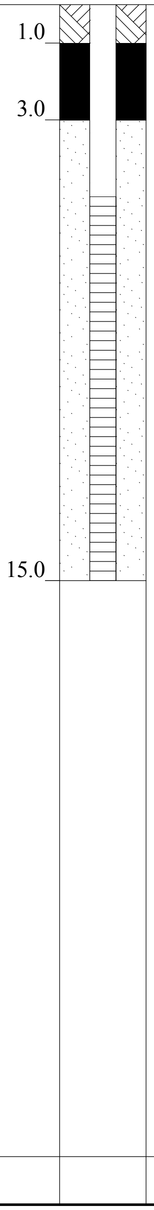
Project Number: **146081**

Sheet **1** of **1**

Project Location: **Waughop Lake**		Logged By: **S. Park**	Checked By:
Drilling Contractor: **ESN**		Date Started: **11/10/14**	Date Finished: **11/10/14**
Drilling Equipment:	Driller: **ESN**	Total Boring Depth: (feet) **15.0**	Depth to Static Water: (feet) **10.00**
Drilling Method: **Geoprobe**	Borehole Diameter: **4"**	TOC Elevation(ft): **228.08**	Ground Elevation(ft): **228.08**
Sampling Method:		Diameter and Type of Well Casing: **2" Schedule 40 PVC**	
Comments:		Slot Size: **0.010"**	Filter Material: **10/20 sand**
		Development Method:	

Depth (feet)	Depth to Water	USC Soil Type	Lithology	Description	PID Readings	Sampled Interval	Recovery (feet)	Sample ID
0–2				TOPSOIL. Organic matter, SILT, fine to coarse sand, and gravel. FILL at 2'; brick.		☒	1.5	
2–5		SW		SAND. Fine to coarse sand with little silt and gravel; dark brown.				
5–8				SILT. Silt with fine sand; dark brown; wet at 10'.		☒	3.0	
8–10		SP		SAND. Fine to medium with trace oxidized roots; gray.				
10–15	▽	SP		SAND. Fine to medium sand with trace oxidized roots; gray. At 15' fine SAND and silt; light gray.		☒	5.0	

Remarks



Concrete

Bentonite

10 slot screen 5'-10'

Prepacked screen 10'-15'

BROWN AND CALDWELL

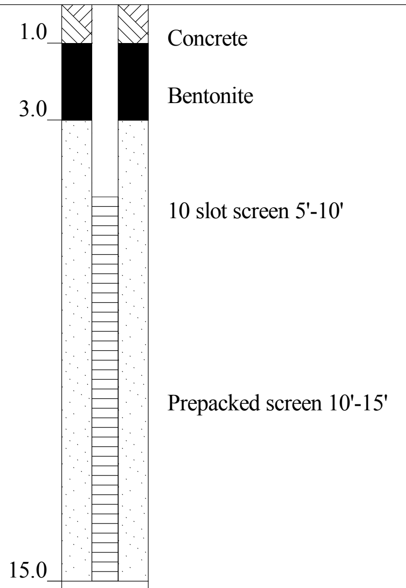
GW-3

Project Name: **Waughop Lake Management Plan**
Project Number: **146081**
Sheet 1 of 1

Project Location: **Waughop Lake**
Logged By: **S. Park**
Checked By:
Drilling Contractor: **ESN**
Date Started: **11/10/14**
Date Finished: **11/10/14**
Drilling Equipment:
Driller: **ESN**
Total Boring Depth: (feet) **15.0**
Depth to Static Water: (feet) **7.00**
Drilling Method: **Geoprobe**
Borehole Diameter: **4"**
TOC Elevation(ft): **228.51**
Ground Elevation(ft): **228.51**
Sampling Method:
Diameter and Type of Well Casing: **2" Schedule 40 PVC**
Comments:
Slot Size: **0.010"**
Filter Material: **10/20 sand**
Development Method:

Depth (feet)	Depth to Water	USC Soil Type	Lithology	Description	PID Readings	Sampled Interval	Recovery (feet)	Sample ID
0–5		SM		Silty SAND. Silt and fine to coarse sand with little gravel; dark brown.		0–5	2.0	
5–7		SM		Silty SAND. Silt and fine to coarse sand, little gravel.		5–10	2.5	
7–12	∇	GW		GRAVEL. Gravel with little coarse sand; wet.		10–15	5.0	
12–15		SP		SAND. Fine sand with silt; gray.				

Remarks



BROWN AND CALDWELL

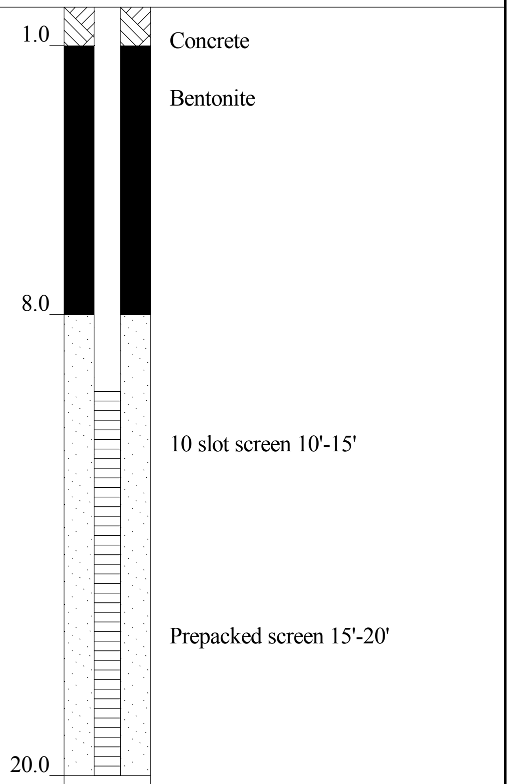
GW-4

Project Name: **Waughop Lake Management Plan**
Project Number: **146081**
Sheet **1** of **1**

Project Location: **Waughop Lake**	Logged By: **S. Park**	Checked By:
Drilling Contractor: **ESN**	Date Started: **11/10/14**	Date Finished: **11/10/14**
Drilling Equipment: Driller: **ESN**	Total Boring Depth: (feet) **20.0**	Depth to Static Water: (feet) **12.30**
Drilling Method: **Geoprobe /auger** Borehole Diameter: **4"**	TOC Elevation(ft): **233.32**	Ground Elevation(ft): **233.32**
Sampling Method:	Diameter and Type of Well Casing: **2" Schedule 40 PVC**	
Comments:	Slot Size: **0.010"**	Filter Material: **10/20 sand**
	Development Method:	

Depth (feet)	Depth to Water	USC Soil Type	Lithology	Description	PID Readings	Sampled Interval	Recovery (feet)	Sample ID
		SW		SAND. Fine to coarse sand with little silt and gravel and organics; brown.			2.5	
2 4		SP		SAND. Medium sand; tan; moist.				
6 8 10 12	▽	SP		SAND. Fine to medium sand with little gravel; gray; moist.			3.0 3.8	
14		SW		SAND. Fine to coarse sand with some gravel and little silt gray; wet at 14'.				
16 18		SP		SAND. Coarse sand with little gravel; gray; wet.			5.0	
20				Sandy SILT. Silt and medium sand; gray.				

Remarks



This log should not be used separately from the original report.

BROWN AND CALDWELL

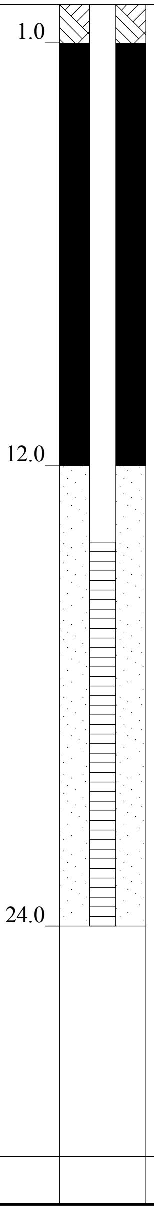
GW-5

Project Name: **Waughop Lake Management Plan**
Project Number: **146081**
Sheet 1 of 1

Project Location: **Waughop Lake**
Logged By: **J. Bethune**
Checked By:
Drilling Contractor: **ESN**
Date Started: **11/10/14**
Date Finished: **11/10/14**
Drilling Equipment:
Driller: **ESN**
Total Boring Depth: (feet) **24.0**
Depth to Static Water: (feet) **17.00**
Drilling Method: **Geoprobe**
Borehole Diameter: **4"**
TOC Elevation(ft): **238.04**
Ground Elevation(ft): **238.04**
Sampling Method:
Diameter and Type of Well Casing: **2" Schedule 40 PVC**
Comments:
Slot Size: **0.010"**
Filter Material: **10/20 sand**
Development Method:

Depth (feet)	Depth to Water	USC Soil Type	Lithology	Description	PID Readings	Sampled Interval	Recovery (feet)	Sample ID
				TOPSOIL.				
		SP		SAND. Poorly graed, fine sand with trace coarse sand and 10% silt; brown; moist.			2.5	
				Gravelly SAND. 70% fine sand, 20% gravel to 1", 10% silt; brown; moist.				
				Gravelly SAND. 70% fine sand, 30% gravel to 1.5"; gray; moist.				
				Gravelly SAND. 60% well graded, fine to coarse sand, 40% gravel; gray; moist.			5.0	
				Sandy CLAY. Clay with 40% sand; low plasticity, low toughness; brown; moist.				
				Gravelly SAND. 60% fine to medium sand, 40% gravel to 1"; gray; moist.				
				Gravelly SAND. 70% well graded, fine to coarse sand, 20% gravel to 0.5", 10% silt; gray; moist.			5.0	
		SP		SAND. Fine sand with silt and trace pea-sized gravel, 10% silt; gray; moist.				
		SM		Silty SAND. 80% fine to medium sand, 20% silt, trace coarse sand; gray; moist.			5.0	
	∇	SP		Gravelly SAND. 80% fine to medium sand, 20% gravel to 1"; gray; moist.				
				SAND. Poorly graded, fine sand with 10% silt and trace gravel; wet at 17'. 2" layer of gravel at 18'.				
		SP		SAND. Poorly graded, fine sand with trace silt and pea-sized gravel; wet.			4.0	
		SP		SAND. Poorly graded, fine to medium sand with trace silt and gravel; wet.				

Remarks



Concrete

Bentonite

10 slot screen 14'-19'

Prepacked screen 19'-24'

This log should not be used separately from the original report.

Appendix D: Management Measures Fact Sheets

This appendix contains a copy of the preliminary management measures matrix and fact sheets.

This page intentionally left blank.

FACT SHEETS: DREDGING

Management Measure Option Name:	Dredging – Hydraulic Dredge
Description	Use hydraulic dredge to remove ~121,000 cy of sediment. Costs may vary substantially depending on whether sediment can be disposed on site and other factors. Lower cost if passive dewatering and on-site disposal. Higher cost if mechanical dewatering and off-site disposal are required.
Objectives	Remove P enriched sediment (approx. 100 cm thick) from bottom of the 33 acre lake.
Initial planning level cost estimate[1]	On-site disposal: $2.7M to $9.40M; Off-site disposal: $8.5M to $15M
Estimated annual operation and maintenance cost[2]	None
Basis for preliminary sizing	121,000 cubic yards
Water quality benefit[3]	Highest. Would remove ~100 years of P enriched sediment
Approximate time to see water quality benefit	<1 year
Duration/frequency	Long-term
Other potential benefits	Increased lake depth, more groundwater inflow, more fish habitat
Other potential impacts/costs	Habitat disturbance during dredging (but less than "Wet" Excavation option, odor from dredge spoils, on-site dewatering/ disposal would require large area, equipment staging on shoreline.
Required infrastructure	Varies based on type of dredging and whether on-site disposal is feasible. Temporary pipes, mechanical dewatering system, and stockpile/dewatering area; temporary treatment facility for water draining from dredge spoils.
Pre-design work needed	Sediment cores, % solids, chemical testing to determine disposal requirements
Additional comments	Passive dewatering impractical due to volume, odor. Disposal costs assume sediment is not hazardous.

Basis of design/assumptions

Item	Low	High	Unit	Assumptions
Sediment Quantity	121,000		cy	
Equipment mobilization	20000	50000	LS	
Hydraulic dredging	5	15	$/cy	
Dewatering	4	10	$/cy	Low - passive dewatering system, high - mechanical systems; May need to differentiate dewatering systems and include costs for geotubes
Polymer addititive	2	7	$/cy	
Offsite disposal	40	60	$/cy	Low - local disposal site, High - multiple handlings, distant disposal facility
Onsite disposal	5	25	$/cy	Low - land application/surface spreading, High - contained/capped

Cost Breakdown for Initial Planning Level Cost Estimates1

Hydraulic Dredge, Onsite Disposal	Low	High		
Unit price dredge and disposal on-site	$ 16	$ 57		
Contractor fees	$ 1,956,000	$ 6,947,000		
Engineering fees and permitting	$ 293,400	$ 1,042,050		
Contingency	$ 449,880	$ 1,389,400		
Taxes (?)	$ 156,480	$ 555,760		
Total (no tax)	**$ 2,699,280**	**$ 9,378,450**		
Hydraulic Dredge, Offsite Disposal	**Low**	**High**		
Unit price dredge and disposal on-site	$ 51	$ 92		
Contractor fees	$ 6,191,000	$ 11,182,000		
Engineering fees and permitting	$ 928,650	$ 1,677,300		
Contingency	$ 1,423,930	$ 2,571,860		
Taxes (?)	$ 495,280	$ 894,560		
Total (no tax)	**$ 8,543,580**	**$ 15,431,160**		

Notes:

1. Based on the planning-level information and concept development stage of this project, conceptual level costs were estimated following the Association for the Advancement of Cost Engineering (AACE) Class 5 Cost Estimate Classification System, providing estimates in the range of-50% to +100% for the candidate actions.

2. Planning-level estimate of annual O&M costs in 2016 dollars

Dredging – “Wet” Excavation

Description	Remove ~121,000 cy of sediment. Costs vary substantially depending on whether sediment can be disposed on site, as well as other factors. Lower cost for passive dewatering and on-site disposal. Higher cost for mechanical dewatering and off-site disposal.
Objectives	Remove P enriched sediment (approx. 100 cm thick) from bottom of the 33 acre lake.
Initial planning level cost estimate[1]	On-site disposal: $3.2M to $12.0M; Off-site disposal: $9.0M to $17.9M
Estimated annual operation and maintenance cost[2]	None
Basis for preliminary sizing	121,000 cubic yards
Water quality benefit[3]	Highest. Would remove ~100 years of P enriched sediment
Approximate time to see water quality benefit	<1 year
Duration/frequency	Long-term
Other potential benefits	Increased lake depth, more groundwater inflow, more fish habitat
Other potential impacts/costs	Habitat disturbance during dredging, odor from dredge spoils, on-site dewatering/ disposal would require large area, equipment staging on shoreline.
Required infrastructure	Varies based on type of dredging and feasibility of lake dewatering, disposal requriements, etc. Temporary pipes, mechanical dewatering system, and stockpile/dewatering area; temporary treatment facility for water draining from dredge spoils.
Pre-design work needed	Sediment core sampling, % solids analysis to evaluate dewatering needs, chemical testing to determine disposal requirements
Additional comments	Dewatering the lake may be impractical due to fine organic sediments, high groundwater, and aquatic habitat impacts. Passive dewatering of dredged material likley impractical due to volume, odor. Disposal costs assume sediment is not hazardous.

Basis of design/assumptions

Item	Low	High	Unit	Assumptions
Sediment Quantity	121,000		cy	
Equipment mobilization	20000	50000	LS	
Mechanical dredging	8	30	$/cy	
Dewatering	4	10	$/cy	Low - passive dewatering system, high - mechanical systems; May need to differentiate dewatering systems and include costs for geotubes
Polymer addititive	2	7	$/cy	
Offsite disposal	40	60	$/cy	Low - local disposal site, High - multiple handlings, distant disposal facility
Onsite disposal	5	25	$/cy	Low - land application/surface spreading, High - contained/capped

Cost Breakdown for Initial Planning Level Cost Estimates1

"Wet" Excavation: Mechanical Dredging, Onsite Disposal	Low	High		
Unit price dredge and disposal on-site	$ 19	$ 72		
Contractor fees	$ 2,319,000	$ 8,762,000		
Engineering fees and permitting	$ 347,850	$ 1,314,300		
Contingency	$ 533,370	$ 2,015,260		
Taxes (?)	$ 185,520	$ 700,960		
Total (no tax)	**$ 3,200,220**	**$ 12,091,560**		

"Wet" Excavation: Mechanical Dredging, Offsite Disposal	Low	High		
Unit price dredge and disposal on-site	$ 54	$ 107		
Contractor fees	$ 6,554,000	$ 12,997,000		
Engineering fees and permitting	$ 983,100	$ 1,949,550		
Contingency	$ 1,507,420	$ 2,989,310		
Taxes (?)	$ 524,320	$ 1,039,760		
Total (no tax)	**$ 9,044,520**	**$ 17,935,860**		

Notes:

1. Based on the planning-level information and concept development stage of this project, conceptual level costs were estimated following the Association for the Advancement of Cost Engineering (AACE) Class 5 Cost Estimate Classification System, providing estimates in the range of-50% to +100% for the candidate actions.
2. Planning-level estimate of annual O&M costs in 2016 dollars
3. Long-term lake monitoring is recommended to evaluate the effectiveness of the selected lake management measure(s).

FACT SHEET AND SUPPLEMENTARY INFORMATION:
WHOLE LAKE TREATMENT, PHOSPHORUS INACTIVATION

Phosphorus Inactivation - Alum Treatment

Description	Add ~20,000 gallons of alum and ~10,000 gallons of sodium aluminate to remove P from water column and form layer on sediment. A lower dose may be needed every 3 to 10 years.
Objectives	Control internal loading of P and mitigate algae problems.
Initial planning level cost estimate[1]	$210K for prep and initial treatment
Estimated annual operation and maintenance cost[2]	$120K every 3 to 10 yrs
Basis for preliminary sizing	Mass of phosphorus in top 10 cm of sediment and lake water; 4 moles of aluminum: 1 mole of phosphorus for dose
Water quality benefit[3]	High initially, slow decline over time
Approximate time to see water quality benefit	Immediate
Duration/frequency	3-10 years
Other potential benefits	Minimal infrastructure, no conflicts with other lake uses. Once 2nd treatment is complete, benefits are expected to continue for 3 to 10 years. "Benefit" does not mean that the lake will be algae or cyanobacteria free.
Other potential impacts/costs	Could increase macrophyte growth. Would need to be repeated every 3-10 yrs; When complete will be able to see everything on the lake bottom - trash, etc.; Flocculent could negatively impact some filter feeder fish; A highly qualified applicator must be used to avoid issues with water pH and alkalinity. Immediately after treatment, some algae may float to the surface for a day or two before settling.
Required infrastructure	None
Pre-design work needed	Jar testing
Additional comments	It would be beneficial to remove emergent vegetation in the lake prior to treatment. That cost is not included. Present Worth Cost: For cost comparison, suggest we assume that the treatment will need to be repeated every 5-10 years; Each of these applications should require less chemical, assume 50% of original amount.

Basis of design/assumptions and Cost Breakdown for Initial Planning Level Cost Estimates1

Item	Labor	Expenses	Total	Assumptions
Sediment analyses	$ 6,000.00	$ 3,500.00	$ 9,500.00	3 days x 2 x $125; 20 samples x $150
Lake Water Jar Testing	$ 6,000.00	$ 7,000.00	$ 13,000.00	3 days x 2 x $125; 40 samples x $150; YSI In-situ
Pre-application Planning	$ 20,800.00	$ 1,000.00	$ 21,800.00	40 hours x $150; 40 hours x $250; 40 hours x $120
Permitting (Costs for permitting are not included in this estimate)	TBD	TBD	TBD	
Observation/Testing during Application	$ 8,000.00	$ 7,000.00	$ 15,000.00	4 days x 2 x $125; 40 samples x $150; YSI In-situ
Application	$ 50,000.00	$ 80,000.00	$ 130,000.00	Contractor - cost breakdown estimated; split application
Post Treatment Testing	$ 8,000.00	$ 10,500.00	$ 18,500.00	8 events x 2 staff x 4 hours x $120; 64 samples x $150; YSI in-situ
Totals	**$ 98,800.00**	**$ 109,000.00**	**$ 207,800.00**	

Aluminum Treatment Calculation

Assumptions:				
Sediment (top 10 cm)		Total P in water	256	kg P
2365	kg P	Total P in sediment	2,365	kg P
Lake Volume		Total P	2,621	kg P
231	ac-ft	Total P	84,557	moles P
284,737,934	L	4 Al:1P molar ratio	338,228	moles Al
Overall dose to water			9,132,146	g Al
35	mg Al/L water	With 10% SF Use	10,000	Kg Al
			228,000,000	g alum
31 g P = 1 mole		Use	45,000	gal alum
27 g Al = 1 mole		Alum alone cannot be used due to low alkalinity		
4:1 ratio				
Use 19,621 gallons of alum and 9,810 gallons of sodium aluminate; apply 50% each in two applications; 2-3 days each application				

Notes:

1. Based on the planning-level information and concept development stage of this project, conceptual level costs were estimated following the Association for the Advancement of Cost Engineering (AACE) Class 5 Cost Estimate Classification System, providing estimates in the range of-50% to +100% for the candidate actions.

2. Planning-level estimate of annual O&M costs in 2016 dollars

Additional Information on the Aluminum Treatment Option

1.1 Chemical Treatment

This appendix provides an introduction to using aluminum sulfate (i.e., alum) as a treatment option, along with a brief summary on its historical use. Information on aluminum chemistry and potential effects on aquatic organisms and plants is also included.

1.1.1 Introduction

Aluminum is the third-most abundant element in the earth, comprising 8 percent of the earth's crust. Aluminum occurs naturally in soil, water, and air. It is a reactive element so it is almost never found as a free metal in nature. It is found combined with other elements, most commonly with oxygen, silicon, and fluorine. These chemical compounds are commonly found in soil, minerals (e.g., sapphires, rubies, and turquoise), rocks (especially igneous rocks), and clays. Throughout the United States, aluminum coagulants are used daily to treat wastewater and drinking water. Aluminum is used to make beverage cans, pots and pans, airplanes, siding and roofing, and foil—it is present in almost all natural waters and in many of the foods and drinks we consume daily.

1.1.2 History of Use

There is evidence that aluminum compounds were used since Roman times for the removal of turbidity and other impurities from surface and drinking water. In the modern era, aluminum coagulants have been used for more than 100 years to remove impurities from drinking water sources and wastewater. Each day a wide range of aluminum coagulants are used extensively throughout the world in wastewater treatment processes to remove phosphorus and other pollutants. In many cases, the treated water is returned to a lake or river and withdrawn downstream as a drinking water supply. Aluminum coagulants are also used extensively to treat surface water drinking water supplies, and are effective for removing a wide range of pollutants including: turbidity, suspended solids, color, heavy metals, nutrients, pathogens, and organic compounds.

There are dozens of aluminum coagulants that are commonly used throughout the United States at this time. The most common forms include alum, polyaluminum chloride, sodium aluminate, and aluminum chlorohydrate. Alum consumes alkalinity and reduces water pH (aluminum chlorohydrate has no effect on water pH), and sodium aluminate increases water pH. For this reason, these coagulants are often used together for whole-lake treatments in poorly buffered lakes. Alum in liquid form is likely the most commonly used aluminum coagulant due to its purity, availability, and relatively low cost.

In 1970, granular alum was mixed with lake water and applied to the surface of Horseshoe Lake in Wisconsin to reduce the concentration of phosphorus in the water column. This is the first recorded surface application of an aluminum coagulant to a lake in the United States. Because of the beneficial effects on water quality, alum and other coagulants are now routinely applied to the surface of lakes as a lake management tool. The surface application of coagulants removes phosphorus in the lake water column and binds phosphorus in lake bottom sediments to substantially reduce internal phosphorus recycling; the reduction in internal phosphorus load improves lake water quality. Phosphorus in lake bottom sediment is sequestered by converting saloid- (i.e., loosely) and iron-bound phosphorus forms to aluminum-bound forms. Loosely bound phosphorus can be released under oxic conditions while iron-bound phosphorus is typically released under anoxic conditions. The bond created with aluminum is very strong and unaffected by the oxidation-reduction potential—in other words, the aluminum phosphorus bond is unaffected by anoxic (low dissolved oxygen [DO]) conditions at the sediment-water interface.

Lake Conine is a 237-acre lake located in Polk County, Florida. For many years the lake received wastewater discharge resulting in hypereutrophic conditions (e.g., very high phosphorus and chlorophyll-a concentrations, algal blooms, and poor water quality) and lake bottom sediment with substantial available phosphorus. A rigorous evaluation was completed of sediment phosphorus speciation and concentration throughout the lake, and isopleth maps were produced of available phosphorus concentrations. These maps were used to calculate the total available sediment phosphorus, required aluminum dose necessary to bind the available phosphorus, and required dose for each of the 14 lake segments. Extensive jar testing was then completed along with lake water quality monitoring to evaluate the lake response to various alum doses. Because of sufficient lake water alkalinity, this surface application required only alum and no additional buffering compounds. Sodium aluminate is commonly used in poorly buffered lakes. In 1995, approximately 127,000 gallons of alum were applied to the surface of Lake Conine during a 2-week period. Lake water chemistry including pH was carefully monitored throughout the treatment process. No adverse impacts on fisheries or other wildlife were observed during or following treatment.

Extensive post-treatment sediment and water quality monitoring was completed to verify the effectiveness of the application. This included a post-treatment evaluation of sediment phosphorus speciation and concentration. Polk County performs routine monitoring, and a plot of Lake Conine in-lake total phosphorus (TP) concentration is shown in Figure 1, below. The surface treatment resulted in substantial water quality improvement that is still evident today. It is important to note that the lake receives untreated stormwater, which does have an impact on lake TP concentration and water quality.

Lake Conine is one of many lakes that have been treated with aluminum coagulants in Florida to substantially reduce the release of phosphorus from lake bottom sediment. In each case, evaluations were completed to estimate the available sediment phosphorus load and response to treatment. Some applications have used combinations of coagulants to provide additional lake water alkalinity and maintain acceptable lake water pH. Successful aluminum treatments have also been completed in lakes throughout the United States during the past 30 years, including recently in Green Lake in the Seattle area.

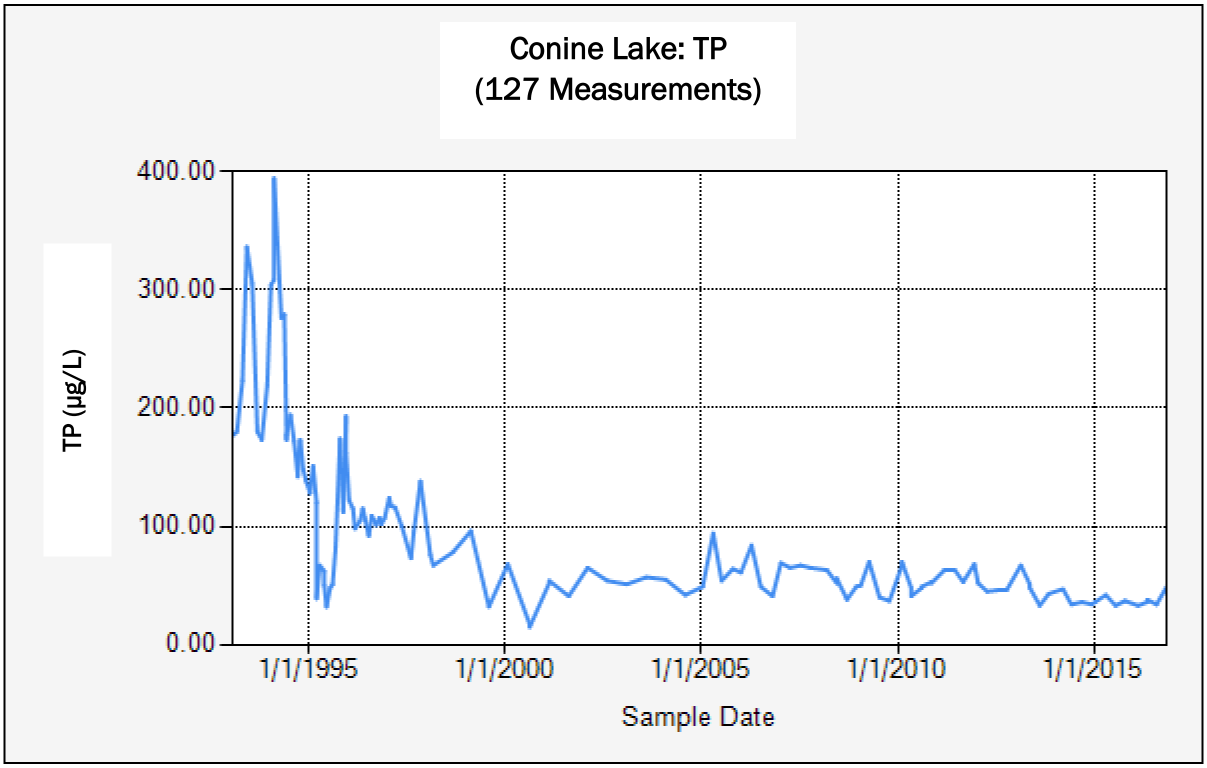


Figure 1. Measured TP concentration in Lake Conine over time
(Source: Polk County Water Atlas 2017).

Aluminum coagulants are also used to treat nonpoint source discharges. The first known use of a metal salt coagulant to treat nonpoint source discharges was at Lake Ella (surface area is 13 acres) in Tallahassee, Florida, in 1987. Stormwater runoff was the primary source of phosphorus to this shallow, hypereutrophic lake. Coagulant treatment of stormwater was selected because there was no space adjacent to the lake to construct traditional stormwater treatment best management practices (BMPs) such as wet or dry retention basins. After extensive jar testing with alum and other coagulants—along with preconstruction testing of lake surface water quality, sediment quality, and benthic macroinvertebrate sampling—a coagulant stormwater treatment system was designed and constructed in 1987. The system, which has now been in operation for almost 30 years, includes water flow meters to continuously measure the flow of water through six stormwater outfalls into the lake. The water flow rate information is sent back to a treatment equipment building, which houses six coagulant feed pumps and a coagulant storage tank. Alum is added automatically on a flow-proportionate basis to maintain the same coagulant dose regardless of water flow rate. Precipitates—which include phosphorus and other pollutants—settle to the bottom of the lake. The project resulted in immediate and substantial improvement in lake water quality. As a condition of construction permit approval from the Florida Department of Environmental Regulation (FDER, now FDEP), extensive post-construction testing was performed on lake surface water quality, sediment quality, and benthic macroinvertebrates; improvements were observed in all areas evaluated. Lake Ella has now been receiving aluminum precipitates for 30 years with no observed adverse impacts, and has received substantially more aluminum than numerous whole-lake treatments.

Since Lake Ella, more than 30 coagulant treatment systems have been constructed to reduce the concentration of phosphorus and other pollutants in nonpoint source discharges and to improve surface water quality. Early systems (1987–96) are mostly in line with the resulting floc settling in natural lakes, and the use of offline systems with floc settling ponds began in the mid-1990s. Current systems use offline settling ponds almost exclusively and have evolved to include automated floc removal and dewatering systems. Coagulant treatment has also been combined with other treatment train components, including sedimentation basins and constructed wetlands to minimize coagulant use.

A graphical history of TP concentrations in Lake Lucerne (Orlando, Florida)—which was retrofitted with an alum stormwater treatment system in June 1993 and provides treatment for approximately 82 percent of the annual runoff inputs into the lake—is provided in Figure 2. Alum is injected into six stormwater outfalls from a 300-acre highly urbanized watershed with precipitates settling on the bottom of the approximately 30-acre lake. Prior to construction of the alum stormwater treatment system, TP concentrations in Lake Lucerne fluctuated widely, with a mean concentration of approximately 100 micrograms per liter (µg/L). Following startup of the alum treatment system, TP concentrations began to decline steadily, reaching equilibrium concentrations of approximately 20 µg/L. A slight increase in TP concentrations was observed during the last half of 1995 when the system was offline due to lightning damage. When system operation resumed in June 1996, TP concentrations returned to equilibrium values of approximately 20 µg/L.

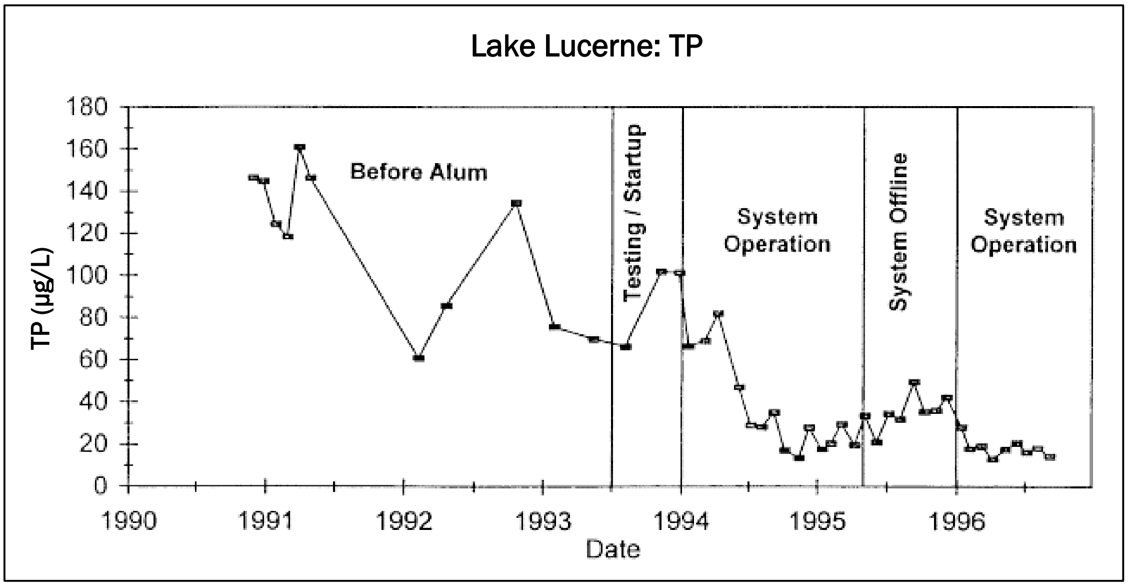


Figure 2. Measured TP concentration in Lake Lucerne over time

Measured concentrations of heavy metals have been extremely low in value in all waterbodies retrofitted with alum stormwater treatment systems, with no violations of heavy metal standards observed in any of these lake systems. In addition, measured levels of dissolved aluminum have also remained low in each lake system. Mean dissolved aluminum concentrations have averaged in the 40 to 70 µg/L range.

A large amount of research has been conducted to evaluate the stability of phosphorus and heavy metals in sediments that are receiving alum floc. These evaluations have been performed using a variety of methodologies, including sediment phosphorus speciation, incubation experiments, and analysis of sediment pore water characteristics.

Analysis of sediment phosphorus has been performed on both pre- and post-alum treatment sediment samples for Lake Ella, Lake Dot, Lake Lucerne, and Lake Cannon, as well as Lake Davis and Lake Conine, which received whole-lake alum treatments for sediment inactivation. The modified Chang and Jackson procedure was used to speciate TP into saloid (i.e., soluble plus easily exchangeable phosphorus, iron phosphate, and aluminum phosphate) (1957). Phosphorus associations with saloid and iron phosphate are generally considered available to recycle back into the water column, particularly under anoxic conditions. Sediment associations with aluminum are typically considered to be inert and stable under a wide range of pH and redox (e.g., DO) conditions. In all lake systems where phosphorus speciation has been evaluated, the addition of alum floc into the sediments has reduced saloid- and iron-bound concentrations and increased aluminum-bound concentrations. Sediment phosphorus is less available following the introduction of alum floc.

1.2 Chemistry of Aluminum Coagulants

Aluminum coagulants are commonly selected over ferric (i.e., iron) coagulants because of the high ionic charge of aluminum and small crystalline radius. Aluminum coagulants are more reactive than any other soluble metal, and another benefit is the quality and availability of aluminum coagulants. Aluminum coagulants are manufactured using quality raw materials with minimal impurities, are approved for drinking water treatment, and are used extensively throughout the United States daily to treat surface drinking water sources for potable use. Aluminum precipitates are also very stable with minimum aluminum solubility in the pH range of natural surface waters (6 to 8 standard units [S.U.]). Ferric coagulants are often manufactured using lower-quality materials such as scrap iron, and ferric precipitates have minimum solubility at a water pH lower than typical for natural surface waters. Aluminum precipitates are also stable with changes in water reduction-oxidation potential (related to the water DO concentration); ferric precipitates can dissolve under reduced conditions (e.g., low DO).

Adding aluminum-based coagulants to water creates precipitates that remove pollutants by two primary reactions. The removal of suspended solids, particulate phosphorus, heavy metals, and bacteria occurs primarily by enmeshment and adsorption onto aluminum hydroxide precipitate, per the following reaction:

$$Al^{+3} + 6H_2O \rightarrow Al(OH)_{3(s)} + 3H_3O^+$$

The aluminum hydroxide precipitate, $Al(OH)_3$, is a gelatinous floc that attracts and adsorbs colloidal particles onto the growing floc, thus purifying the water. Removing dissolved phosphorus is achieved by the direct formation of aluminum phosphate, per the following reaction:

$$Al^{+3} + HnPO_4^{n-3} \rightarrow AlPO_{4(s)} + nH^+$$

The aluminum chemical reactions occur quickly and are generally complete in less than 30 to 45 seconds. In less than 1 minute of contact time between the coagulant and water, the coagulant no longer exists, and only the resulting aluminum hydroxide and aluminum phosphate are present in the treated water. The solubility of dissolved aluminum in the treated water is regulated primarily by water pH. Because the addition of many aluminum coagulants slightly reduces water pH, and the minimum solubility of aluminum is in the 6 to 7 S.U. pH range, the dissolved aluminum concentration in treated water is often less than the raw water. A solubility diagram for simultaneous aluminum hydroxide and aluminum phosphate precipitates is shown in Figure 3, below.

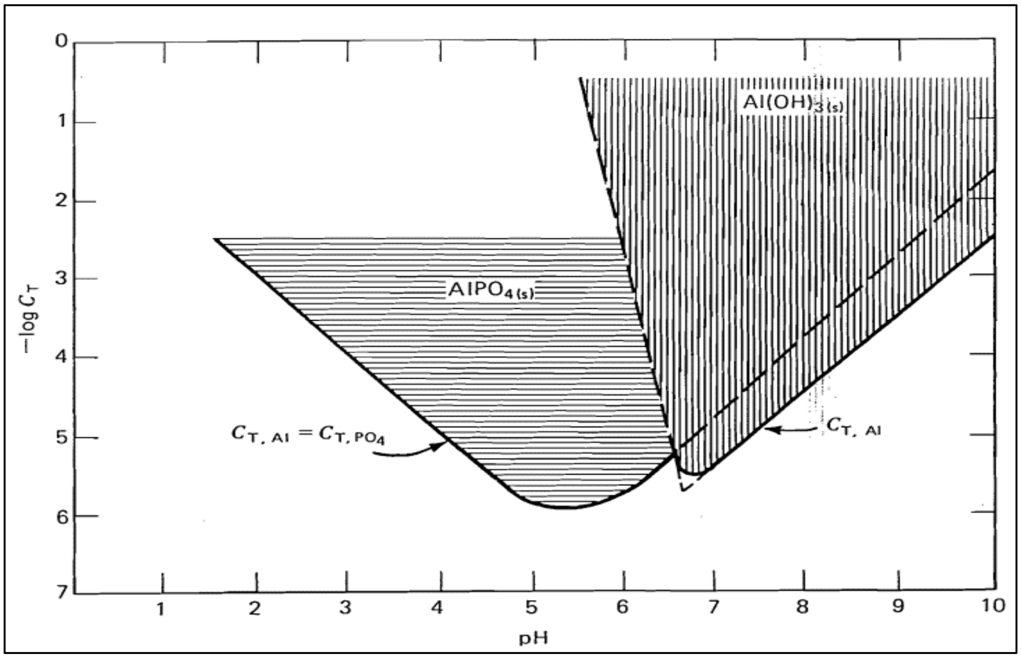


Figure 3. Solubility of simultaneous aluminum hydroxide and aluminum phosphate precipitates

Aluminum precipitates (once formed) are exceptionally stable and do not dissolve because of typical changes in pH or redox potential in natural waters; therefore, pollutants such as phosphorus trapped by the precipitates are not released into soils or groundwater. As the floc ages at the bottom of the lake or settling pond, more stable complexes form, eventually forming gibbsite. Gibbsite is an important ore of aluminum and is one of the three phases that make up the rock bauxite. Bauxite is mined around the world and is the primary source of raw aluminum.

The floc formed as a result of the coagulation process will settle to the bottom of the lake or wet settling pond and will remain there. The typical floc volume is 0.2 to 0.4 percent of the treated water volume, depending on the aluminum dose. Based on the monitoring of floc accumulation at multiple lakes that receive aluminum precipitates, the actual floc accumulation depth is less than the predicted depth. Benthic organisms tend to mix the flocculent precipitates into the lake bottom sediment over time, so there is often no measurable floc layer. In several lakes, no distinct floc layer was visible 1 year following treatment.

Because phosphorus and other pollutants contained in the floc are tightly bound, under natural conditions these pollutants will not be released from the floc into the lake, pond bottom soils, or surrounding groundwater system. Freshly formed floc is typically 98 to 99 percent water. As additional floc depth accumulates, it will consolidate to some extent but will still be on the order of 95 to 98 percent water until dewatered.

1.3 Drinking Water Standards and Recommended Water Quality Criteria for Aluminum

The U.S. Environmental Protection Agency (EPA) has established National Secondary Drinking Water Regulations that set non-mandatory water quality standards for 15 contaminants. EPA does not enforce these secondary maximum contaminant levels (SMCLs), they are established only as guidelines to assist public water systems in managing drinking water for aesthetic considerations, such as taste, color, and odor. These contaminants are not considered to be a risk to human health at the SMCL. The secondary drinking water standard for aluminum is 0.05 to 0.20 milligram per liter (mg/L) related to water color.

In 1988, EPA published recommendations on surface water quality criteria for the protection of aquatic organisms from the effects of aluminum. EPA completed an extensive analysis of the latest information on the effects of aluminum on aquatic vertebrates, invertebrates, and plants. This included acute toxicity data for 20 species of freshwater organisms and chronic toxicity data for 5 species of freshwater organisms. A summary of information gathered by EPA on the effect of aluminum on aquatic freshwater species is summarized in Table 1. The most sensitive freshwater vertebrate is the juvenile brook trout (Salvelinus fontinalis) with a lethal concentration 50 (LC50) of 3,600 µg/L (Decker and Menendez 1974). The most sensitive freshwater invertebrate is a cladoceran (Ceriodaphnia dubis) with an LC50 of 1,900 µg/L (McCauley et al. 1986).

A summary of information gathered by EPA on the effects of aluminum on aquatic freshwater plants is listed in Table 2, below. The most sensitive freshwater alga is Selenastrum capricornutum with a half maximal effective concentration (EC50) of 460 µg/L (Call 1984). A review of the available data on the chronic effect of aluminum is shown in Table 3, below. Daphnia magna is the most sensitive invertebrate species tested, with a chronic value of 742 µg/L.

Based on a review of the previously described studies and reports, EPA established guidelines for aluminum concentrations based upon protection of the most sensitive aquatic species. As a result, the criteria are conservative. To provide protection from chronic toxicity, the criteria recommend that the 4-day average concentration of dissolved aluminum not exceed 87 µg/L more than once every 3 years (on the average) when the ambient pH is between 6.5 and 9.0 S.U. EPA also recommends that to provide additional protection from acute toxicity, the 1-hour average concentration of dissolved aluminum not exceed 750 µg/L more than once every 3 years (on the average) when the ambient pH is between 6.5 and 9.0 S.U.

1.4 Effects of Aluminum on Benthic Macroinvertebrates

A comparison of benthic surveys was completed for Lake Ella from 1985–90. No benthic organisms were found at any of the six monitoring sites conducted within the lake immediately prior to drawdown of the lake for construction and sediment removal purposes. Following the dredging and refilling process in January 1987, no benthic organisms were (again) found at any of the six monitoring locations. However, after approximately 2.5 years of alum system operation, benthic macroinvertebrates were recolonizing the sediments of Lake Ella. This recolonization is thought to be a response to improved water quality and reduced toxicity within the sediments as a result of the incorporation of heavy metals and other toxic compounds into stable associations with alum floc.

Changes in benthic macroinvertebrate population density and diversity were studied in Newman Lake prior to and following alum treatment, and before hypolimnetic oxygenation. Historical low-oxygen concentrations created a benthic zone with reduced fish predation, which allowed chaoborids to flourish. Population densities of chironomids and oligochaetes were reduced by extended summer anoxia. Benthic macroinvertebrate community diversities were indicative of poor water quality and/or habitat quality. Following alum treatment and prior to hypolimnetic oxygenation, chaoborid densities doubled. Alum treatment had no effect on chironomid or oligochaete populations.

According to Cooke, Narf conducted the most detailed study on the impacts of lake alum treatment on benthic insects (Cooke et al. 1986; Narf 1978). The impacts were evaluated for two soft-water and three hard-water lakes in Wisconsin. Lake bottom benthic insect populations either increased in diversity or stayed the same after treatment.

1.5 Effects of Aluminum on Humans

The average North American diet contains from 20 to 30 milligrams (mg) per day of aluminum. Individuals who consume substantial quantities of aluminum-based antacids and other certain foods can consume much more (Greger 1985). Lione estimated that 840 to 5,000 mg and 126 to 728 mg of aluminum were possible daily doses of aluminum in antacids and in buffered analgesics, respectively (Lione 1985). A list of aluminum content of some common food products is summarized in Table 4, below.

The primary source of aluminum consumption for humans is through diet rather than drinking water sources. Steeped tea contains an average of 4,600 µg/L of aluminum and milk contains 700 µg/L. Aluminum concentrations in these common foods are 1 to 2 orders of magnitude greater than the 50 to 100 µg/L of aluminum normally found in drinking water or lake water that is treated with aluminum coagulants.

In the 1970s, research on Alzheimer's disease showed excessive amounts of aluminum in the brains of Alzheimer's patients. As a result, there was concern in the medical community that aluminum might cause or at least contribute to the development of the disease. Current researchers believe that Alzheimer's disease is the result of inflammation and hardening of the arteries. Aluminum in patient brains is thought to be stored after the disease develops.

Table 1. Acute Toxicity of Aluminum to Aquatic Freshwater Species

Test Species		Test Conditions		LC Value (µg/L Al)	Reference
Common name	Taxonomic name	Hardness (mg/L)	pH (S.U.)		
Planarian (adult)	*Dugesia tigrina*	47.40	7.48	> 23,000	Brooke et al. 1985
Snail (adult)	*Physa sp.*	47.40	7.46	55,000	Call 1984
Snail (adult)	*Physa sp.*	47.40	6.59	> 23,000	Call 1984
Snail (adult)	*Physa sp.*	47.40	7.55	30,600	Call 1984
Snail (adult)	*Physa sp.*	47.40	8.17	> 24,700	Call 1984
Cladoceran (<16 hour)	*Ceriodaphnia dubia*	50.00	7.40	1,900	McCauley et al. 1986
Cladoceran (< 24 hour)	*Ceriodaphnia sp.*	47.40	7.68	3,690	Call 1984
Cladoceran	*Daphnia magna*	45.30	6.50–7.50	3,900	Biesinger and Christensen 1972
Cladoceran	*Daphnia magna*	45.40	7.61	> 25,300	Brooke et al. 1985
Amphipod (adult)	*Gammaros pseudolimnaeus*	47.40	7.53	22,000	Call 1984
Stonefly (nymph)	*Acroneuria sp.*	47.40	7.46	> 22,000	Call 1984
Midge (larva)	*Tanytarsus dissimilis*	17.43	7.71–6.85	> 79,000	Lamb and Bailey 1981
Fathead Minnow (adult)	*Pimephales promelas*	–	7.60	> 18,900	Boyd 1979
Fathead Minnow (juvenile)	*Pimephales promelas*	–	7.61	> 48,200	Call 1984
Fathead Minnow (juvenile)	*Pimephales promelas*	–	8.05	> 49,800	Call 1984
Channel Catfish (juvenile)	*Ictalaros punctatus*	47.40	7.54	> 47,900	Call 1984
Green Sunfish (juvenile)	*Lepomis cyanellus*	47.40	7.55	> 50,000	Call 1984
Yellow Perch (juvenile)	*Perea jlavescens*	47.40	7.55	> 49,800	Call 1984
Brook Trout (juvenile)	*Salvelinus fontinalis*	–	6.50	3,600	Decker and Menendez 1974

NOTE: All tests conducted as static bioassay experiments.

Source: (EPA 1988).

Table 2. Toxicity of Aluminum to Aquatic Freshwater Plants						
Test Species		Test Conditions		Effect	Concentration (µg/L Al)	Reference
Common name	Taxonomic name	Hardness (mg/L)	pH (S.U.)			
Diatom	*Cyciotella meneghiniana*	–	8	Inhibited growth Algistatic	810 3,240	Rao and Subramanian
Green Alga	*Selenastrum capricomutum*	15.0	14	Reduced cell counts and dry weight	900–1,320	Peterson et al. 1974
Green Alga	*Selenastrum capricomutum*	14.9	4	EC50 (biomass)	570	Call 1984
Green Alga	*Selenastrum capricomutum*	14.9	4	EC50 (biomass)	460	Call 1984
Eurasion Watermilfoil	*Myriophyllum spicatum*	–	32	EC50 (not weight)	2,500	Stanley 1974
Duckweed	*Lemna minor*	14.9	4	Reduced frond production	> 45,700	Call 1984
Duckweed	*Lemna minor*	14.9	4	Reduced frond production	> 45,700	Call 1984

Source: (EPA 1988).

Table 3. Chronic Toxicity of Aluminum to Selected Freshwater Aquatic Species							
Test Species		Test Conditions		Type of Test	Range Tested (µg/L Al)	Chronic Value (µg/L Al)	Reference
Common name	Taxonomic name	Hardness (mg/L)	pH (S.U.)				
Cladoceran	*Ceriodaphnia dubia*	50	7.15	Life-cycle	1,400–2,600	1,908	McCauley et al. 1986
Claocern	*Daphnia magna*	220	8.30	Life-cycle	540–1,020	742	Kimball, Manuscript
Fathead Minnow	*Pimephales promelas*	220	7.24–8.15	Early life-stage	2,300–4,700	3,288	Kimball, Manuscript

Source: (EPA 1988).

Table 4. Estimated Aluminum Concentrations of Selected Foods

Food	Aluminum concentration [a] (µg/g)	Food	Aluminum concentration [a] (µg/g)
Animal Products		**Vegetables**	
Beef, cooked [b]	0.2	Asparagus	4.4
Cheese, natural	15.7	Beans, green cooked [b]	3.4
Cheese, processed	297.0	Cabbage, raw	0.1
Eggs, cooked [b]	0.1	Cauliflower, cooked [b]	0.2
Milk	0.7	Cucumber	1.7
Fruits		Lettuce	0.6
Bananas	0.40	Peas, cooked [b]	1.9
Grapes	0.40	Potatoes, unpeeled	0.1
Orange juice	0.05	Potatoes, with skin	2.4
Grains		Tomatoes, cooked [b]	0.1
Bread, white	3.0	**Other**	
Bread, whole wheat	5.4	Baking powder	23,000.0
Rice, cooked [b]	1.7	Cocoa	45.0
Herbs		Coffee, brewed	0.4
Basil	308	Pickles, with alum	39.2
Bay	436	Salt with aluminum	164.0
Celery seed	465	Tea in bag, dry	1,280.0
Oregano	600	Tea, steeped	4.6
Pepper, black	143	Thyme	750.0

a. Values are arithmetic averages of (sometimes) widely differing individual values.

b. Food not cooked or stored in aluminum pans, trays, or foils.

1.6 Position of the North American Lake Management Society and State and Federal Regulatory Agencies

The North American Lake Management Society (NALMS) has determined that alum is a safe and effective lake management tool. A copy of its position paper can be found online (NALMS 2004). In addition to NALMS, numerous state environmental regulatory agencies and EPA have made the same determination. Some of the state agencies approving aluminum treatments include: FDEP, Ohio EPA; Wisconsin Department of Natural Resources (DNR); and Washington State Department of Ecology (Ecology). Some state environmental agencies have provided grant funding for whole-lake aluminum treatments and aluminum stormwater treatment systems.

1.7 Pretreatment and Application Requirements

With any chemical application it is essential to perform the necessary pretreatment testing. This includes lake surface water quality monitoring, sediment chemical analysis including phosphorus speciation, and laboratory jar testing with the actual water to be treated and coagulant to be used for the full-scale application. Lake surface water quality monitoring is used to determine the current physical and chemical characteristics of the lake water. The sediment analysis is used to estimate the mass of available phosphorus in the sediment and the required aluminum dose. Jar testing is performed to determine the optimum coagulant or combination of coagulants to be used, and the effect of the aluminum dose on lake water quality.

It is also important to use a highly qualified and reputable consultant and applicator with extensive experience. Only high-quality coagulants that are certified for drinking water treatment should be used. There are less expensive coagulants available that can contain substantial contaminants and less aluminum than stated. For lakes that require a substantial aluminum dose, it can be beneficial to divide the treatment into two or more applications. This has resulted in longer lasting water quality benefits. Prior to and throughout the application process, in-situ vertical profile lake water monitoring should be performed for parameters including: pH, conductivity, DO, and turbidity. This ensures that lake water quality remains within state water quality standards during and after the treatment.

1.8 Qualifications

Jeff Herr has more than 33 years of environmental engineering experience in watershed and stormwater management, surface water monitoring and assessment, and stream and lake restoration. This experience ranges from contract preparation through study, design, quality assurance/quality control, value engineering, permitting, bidding, construction administration, startup, and operation and maintenance. He received a bachelor of science in engineering degree (environmental engineering) in 1981 and a master of science in engineering degree (environmental engineering) in 1983 from the University of Central Florida.

Mr. Herr's primary areas of expertise include: surface water quality monitoring; assessment and restoration; development of surface water hydrologic and pollutant budgets based on water and sediment field monitoring; stormwater and sediment characterization; watershed improvement planning; stormwater treatment performance efficiencies; watershed pollutant sources and loadings; total maximum daily loads (TMDLs); National Pollutant Discharge Elimination System (NPDES); coagulant treatment of nonpoint sources; structural and nonstructural stormwater BMP evaluation, design, permitting, and construction oversight; regional stormwater retrofits including wetland and chemical treatment; development of enhanced land development regulations; stormwater design criteria; and operation and maintenance procedures. He has successfully completed more than 160 water quality projects including more than 50 regional stormwater retrofit projects (35 chemical stormwater treatment projects) for public entities. Mr. Herr is a Diplomate, water resources engineer, American Academy of Water Resources Engineers member, and is a registered professional engineer (P.E.) in Washington and several other states.

Mr. Herr has been conducting detailed lake water quality assessments and planning, designing, supervising construction, performing startup, conducting operations training, and operating coagulant treatment systems to reduce pollutant loads from nonpoint sources and improve surface water quality since 1988. Since that time, he has planned and completed more than 12 whole-lake aluminum treatments, and designed, permitted, and completed construction administration and startup for more than 30 nonpoint source treatment systems using aluminum coagulants.

1.9 References

Biesinger and Christensen. 1972. Effects of various metals on survival, growth, reproduction, and metabolism of Daphnia magna. J Fish Res Bd Can 29: 1691–1700

Call, D.J. 1984. *The Toxicity of Aluminum to Aquatic Species in the United States*. F Grostomski. University of Wisconsin-Superior, Superior, WI. (Memorandum to C. Stephan, EPA, Duluth, MN, November 27).

Chang, S.C., and M.L. Jackson. 1957. *Soil Science*, “Fractionation of soil phosphorus.” Pp. 84, 133–144.

Cooke, G.D., E.B Welch, S.A. Peteson, and P.R. Newroth. 1986. *Lake and Reservoir Restoration*. Stoneham, MA: Butterworth Publishers.

Decker, C. and R. Menendez. 1974. *Proceedings of the West Virginia Academy of Science.* “Acute toxicity of iron and aluminum to brook trout.” Pp. 46, 159–167.

Kimball, G. Manuscript. *The effects of lesser known metals and one organic to fathead minnows (Pimephales promelas) and Daphnia magna*. University of Minnesota, St. Paul, MN.

Lamb, D.S., and G.C. Bailey. 1981. *Bulletin of Environmental Contamination and Toxicology.* "Acute and chronic effects of alum to midge larvae (Diptera; Chiromonidas)." Pp. 27, 59–67.

Lione A. 1985. Aluminum toxicology and the aluminum-containing medications. Pharmacol Ther; 29: 255–85

McCauley, D.J., L.T. Brooke, D.J. Call, and C.A. Lindberg. 1986. *Acute and chronic toxicity of aluminum to Ceriodaphnia dubia at various pH's*. University of Wisconsin-Superior, Superior, WI.

NALMS position paper. 2004: https://www.nalms.org/home/our-mission/nalms-position-papers/

Narf, R.P. 1978. *An Evaluation of Past Aluminum Sulfate Lake Treatments: Present Sediment Aluminum Concentrations and Benthic Insect Communities*. Madison, WI: Department of Natural Resources.

Peterson, S.A., W.D. Sanville, F.S. Stay, and C.F. Powers. 1974. *Nutrient Inactivation as a Lake Restoration Procedure*. Laboratory investigations. EPA-660/3-74-032. Springfield, CA: National Technical Information Service.

Polk County Water Atlas, January 9, 2017. http://www.polk.wateratlas.usf.edu/

Rao, V.N.R. and S.K. Subramanian. 1982. *Acta Botanica Indica*. "Metal toxicity tests on growth of some diatoms." Pp. 10, 274–281.

Stanley, R.A. 1974. *Archives of Environmental Contamination and Toxicology Journal.* "Toxicity of heavy metals and salts to Eurasian watermilfoil (*Myriophyllum spicatum L.*)." Pp. *2*, 331–341.

U.S. Environmental Protection Agency (EPA). 1988. *Ambient Water Quality Criteria for Aluminum*. EPA-440/5-86-008.

FACT SHEET: BOTTOM AERATION WITH VIGOROUS EPILIMNETIC MIXING

Lake Aeration and "Vigorous Mixing"

Description	Inject air near lake bottom to (1) avoid anoxic conditions that foster P release from sediment, and (2) create vertical currents that disrupt cyanobacteria.
Objectives	Reduce P release from sediment, physically disrupt cyanobacteria
Initial planning level cost estimate[1]	$1.9M
Estimated annual operation and maintenance cost[2]	$20,000
Basis for preliminary sizing	200-12" diffusers, spaced approximately 10x the water depth apart
Water quality benefit[3]	High. Reduce P release from sediment, disrupt blue greens, increase dissolved oxygen for fish.
Approximate time to see water quality benefit	2 years
Duration/frequency	Long-term. Operate 8 mos/yr initially and adjust based on lake response.
Other potential benefits	Few conflicts with other uses. Increased DO should improve fish habitat.
Other potential impacts/costs	Blower building would be required. Energy use.
Required infrastructure	Small building with blowers, plastic pipes on lake bottom, etc.
Pre-design work needed	Site survey including bathymetery, geotech, etc.
Additional comments	Operate 8 mos./yr initially; adjust as needed based on lake response.

Basis of design/assumptions

Item	Units	Unit	Cost per Unit	Cost (1,000s)	Assumptions
Site Work					
Site Grading	lsum	1	$ 5,000	$ 5	
Building	sq ft	400	$ 210	$ 84	25.5 ft by 15.5 ft
Buried piping	lf	600	$ 70	$ 42	2-inch ID, Type 316 SST schedule 40; backfill with native
VEM manifolds	lf	16,300	$ 30	$ 489	2x2" HDPE, weights at 20' c-c
VEM 12-inch diameter diffusers	each	200	$ 240	$ 48	EDI Flexible Membrance plus dedicated pressure regulator for each diffuser, cost includes diver installation
			Subtotal	$ 668	
Mechanical					
Compressor	each	2	$ 20,000	$ 40	250 scfm each; 40 hp
Compressor installation	each	2	$ 2,500	$ 5	
Receiver	each	2	$ 4,500	$ 9	Two 500-gal galv steel tanks, incl. welds, straps, crane rent
Ventilation Fans	each	2	$ 3,000	$ 6	
Air manifold	each	1	$ 40,000	$ 40	Includes pressure regulators, isolation valves, and thermal mass flow meters
			Mechanical Subtotal	**$ 100**	
Electrical					
Electrical Service	each	1			600 amps, interior
Electrical Equipment	each	1			
Wiring	each	1			
EIC - Allowance	lsum	1	#######	$ 100	This includes all items above and SCADA/I&C
SCADA	each	1			
			Electrical Subtotal	**$ 100**	
			Construction Subtotal	**$ 868**	
Contractor's Mobilization/Overhead	percent	10	--	$ 087	
			Subtotal	**$ 955**	
Contractor's Mark Ups	percent	10	--	$ 095	
			Subtotal	**$ 1,050**	
Contingency	percent	40	--	$ 420	
			Subtotal	**$ 1,470**	
Contractor's Bonding and Insurance	percent	5	--	$ 074	
			Subtotal	**$ 1,544**	
Allowances	percent	20		$ 309	Engineering, Legal, Admin
			Total Capital Cost	$ 1,853	

Notes:

1. Based on the planning-level information and concept development stage of this project, conceptual level costs were estimated following the Association for the Advancement of Cost Engineering (AACE) Class 5 Cost Estimate Classification System, providing estimates in the range of-50% to +100% for the candidate actions.

2. Planning-level estimate of annual O&M costs in 2016 dollars

3. Long-term lake monitoring is recommended to evaluate the effectiveness of the selected lake management measure(s).

FACT SHEETS: PUMP AND TREAT SYSTEMS

Pump and Treat with Coagulant

Description	Pump water from lake, add coagulant to remove P, return treated water to lake.
Objectives	Treat the water for P removal.
Initial planning level cost estimate[1]	$1.5M
Estimated annual operation and maintenance cost[2]	$80K/yr
Basis for preliminary sizing	Treat lake water flow rate of 2,500 gpm; coagulant dose assumed to be 5 mg aluminum/Liter of water
Water quality benefit[3]	Medium
Approximate time to see water quality benefit	1 year
Duration/frequency	Long-term
Other potential benefits	Would require ~3 acres of land. Temporary impacts during construction.
Other potential impacts/costs	Flexible operation. Higher treatment capacity than wetland treatment system. Learning opportunity for college students.
Required infrastructure	Intake and discharge pipes, pumps, chemical storage tank, small equipment structure settling pond.
Pre-design work needed	Sediment and water column testing to estimate future treatment needs. Jar testing, floc dewatering testing, survey and geotech.
Additional comments	Run system ~6 mos./yr. Cost estimate assumes treatment facility can be sited within 1,000 ft of lake. Could combine with small wetland treatment system. A design flow rate of 2,500 gpm was used for the coagulant treatment system. Cost does not include the cost to purchase a dredge to pump floc from the settling pond to the dewatering basin.

Basis of design/assumptions

Description	Est. Qty.	Unit	Unit Cost ($)	Total Cost ($)
Mobilization and Demobilization	1	LS	--	$ 111,600
Maintenance of Traffic	1	LS	--	$ 10,000
Project Construction Sign	1	EA	$ 1,000.00	$ 1,000
Water Management				$ 50,000
One-Year Warranty	1	LS	--	$ 10,000
Construction Stakeout and Surveys	1	LS	--	$ 10,000
Clearing and Grubbing (does not include tree removal > 12-inch DBH)	3	AC	$ 7,500.00	$ 22,500
Temporary Silt Fence – Type C	3,000	LF	$ 5.00	$ 15,000
Temporary Construction Entrance/Exit Drives	2	EA	$ 2,500.00	$ 5,000
Final Seeding	2.5	AC	$ 2,500.00	$ 6,250
Removal/disposal of buried trash, debris, concrete, etc	50	CY	$ 100.00	$ 5,000
Classified Stone (#57, #3, #4, etc)	50	CY	$ 100.00	$ 5,000
Grading Complete (earthwork - includes excavation, fill, compaction, final grading, removal of excess)				
Grading - Cut/Fill In place	10,000	CY	$ 20.00	$ 200,000
HDPE Liner	32,000	SF	$ 2.00	$ 64,000
2,500 GPM Water Pump Station and Intake	1	LS	--	$ 200,000
HDPE Intake Pipe	1000	LF	$ 75.00	$ 75,000
HDPE Discharge Pipe	1000	LF	$ 75.00	$ 75,000
Pond Outfall Structure	1	EA	$ 15,000.00	$ 15,000
Water Flow Measurement	--	LS	--	$ 25,000
Building Piping, Valves and Appurtenances	--	LS	--	$ 25,000
4,000-gallon Chemical Storage Tank	1	EA	$ 20,000.00	$ 20,000
Water Flow Meter Conduit and Coagulant Feed Piping	500	LF	$ 50.00	$ 25,000
Coagulant Pump and Control Panel	--	LS	--	$ 50,000
Coagulant Flow Meter	1	EA	$ 15,000.00	$ 15,000
Equipment and Controls Building	400	SF	$ 150.00	$ 60,000
Rapid Mix Tank/Mixer	--	LS	--	$ 35,000
Tree Cutting and Mulching (12-inch DBH and greater)	15	EA	$ 750.00	$ 11,250
Bare Root Tree	100	EA	$ 10.00	$ 1,000
Herbaceous Plants	500	EA	$ 10.00	$ 5,000
Electrical/HVAC	--	LS	--	$ 75,000
		Subtotal		$ 1,227,600
		20% Contingency		$ 245,520
			TOTAL AMOUNT:	**$ 1,473,120**

Estimated Average Annual Cost ($)

Mowing/General Maintenance	6 visits/year x 2 person crew x 4 hrs/visit x $50/hr	$ 2,400.00
System weekly testing/operations	52 weeks x 1 person x 4 hrs/week x $50/hr	$ 10,400.00
Equipment/Supplies	$100/visit x 52 visits /year	$ 5,200.00
Chemical purchase	4,900 gal x $4.50/gal	$ 22,050.00
Sediment removal/disposal	680 cubic yards x $20/cy	$ 13,600.00
Power	82,000 kwhrs x $0.08/kwhrs	$ 6,560.00
	Subtotal	$ 60,210.00
	20% contingency	$ 12,042.00
	Total	$ 72,252.00
	Equipment Renewal and Replacement ($250,000/30 years)	$ 8,333.00
	Total Estimated Average Annual O&M cost	**$ 80,585.00**

Notes:

1. Based on the planning-level information and concept development stage of this project, conceptual level costs were estimated following the Association for the Advancement of Cost Engineering (AACE) Class 5 Cost Estimate Classification System, providing estimates in the range of-50% to +100% for the candidate actions.

2. Planning-level estimate of annual O&M costs in 2016 dollars

Pump and Treat with Constructed Wetland	
Description	Pump water from lake, treat in a ~8-acre wetland system, discharge treated water to lake.
Objectives	Remove phosphorus from the lake water.
Initial planning level cost estimate[1]	$3.1M
Estimated annual operation and maintenance cost[2]	$100K/yr
Basis for preliminary sizing	Treat lake water flow rate of 1,000 gpm; assumed wetland HLR = 16 cm/day
Water quality benefit[3]	Medium
Approximate time to see water quality benefit	1 year
Duration/frequency	Long-term
Other potential benefits	Would require ~9 acres of land. Temporary impacts during construction.
Other potential impacts/costs	Flexible operation. Increased habitat for birds and other wildlife. Learning opportunity for college students.
Required infrastructure	Intake and discharge pipes, pumps, constructed wetland.
Pre-design work needed	Sediment and water column testing to estimate future treatment needs; Survey and geotech
Additional comments	Need for treatment may diminish over time. Run system ~6 mos./yr. Cost estimate assumes treatment wetland can be sited within 1,000 ft of lake. A design flow rate of 1,000 gpm was assumed for this treatment project.

Basis of design/assumptions

Description	Est. Qty.	Unit	Unit Cost ($)	Total Cost ($)
Mobilization and Demobilization	1	LS	--	$ 236,600
Maintenance of Traffic	1	LS	--	$ 10,000
Project Construction Sign	1	EA	$ 1,000	$ 1,000
Water Management				$ 50,000
One-Year Warranty and Maintenance	1	LS	--	$ 10,000
Construction Stakeout and Surveys	1	LS	--	$ 20,000
Clearing and Grubbing (does not include tree removal > 12-inch DBH)	9	AC	$ 7,500	$ 67,500
Temporary Silt Fence – Type C	4,500	LF	$ 5	$ 22,500
Temporary Construction Entrance/Exit Drives	2	EA	$ 2,500	$ 5,000
Temporary Seeding	8	AC	$ 2,500	$ 20,000
Removal/disposal of buried trash, debris, concrete, etc.	50	CY	$ 100	$ 5,000
Classified Stone (#57, #3, #4, etc.)	100	CY	$ 100	$ 10,000
Grading Complete (earthwork - includes excavation, fill, compaction, final grading, removal of excess)				
Grading - Cut/Fill In place	29,000	CY	$ 20	$ 580,000
Import Topsoil (6-inch depth)	6,500	CY	$ 20	$ 130,000
Export Excess soil	15,000	CY	$ 15	$ 225,000
HDPE Liner	350,000	SF	$ 2	$ 700,000
1,000 GPM Water Pump Station	1	LS	--	$ 150,000
HDPE Intake Pipe	1000	LF	$ 60	$ 60,000
HDPE Discharge Pipe	1500	LF	$ 60	$ 90,000
Type 1 and 3 Rip Rap	250	SY	$ 100	$ 25,000
Permanent Seeding	9	AC	$ 2,500	$ 22,500
Tree Cutting and Mulching (12-inch DBH and greater)	50	EA	$ 750	$ 37,500
Bare Root Tree	2500	EA	$ 10	$ 25,000
Herbaceous Plants	10,000	EA	$ 10	$ 100,000
		Subtotal		$ 2,602,60
		20% Contingency		$ 520,52
			TOTAL AMOUNT:	$ **3,123,12**

Estimated Average Annual Cost ($)

Annual O&M	$10,000/acre x 8 acres	$ 80,000
	Subtotal	$ 80,000.00
	20% contingency	$ 16,000.00
	Subtotal	$ 96,000.00
	Equipment Renewal and Replacement ($150,000/30 years)	$ 5,000.00
	Total Estimated Average Annual O&M cost	**$101,000**

Notes:

1. Based on the planning-level information and concept development stage of this project, conceptual level costs were estimated following the Association for the Advancement of Cost Engineering (AACE Class 5 Cost Estimate Classification System, providing estimates in the range of-50% to +100% for the candidate actions.

2. Planning-level estimate of annual O&M costs in 2016 dollars

Appendix E: Review Comments

This appendix contains a copy of the review comments to the Draft LMP and responses.

No.	Commenter	LMP Section	Comment	Response
1	Isabel Ragland	Executive Summary	Use cyanobacteria instead of blue-green algae to be consistent with rest of document.	The term 'cyanobacteria' has replaced 'blue-green algae' throughout the LMP.
2	Isabel Ragland	1.2	Spell out LMP in first sentence of Section 1.2.	The draft LMP has been revised accordingly.
3	Isabel Ragland	1.1.4	Is the number of mallards describing one instance of more than 40 total?	The text in question is from a previous report and is intended as general background information. The LMP monitoring included regular waterfowl counts as described in Section 2.10.
4	Isabel Ragland	2.7, Figure 2-11	Add a legend to the figure.	Legend has been added to the figure.
5	Isabel Ragland	3.2, Figure 3-1	McChord also records precipitation and is much closer (geographically) to Waughop Lake.	Section 3.2 has been revised to note that the McChord gauge recorded 22.6 inches and WSU Puyallup recorded 21.9 inches of precipitation during the water budget monitoring period.
6	Isabel Ragland	3.5, Figure 3-7	Add a legend to the figure.	Legend has been added to the figure.
7	Lisa Lombardo	General	Why is dog poop not part of the equation since wildlife poop is considered as a source of contamination? "As a regular user of the sloped areas around the lake I see a LOT of poop, and know that it has to have an impact on the water quality."	The mass balance model used average literature values for N and P for the Puget Sound region which would include pet waste. The nutrient budget analysis indicates that the shoreline area contributes a small fraction of the annual phosphorus load to the lake, mainly because the runoff volume is very small and the phosphorus load released from sediment is very large. Nevertheless, current practices to reduce loadings from dog waste (e.g., signage, dog waste bag stations) should be continued and enhanced as appropriate.
8	Don Russell	1, Introduction	On page 1-1 Microcystin is listed as a neurotoxin and Saxitoxin is listed as a liver toxin. Microcystin is a liver toxin and Saxitoxin is a neurotoxin.	The LMP has been revised accordingly.
9	Don Russell	1.1.4	"Most of the numerous ducks note by LaFontaine were probably Northern Shovelers not Mallards."	The text in question is from a prior report on the lake. The monitoring conducted for the Waughop LMP included regular waterfowl counts that were used to estimate phosphorus loads to the lake, as described in Section 2.10 of the LMP.
10	Bob Warfield	1, Introduction	"Astonished to learn vast area of "uphill residents" remain on septic (outside of local jurisdiction; hopefully contributing a fee for exemption). What's with that; any plan afoot to eventually sewer this area? Looks like Lake Louise is much deeper (70 feet ?), v. Waughop (It would be marvelous to have some orientation (glossary) re otherwise cryptic data points discussed in the report. Missed a merit badge on hydrologic assessment."	The septic systems do not appear to be a significant contributor of nutrients to Waughop Lake, as shown in Figure 4-3. Groundwater is calculated to contribute less than 1% of phosphorus to the lake; groundwater monitoring at the well located downgradient of the septic system area (GW-1) did not indicate elevated phosphorus concentrations from septic systems.
11	TPCHD	5	For the management measures section (section five), it would be good to provide more specific goals than just “improve water quality” as this will dictate the level of lake management needed. For example, if the goals are to support the beneficial uses of fishing and model boating, this could be accomplished by reducing toxic algae blooms to infrequent occurrences. The management measures needed to accomplish this goal are likely much less costly and complex than to meet a goal that the lake support swimming.	Section 5 has been revised to clarify that the primary objective of the LMP is to minimize the frequency of cyanobacteria blooms in the lake. The recommended measures should also provide ancillary benefits for fish and waterfowl.

No.	Commenter	LMP Section	Comment	Response
12	TPCHD	4.6	For the stormwater section, should this be modified given the recent identification of a periodic sewage discharge to the lake via the storm drain from Pierce College? Could this sewage discharge be from the same source as the sewage discharge noted in December 2007? If so, and the discharges have occurred periodically for at least the past nine years, what could be the impact from the sewage discharges on the lake? Also, the stormwater sampling conducted as part of the project doesn't seem very thorough. It seems there are a lot of assumptions about the stormwater flow and the sources of runoff. There is a large portion of Pierce College property that was not represented at all in the stormwater sampling. This may have been how the sewage discharge went unnoticed. Maybe the report should include a more strongly worded disclaimer about the reliability of the stormwater sampling values, even though there relative impact is small.	The sewage discharges observed since November 2016 were not caused by stormwater runoff. The sewage discharges were related to a malfunctioning lift station at Pierce College that was connected to the storm line that discharges to the lake. The cross-connection has since been capped. No sewage discharges were observed by UWT or BC field staff or reported by park visitors during the lake monitoring period (October 2014-October 2015). Given the location and visibility of the stormwater outfall, it is unlikely that frequent sewage discharges occurred during the LMP monitoring period without being observed. Based on information from the college, the discharges appear to have occurred only when the sewer pumps were malfunctioning, which was apparently infrequent before November 2016. The water and nutrient budgets did not identify significant unaccounted-for flows or phosphorus loads indicative of recurrent sewage discharges or other unidentified sources. (Response continued below.) The LMP budget allowed stormwater monitoring at one location. Monitoring at the stormwater outfall in the lake was ruled out because it is often inundated. The available storm sewer mapping indicated that the outfall receives runoff from two catchment areas on the Pierce College campus, SW-1 (21 acres, mostly parking lots with some landscaped areas) and SW-2 (5.5 acres, mostly building roofs). SW-1 was selected for stormwater monitoring because it encompasses about 80% of the total drainage area for the outfall and because runoff from parking lots and landscaped areas typically has higher phosphorus concentrations than roof runoff. As noted in LMP Section 4, stormwater runoff was estimated to contribute about 1% of the observed phosphorus load to Waughop Lake during the monitoring period.
13	TPCHD	5.1	If dredging is considered to be the primary option, we recommend additional sediment sampling be conducted to more precisely determine the extent of high-phosphorus sediment for removal.	Section 5.0 states that each management measure will require additional investigation to support design, cost estimation, and bidding. A statement has been added to the end of Section 5.1 with the suggested text to emphasize the need for additional sediment sampling should this measure be selected.
14	TPCHD	1, Introduction	Page 1-1, fifth paragraph. Microcystin is a liver toxin and Saxitoxin is a neurotoxin, not vice versa.	The LMP has been updated accordingly.
15	TPCHD	1, Introduction	Page 1-1, fifth paragraph. Our "do not eat the fish" advisory went into effect in June 2010, not December 2015.	The LMP has been updated accordingly.

No.	Commenter	LMP Section	Comment	Response
16	TPCHD	2-1, Table 2-3	Page 2-4, Table 2-3, groundwater well GW-4. This well had very unusual results, with extremely low concentrations of phosphorus and quite variable and frequently extremely high concentrations of nitrogen. The TN concentrations ranged from 0.16 mg/L to 29.2 mg/L. The highest concentration occurred in February 2015 and this was the only time period when the well seemed to show groundwater from this area recharging the lake, rather than the lake recharging groundwater. We recommend that GW-4 be sampled again in February 2017 (and ideally May 2017) and the water samples analyzed for TN, nitrate, and ammonia. Further sampling could be conducted in the fall of 2017, prior to and following macrophyte die off to assess if this could be the source of nitrogen to this well. This seems possible, since the TN concentration for GW-4 was 0.163 mg/L on August 5, 2015 but was 14.2 mg/L on December 18, 2014 (a year prior but following macrophyte die off). An additional step, if resources allow, would be to install another monitoring well. The well should be drilled further back from the lake, up on the top of the hill, to assess if there is a nitrogen source in this area.	We agree, the TN concentrations at GW-4 were anomalous while TP concentrations were similar to the other wells. Since P is the limiting nutrient in Waughop Lake, the implications of the elevated TN are unclear. The limited LMP budget did not allow for follow-up sampling or other investigations to identify the source or cause for the TN concentrations at GW-4. GW-4 and the other wells installed for the LMP have not been abandoned, so they are available for future sampling by TPCHD or others.
17	TPCHD	2.5	Page 2-12, last paragraph, first sentence. This sentence is a bit confusing. It would be better to reword to something like the following "Nitrate and nitrite have been analyzed in shallow water samples since 2011…" Who collected these samples?	The LMP has been revised to note that the samples were collected by volunteers.
18	TPCHD	3.2	Page 3-2, equation explanations. Psychometric should be changed to psychrometric.	The LMP has been revised accordingly.
19	TPCHD	4.1	Page 4-5, Table 4-4, last two columns. Change TP to TN.	The LMP has been revised accordingly.
20	TPCHD	5.4	Page 5-8, second paragraph, last sentence. This sentence should be rewritten to note that an alum treatment would be likely to greatly increase macrophyte growth and distribution in the lake. This would be due to the very high nutrient concentrations in the sediment, the fact that the lake is quite shallow, and the increased water clarity that would result from an alum treatment.	The LMP has been revised to note that alum treatment could substantially increase macrophyte growth. However, an alum treatment should help to offset the effects from increased sunlight transparency by reducing the amount of phosphorus available for macrophytes like coontail that absorb nutrients directly from the water. Coontail currently dominates the macrophyte community in much of Waughop Lake.

No.	Commenter	LMP Section	Comment	Response
21	Conservation Committee of Tahoma Audubon Society, the Pierce County chapter of National Audubon Society (Letter from Jerry Broadus, President) (Letter, part 1)	General	After reviewing the draft plan, and the proposed options for treatment of lake water for excess phosphorous (P) and related algae blooms, we urge the City of Lakewood to pursue option 4b (listed in Appendix D)– creation of a nearby 8-acre wetland to provide filtration and deposition of excess nutrients naturally occurring in the lake. Option 4b is the best opportunity to provide a long-term sustainable solution that will lead to improved water quality and have the added benefits of creating wetland habitat, which are in steep decline through decades of extensive conversion to other uses. Creation of wetlands may also make this project eligible for other programs like wetland mitigation credits, in-lieu fees, or mitigation banking, depending on what programs are available in Lakewood, Pierce County and the State. This could be another viable funding source. By choosing option 4b, you would be presenting a larger vision and opening up more opportunities to create a significant environmental benefit above and beyond improving the lake's water quality alone. Freshwater wetlands are important habitats for migratory birds. Many species of birds are known to breed each spring in Waughop Lake, and many seabirds are found there in winter, and other birds are attracted to it do to access to freshwater year round. In fact, eBird.org (University of Cornell's Lab of Ornithology) reports 151 bird species observed in Fort Steilacoom Park and 740 checklists as of 12/30/16. Further information and data from these observations can be found at: https://ebird.org/ebird/hotspot/L457092 . We recognize that option 4b is the more costly option and that funds would need to be sought to go this route. Creation of wetland habitats opens up opportunities for additional funding sources for this water quality project, including federal and state wildlife and habitat restoration grant programs. Tahoma Audubon is ready to help advocate and support efforts to seek this funding with you whether it be through grants, donations, legislation or appropriations.	The primary objective of the LMP is to minimize the frequency of cyanobacteria blooms in Waughop Lake. The LMP evaluation concluded that dredging of lake bottom sediment would provide the greatest long-term benefits. A constructed wetland treatment system would provide multiple environmental benefits but its treatment capacity would be limited by its area and design hydraulic loading rate. The LMP assumed an 8-acre wetland with a hydraulic loading rate of about 6 inches per day, which may remove 50 kg of TP per year, or about 13% of the lake's phosphorus load during the monitoring period. The lake bottom sediment contains approximately 2,400 kg of TP. The whole-lake phosphorus inactivation option and the lake aeration and mixing option are expected to provide greater TP load reduction by directly reducing the amount of TP cycling from the sediment to the water column. The 20-year cost of the constructed wetlands option ($5.1M) is considerably higher than the whole-lake treatment option or the lake aeration and mixing option.

No.	Commenter	LMP Section	Comment	Response
21 (Cont.)	Conservation Committee of Tahoma Audubon Society, the Pierce County chapter of National Audubon Society (Letter from Jerry Broadus, President) (Letter, part 2)	General	We would like to state our opposition to any lake treatment alternatives that introduce toxins, including those presented in the listed alternatives, into the marine environment that can have adverse effects on fish, macroinvertebrates, birds or mammals. Macroinvertebrates are an important part of the food web, in which fish, and then birds are impacted by a loss of macroinvertebrates that they feed on. One study of the effects of alum application on Lake Morey, Vermont, showed a 90% decline in density of benthic macroinvertebrates in the first year (Smeltzer, E., R.A. Kern, and S. Fiske, 1999. Long-term water quality and biological effects of alum treatment of Lake Morey, Vermont. Lake and Reserv.Manage. 15(3): 173-184. http://www.tandfonline.com/doi/pdf/10.1080/07438149909354115). That same study also showed much smaller (by weight) fish in the lake after treatment with alum. If birds were preying on those fish, then they, too, would be impacted. As stated above, several species of birds breed, nest, and raise their young at Waughop Lake. These birds, migratory as they are, are protected under the federal Migratory Bird Treaty Act (https://www.fws.gov/birds/policies-and-regulations/laws-legislations/migratory-bird-treaty-act.php).	Whole-lake alum treatments have been used extensively throughout the US for more than 40 years (e.g., Green Lake in Seattle, WA). The North American Lake Management Society (NALMS) has determined that alum is a safe and effective lake management tool. In addition to NALMS, numerous state environmental regulatory agencies and the USEPA have determined that alum treatment is an acceptable stormwater treatment and lake management tool. Some of the state agencies approving alum treatments include: Florida Department of Environmental Protection, Ohio EPA; Wisconsin DNR; and Washington Department of Ecology. Some state environmental agencies have provided grant funding for whole-lake alum treatments and alum stormwater treatment systems. It is very important to recognize that with any chemical application it is essential to perform the necessary pre-treatment testing. It is also very important to utilize a highly qualified and reputable consultant and applicator with extensive experience. Only high quality coagulants certified for drinking water treatment should be used. Appendix D contains a detailed discussion of alum treatment.
21 (Cont.)	Conservation Committee of Tahoma Audubon Society, the Pierce County chapter of National Audubon Society (Letter from Jerry Broadus, President) (Letter, part 3)	General	These are not just the waterfowl birds that were cited in the draft plan studies, but also songbirds and other birds that use the lake as a vital source of fresh water although not seen floating on the lake itself. A loss of macroinvertebrates may harm fish, birds and other animals further up the ‘food chain.’ This was not considered in the draft Waughop Lake Management Plan. Fort Steilacoom Park is a popular regional park with ample natural areas and diverse habitats, including the lake, forest, and remnant oak woodland prairie. It is a popular destination for birdwatching, as seen in the eBird hotspot observations and trip reports cited above. Tahoma Audubon Society’s volunteers host a monthly bird walk at Fort Steilacoom Park and Waughop Lake is an important part of that experience. The lake itself draws birds, and in turn, the birds draw more park users. This is an opportunity to improve water quality and more. This is a chance to create wetlands when the long term trend, locally and nationally, has been to fill them. This is a chance to create habitat and enhance the natural features and passive recreational opportunities in the park while improving water quality. It will make Fort Steilacoom Park an even more significant public asset for the residents of the City of Lakewood and visitors from across the region. We can’t think of a better win-win situation.	

No.	Commenter	LMP Section	Comment	Response
22	Kurt and Janet Spingath, Lakewood residents	General	The Lake Management Plan seemed very thorough. The options for clearing the lake up were also easy to understand. It would seem the most prudent and cost effective plan would be to apply alum. After waiting for several generations for the lake to be transformed from a manure pond back to a kettle lake, it is time that something actually be done! Since putting docks on the water is part of the recreational use plan, we need to be sure the lake can support activities like fishing, from a dock. Toxic algal blooms need to be controlled if people are going to enjoy that kind of recreation. But before taking the next step to make the water safer, we would like the City to consider one more option for treatment. There are enzyme and bacterial treatments that may be available as a long-term solution. These products will reduce nitrogen and phosphorous from the water column by taking it out of the sludge. They have been used to treat municipal water systems and farm ponds. There are several such products on the market. We are currently researching one through BioSafe Systems. When we have more information about treatment details, efficacy and cost, we will pass it along to the city. A BioSafe representative should be contacting us within the next two weeks.	The lake bottom sediment is the main source of phosphorus and is the primary cause of cyanobacteria blooms in the lake. Algaecides and bacteria treatments were initially evaluated as part of the LMP. Algaecides treat the symptom (algae in the water column). The large pool of phosphorus in the sediment will continue to provide a food source for continued algae and cyanobacteria growth in the lake. The algae will settle on the lake bottom and could be available as a source of phosphorus. Bacteria can consume nutrients and organic matter in the water column, but at least a portion of the resulting material will settle on the lake bottom where it can become part of the phosphorus cycle in the lake. Algaecides and bacteria are not expected to provide direct and long term water quality benefits to the lake. Sediment phosphorus inactivation using whole-lake alum treatment would quickly reduce phosphorus concentrations in the lake, reduce the release of phosphorus from the sediment, and reduce cyanobacteria blooms.
23	Tom McClellan (Letter, part 1)	General	I have read the study and proposals from the consultants at Brown and Caldwell concerning remedial action for Waughop Lake, and I also attended the Nov. 16, 2016 informational briefing for the Chambers - Clover Creek Watershed Council. It is clear from this information, and from the December 2012 Remedial Action Plan which was submitted at no cost to the City of Lakewood, that the only suitable options are the ones that involve the dredging and removal of phosphorous-laden sediments from the lake bottom. This analysis is also supported by the most recent academic study of the lake bottom sediments, conducted by Halle Peterson of the University of Puget Sound (see attached). I further find that the City must move forward against the property owner (State of Washington) with a code-enforcement action, mandating that the State provide the necessary funds to conduct the cleanup operation. Discussion: Brown and Caldwell identified numerous remediation options which involved leaving the sediments in the lake, but (hopefully) rendering the nutrients unavailable for the algae to use. These included chemical treatment to achieve phosphorous inactivation, and “lake aeration and mixing”. These options are not acceptable, first because they have a low probability of having any noticeable effect in a lake with the specific geology and chemistry in Waughop Lake, but more importantly because they do not achieve the law’s mandate that the public nuisance be remediated by removal.	The LMP has been revised to emphasize that dredging is recommended as the most effective measure for reducing cyanobacteria blooms in Waughop Lake over the long-term. However, dredging costs could range from $2.7M to $15M depending on sediment volume, dewatering requirements, disposal needs, etc. Securing the funds needed for dredging may be difficult, especially if costs are closer to the high end of the range. It could take several years or more to complete additional sediment characterization, secure funding, obtain permits, perform dredging, and properly dispose of the sediments. Sediment phosphorus inactivation using whole-lake alum treatment would quickly reduce phosphorus concentrations in the lake, reduce the release of phosphorus from the sediment, and reduce cyanobacteria blooms. Initial costs and permitting requirements would be much lower than dredging. However, alum treatment would need to be repeated periodically and could increase aquatic plant growth. Bottom aeration and epilimnetic mixing would add dissolved oxygen to reduce anoxic conditions that favor phosphorus release from sediment and create vertical currents that physically disrupt cyanobacteria. This measure would entail significant capital and ongoing costs and should be pilot tested to confirm its effectiveness.

No.	Commenter	LMP Section	Comment	Response
23 (Cont.)	Tom McClellan (Letter, part 2)	General	As noted in the attached Summary Of Legal Obligations document, Lakewood Municipal Code mandates that whenever there is an accumulation of organic matter that has been deemed to be a health hazard, the condition "SHALL be abated by rehabilitation, removal, trimming, demolition, or repair." [emphasis added] The County and State codes regarding public nuisances contain similar and non-contradictory language. Leaving the phosphorous-laden in the lake would not meet that legal standard, and thus any options involving leaving the sediments in the lake must be set aside. This leaves mechanical dredging, hydraulic dredging, or perhaps some combination of the two, as the only acceptable options to pursue.	The City proposes a phased approach for implementing the LMP. Phase 1 would include whole-lake alum treatment and preparations for dredging (i.e., obtain funding, collect & analyze sediment cores, prepare SEPA documentation and permit applications, prepare bid documents, etc.). Phase 2 would consist of dredging, provided the City is able to obtain the necessary funds. If the City cannot obtain the funds needed for dredging, Phase 2 would probably involve additional alum treatment. The latter part of this comment raises legal issues that are beyond the scope of this LMP.
23 (Cont.)	Tom McClellan (Letter, part 3)	General	On Code Enforcement Action: Officials of the City of Lakewood have expressed reluctance on multiple occasions to initiating an official code enforcement action against the State of Washington (as property owner of Waughop Lake, and as the agency responsible for depositing the pollutants in the lake). Declining to initiate this action is not within the City officials' administrative powers. Discretion can be used in certain cases. There is a long-standing principle of allowing law enforcement officials to use discretion when determining to take or not take law enforcement action, based on scarcity of administrative resources. It is understandably not possible to take action against every possible crime, and so prioritization must take place. This is similar to the idea of prioritizing which road potholes must be filled sooner rather than later.	This comment raises legal issues that are beyond the scope of the LMP.
23 (Cont.)	Tom McClellan (Letter, part 4)	General	Lakewood Municipal Code, Pierce County Municipal Code, and the Revised Code of Washington all mandate that when a "public nuisance" exists, it shall be remediated. There is no option under the statute to not remediate the problem, and so the only place such latitude exists is in the historical precedent based on that principle of discretion based on scarcity of law enforcement resources. So, for example, if the City did not have the staff available to prepare the code enforcement action documents, the City could reasonably claim that such enforcement action is not possible at a given moment in time. Many "shall happen" events described under the law must be deferred or delayed based on resource scarcity. In the current case, however, resource limitation is not the driving force behind the City's officials declining to initiate code enforcement action against the state. The City has sufficient staff available to pursue grant applications and other methods of asking the State to provide the money for the cleanup, and so those same staffers' time and availability is not a limiting factor. Those resources are not scarce. Instead, the reason which has repeatedly been cited for not initiating code enforcement actions against the State is that City officials do not want to risk angering State agencies, including some from whom funding for City programs is provided. This is not a legitimate basis to cite in choosing not to take an action which the law mandates.	This comment raises legal issues that are beyond the scope of the LMP.

No.	Commenter	LMP Section	Comment	Response
23 (Cont.)	Tom McClellan (Letter, part 5)	General	The nature or category of a specific property owner cannot be cited as a factor when contemplating code enforcement action. This is specifically written into the “equal protection” clause of the 14th Amendment of the U.S. Constitution. That provision was put into the Constitution after the Civil War, specifically because certain law enforcement officials were declining to enforce the law when crimes were committed by white persons, even though those same laws were enforced if others committed the crimes. That was an example of making distinctions among accused persons based on their status. The City of Lakewood regularly initiates code enforcement actions involving property owned by individuals or corporations. And so to decline to initiate a code enforcement action just because of the status of a property owner (i.e. being the State of Washington) is a violation of the “equal protection” clause, and thus the City of Lakewood cannot make a determination not to enforce on that basis. Indeed, doing so puts the City at risk of a civil rights lawsuit, which would be expensive to defend.	This comment raises legal issues that are beyond the scope of the LMP.
23 (Cont.)	Tom McClellan (Letter, part 6)	General	If it were a case of insufficient staffing or other assets needed to make the code enforcement action, then it might perhaps be a different matter. But as discussed above, that is not the case, and so the City staff does not have the power to refuse to initiate such action. I do recognize that cooperation from the State’s legislative bodies will be needed in order for the funding to be allocated to respond to the City’s code enforcement action. I therefore recommend that the language be changed in the City’s proposed budget proviso language, described on page 4 at https://www.cityoflakewood.us/documents/city_council/city_council_agenda_packets/2016_12_14_Council_Special_Meeting_Agenda.pdf, to more specifically indicate that the total cost for the cleanup of Waughop Lake and other legacy environmental problems within the entirety of Fort Steilacoom Park shall remain the sole responsibility of the State of Washington, and that the State acknowledges its responsibility to pay for such remediation. In closing, I wish to convey that I have appreciated being allowed to be a part of this discussion, and I hope to continue to be an asset to the City’s efforts to clean up the toxic condition in Waughop Lake. I wish that we all could have gotten moving on the cleanup sooner instead of wasting the last 4 years and $250,000 doing an additional study, which came up with the same findings as the one I provided to the City in 2012 at no cost. I would be happy to be involved further in the management of the project as it gets started, or in some other useful way. Tom McClellan	This comment raises legal issues that are beyond the scope of the LMP.

No.	Commenter	LMP Section	Comment	Response
24	Don Russell	General	Whereas I believe that Jim Gawel's monitoring and assessment of Waughop Lake's condition was well done, I cannot say the same for B&C's listing of options for remediation of its hazardous cyanobacteria bloom condition or for the options that B&C lists for funding its remediation. The only option that makes any ecological, environmental and technically feasible sense for remediation of Waughop Lake's cyanobacteria impaired condition is a combination of drawdown followed by a combination of dry and wet sediment removal as noted in the Waughop Lake Cleanup Plan that Tom McClellan submitted to the City in 2012. That Plan cited all the reasons why other options should not be considered appropriate for the remediation of the damage done to Waughop Lake by Western State Hospital's past farming practices. For all the reasons cited in that 2012 Cleanup Plan plus that described in the attached document (B&C's number 1 option for Waughop Lake) all other options proposed by B&C should be dismissed as being inappropriate, environmentally undesirable, technically impractical, too costly and, most of all, lacking in holding the party responsible for Waughop Lake's impairment responsible for funding its remediation. Bottom line: The State should fund the restoration of Waughop Lake by drawdown followed by a combination of dry and wet sediment removal in order to restore its the pre-farming activity condition. Be happy to elaborate on why all remediation options listed by B&C, except a combination of lake drawdown and subsequent dry and wet sediment removal, are not ecologically, environmentally and economically (for the City of Lakewood and its residents) viable. -Don	Please see the response to comments 27 and 29 above. The LMP recommends dredging as the most effective measure but recognizes that obtaining the necessary funding may be difficult. The latter part of this comment raises legal issues that are beyond the scope of the LMP.

No.	Commenter	LMP Section	Comment	Response
25	Don Russell	General	A point worth mentioning is that whereas B&C lists hypolimnetic oxygenation/aeration as its first option, it is predicated on the assumption that Waughop stratifies to form a discrete hypolimnion that can be so treated. This assumption is based upon the Jim Gawel's study data that indicates that during the summer the lower waters of Waughop Lake do exhibit the characteristics of a hypolimnion, i.e., low temperature, thermal separation from a warm upper layer of water and atmospheric exposure, and a lack of dissolved oxygen at the water column/sediment surface interface. What is really going on here is that during the summer there is substantial Coontail (Ceratophyllum demersum) aquatic plant growth beneath the cyanobacteria canopy. This growth interferes with wind driven mixing of the water in the lake to the extent that water near the bottom remains stagnant even when wind mixing of the water column above Coontail influence is occurring. This stagnant water remains cold because it is a residual from the winter time wet season precipitation contribution to the lake plus a limited amount of cold groundwater that discharge into the lake.	The draft LMP did not list the options in order of preference. The draft LMP noted that dredging would be the most effective option. Bottom aeration with epilimnetic mixing was identified as a potentially viable option. The LMP did not advocate hypolimnetic oxygenation because the lake monitoring found bottom anoxia but not a distinct hypolimnion. Coontail is a native plant that can develop dense subsurface mats in high nutrient waters. Unlike cyanobacteria, it is does not produce toxic substances that can harm people, pets, or wildlife. It provides habitat for invertebrates and food for waterfowl. Coontail has no roots to obtain nutrients from the sediment. It absorbs nutrients directly from the water, so reducing phosphorus concentrations in the water column should help limit its growth.
25 (Cont.)	Don Russell	General	Coontail aquatic plants respond to nutrients contained in both bottom sediments and in the water column itself. Should the population of light, space and nutrient competing cyanobacteria be reduced or eliminated by aeration/oxygenation the response will be even greater Coontail aquatic plant growth to the extent that the entire surface of Waughop Lake will be covered by a mat of Coontail plant bushy leaf tips. This is the same prolific aquatic plant growth response that will also occur should Waughop Lake be alum batch treated or alum emitters be used to suppress hazardous cyanobacteria populations in the lake. The sediment induced nutrient condition of the lake will foster either hazardous cyanobacteria blooms, excessive native and/or noxious aquatic plant growth, or a mix of each, as is now the case. Algaecide and herbicide applications are undesirable since they merely treat a symptom, not the cause of cyanobacteria blooms and excessive aquatic plant growth. As Tom McClellan rightly concluded in his 2012 Waughop Lake Cleanup Plan the only ecologically and environmentally responsible and cost effective action to restore Waughop Lake's natural function is to remove the nutrient rich sediment layer that has been deposited on the lake's natural bed by Western State Hospital's use of the lake to dispose of its farm activity related waste material.	