Vancouver Lake Research Plan

Vancouver Lake Watershed Partnership

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This research plan for Vancouver Lake is based on the Technical Foundation Report developed by the Vancouver Lake Watershed Partnership in 2008, in which issues, questions, and research needs for the lake were identified. A technical understanding of the Lake is a prerequisite for identifying and initiating important changes to the lake. However, because the Vancouver Lake system is complex, the breadth of initial technical study should be directed toward those inquiries that provide a scientific foundation for the most critical management decisions.

Research Plan Goals

The overarching goal of this research plan is to provide a tool for decision makers to select appropriate studies that lead ultimately to appropriate restoration and management decisions for Vancouver Lake. To that end, this study seeks to: 1) identify key research needs for the restoration and management of Vancouver Lake; 2) identify the critical path for the research to follow; and 3) develop a clear understanding of the associated costs.

Research Plan Development Strategy

The approach used for developing this research plan is as follows:

1. Identify research steps currently underway.
2. Work with lake experts for technical guidance.
3. Develop approach with the Technical Group.

Research Plan Overview

The Technical Foundation presented many issues that the lake faces, but suggests using nuisance cyanobacteria (blue-green algae) blooms as a "point of entry" to guide our learning about Vancouver Lake. The Technical Foundation identified six major study areas as critical areas of inquiry. The Steering Group requested a broad prioritization of these research tasks so that a critical path through these study areas could be understood by all Partnership members. As such, this Research Plan looks at all of the research tasks identified in the Technical Foundation.

This research plan is organized into the six major study areas described in the Technical Foundation: 1) water dynamics; 2) nutrients; 3) sediment; 4) food web interactions; 5) toxic contaminants; and 6) fish, wildlife and habitat. In each of these areas study tasks are identified, with cost and timeframe of each study identified. At the end of the document the prioritization of these research tasks is identified in a timeline that suggests which research tasks should take place in what order.

Ultimately the information collected through the studies identified here will likely be used to populate a comprehensive numerical water quality model to allow for a thorough understanding of the physical, chemical, and biological processes in the Vancouver Lake system.

Water Dynamics

A seasonal water balance for Vancouver Lake is important to understanding the fundamental hydrology of the system and factors that cause nuisance algal blooms. Water inputs and outputs are primary pathways for nutrients entering, exiting, or remaining in the system. Vancouver Lake's tidal connection and relationship to the larger watershed makes understanding the water dynamics of the lake particularly important.

Table 1
Water Dynamics Studies

Study task	Description	Timeframe
Task 1.1: Physical Bathymetry	Physical bathymetry mapped by U.S. Army Corps of Engineers	complete
Task 1.2: 1-D Model	1-D model completed by US Army Corps of Engineers. Boundary conditions may not include all areas critical to Vancouver Lake.	complete
Task 1.3: 2-D Model	2-D model completed by US Army Corps of Engineers. Boundary conditions may not include all areas critical to Vancouver Lake.	complete
Task 1.4: Identify and Acquire Water Balance Data	1. Precipitation: use existing data from rain gage on site or nearby 2. Evaporation: use existing pan evaporation data for a nearby site, measure on site using a 3' diameter pan, or calculate using temperature and wind data for a nearby weather station (or a new on-site weather station) 3. Groundwater: calculate by difference in the surface water balance and estimate inflow/outflow using previous studies 4. Surface Waters: Measure water inflows (and outflow at Lake River) at Burnt Bridge Creek, Lake River, Flushing Channel; estimate inflows from small tributaries and nearshore areas using runoff coefficients.	27 months

Nutrients

A nutrient budget is a critical first step toward understanding water quality limiting factors in the lake. Data collected on nutrient sources, quantities, and pathways in Vancouver Lake will help to inform this nutrient budget. In particular, the system's nutrient sources and sinks must be understood in order to make informed management decisions with the goal of reducing nutrient availability to cyanobacteria. The primary nutrient of concern is phosphorus because it is typically the nutrient that limits cyanobacteria growth in lakes, but a nitrogen budget will also be developed to identify nitrogen sources if there are periods of the year when it becomes limiting. Potential limitation by inorganic carbon will also be evaluated by calculating the amount of inorganic carbon in the lake using alkalinity and pH data.

Table 2
Nutrient Budget Studies

Study task	Description	Timeframe
Task 2.1: Analyze Existing Data	With assistance from Partnership agencies, compile all available nutrient data, including sources such as groundwater chemistry information from the Port of Vancouver and Clark Public Utilities and tributary nutrient and flow information from the Port, the City of Vancouver, and Clark County. These data would be compiled into Clark County's data management system, and a data gap assessment to inform new data collection would be conducted.	3 months
Task 2.2: Conduct Nutrient Budget Study	Collect water chemistry data in the lake and at major inputs and outputs to the system for two water years. Lake and tributary samples will be analyzed for total phosphorus, orthophosphate, nitrate and nitrite nitrogen, ammonia nitrogen, total nitrogen, turbidity, total suspended solids (TSS), total organic carbon, alkalinity, and chlorophyll *a* and cyanotoxins (lake only). While collecting grab samples in the field, secchi transparency depth (lake only), pH, water temperature, dissolved oxygen (DO), and conductivity will also be measured. Measure atmospheric inputs of total phosphorus and total nitrogen if local data are not available. Estimate groundwater inputs and outputs using tributary and lake data, respectively. Phytoplankton and zooplankton data will be collected concurrently with the chemistry data as part of Food Web Interactions (Task 4.1)	24 months
Task 2.3: Data Analysis and Reporting	Develop a full report detailing the nutrient budget based on collected data. Analyze data to identify primary sources and losses of total phosphorus and total nitrogen in the lake, and determine internal and external loading using a mass balance approach. Describe in-lake recycling of nutrients (net retention and internal loading) and related water quality parameters (chlorophyll *a*, water clarity, oxygen, etc.). Describe relationships between lake chemistry and tributary chemistry, and evaluate relationships between lake chemistry and plankton populations evaluated for Task 4.1.	21 months

Sediment

Understanding Vancouver Lake's sedimentation rates, sediment transport, and sediment release rates will be essential to understanding the role of sediment as a nutrient source and/or sink. The three principle mechanisms of internal nutrient inputs should be examined: the physical re-suspension of sediment and associated nutrients and the chemical and biological release of nutrients from sediment.

Table 3 *Sedimentation Rate Studies*		
Study task	Description	Timeframe
Task 3.1: Analyze Existing Sediment Data	Develop short annotated bibliography of existing sediment data.	3 months
Task 3.2: Conduct Sediment Studies	a: Install and monitor sediment traps, to be done by USGS, to measure sedimentation rate in the lake. b: Collect surface sediment grabs with an Ekman or Ponar grab sampler to: 1) measure sheer stress and particle size for estimating sediment suspension from wind; 2) measure release of phosphorus from sediments in small chambers under controlled laboratory conditions, 3) measure phosphorus fractions in the sediment to estimate the pool of available phosphorus for physical and chemical release to support Task 3.3 evaluations. c: Estimate inputs of suspended sediment from tributaries using data collected for Task 2.2.	a: 24 months b: 3 months c: 24 months
Task 3.3: Evaluate Mechanisms of Internal Phosphorus Input	a: Physical: Estimate the physical resuspension of sediment and associated phosphorus from wind using a simple model based on data collected in Task 3.2 and existing bathymetric and wind data. b: Chemical/Microbial: Estimate the amount of phosphorus released from lake sediments by chemical dissolution and microbial decay using collected sediment data (Task 3.2) and oxygen data (Task 2.2). c: Biological: Estimate the amount of internal phosphorus input to the lake from decaying aquatic plants, sediment disturbance by benthic fish (e.g., carp), and fecal inputs from waterfowl using information collected for Task 6 and reported in the literature.	a: 12 months b: 12 months c: 15 months
Task 3.4: Investigate Lake History	Collect and analyze lake sediment cores to develop a more complete understanding of historical conditions at Vancouver Lake and determine the degree to which water quality has changed over time. Analyze vertical segments of the cores for analysis of lead (210Pb), nitrogen (15N and N), phosphorus (P), carbon (C), titanium (Ti), aluminum (Al), diatoms, and cyanobacterial akinetes. Dating of the cores would be determined by the 210Pb analysis; 15N, N, P and C would describe nutrients in the lake and eutrophication; diatoms act as water quality indicators; akinetes describe cyanobacteria; and metals Ti and Al describe watershed contributions, sedimentation rates, and atmospheric inputs. By analyzing material preserved in the sediment, the Partnership would be able to determine how water quality and cyanobacteria composition has changed over the past century, gain a better understanding of changes in sediment chemistry related to changes upstream in the watershed, and define sediment accumulation rates.	12 months

Food Web Interactions

Cyanobacteria blooms at Vancouver Lake frequently cause summer closures of the lake. However, the cycling and timing of these blooms and how other plankton influence these blooms, if at all, are not well understood. Since 2007, Washington State University (WSU) has studied the distribution and species composition of the cyanobacteria, algae and zooplankton throughout the year. Current work by WSU is looking at cyanobacteria growth and death rates, trophic interactions between plankton grazer populations, and factors that influence grazing. Understanding the planktonic community and its trophic interactions will better inform management decisions that attempt to control cyanobacteria blooms.

Table 4
Food Web Interactions

Study task	Description	Timeframe
Task 4.1: Study Planktonic Assemblages	WSU research to: (1) determine the abundance, distribution, and taxonomic composition of cyanobacteria, algae, and zooplankton in Vancouver Lake over a full annual cycle, (2) initiate preliminary investigations of the biotic factors (e.g., grazers) and abiotic factors (e.g., temperature and mixing) that influence these blooms, and (3) analyze the existing data on cyanobacteria blooms in Vancouver Lake for spatial and temporal patterns and trends in abundance.	12 months *(underway)*
Task 4.2: Determine Rate Processes	Determine rate processes—the growth and death rates of cyanobacteria — and effects of nutrient concentrations on those rate processes through nutrient manipulation experiments in the laboratory. Work conducted by WSU.	12 months *(underway)*
Task 4.3: Broader Food Web Study	Integrate plankton work into broader food web dynamics and other important species in the ecosystem, such as salmonids. With the completion of Task 4.2 and the continuation of background monitoring (e.g., parts of Task 4.1), the Partnership should have a good understanding of the lower trophic levels forming the base of the lake's food web, such as algae, cyanobacteria and zooplankton. However, these parts of the lake's food web will need to be linked to higher trophic levels, such as planktivorous and piscivorous fishes (see also Task 6.4 below), as well as to the benthic (bottom-dwelling) community of invertebrates (see Task 6.2.b below). This "whole lake" food web perspective will be essential to considering any biological manipulation of the lake to manage cyanobacteria blooms.	12 months

Toxic Contaminants

Toxic contaminant studies have been conducted by the Environmental Protection Agency (EPA) and Washington Department of Ecology (Ecology). In 2007, Ecology published the results of a study where they investigated PCBs, chlorinated pesticides, and dioxins in fish tissue and sediment from Vancouver Lake. Contaminants in Lake River fish and sediment also were assessed.

Toxic contaminants, although not directly linked to the cyanobacteria, are a priority for consideration due to the human health issues. Still, because this initial investigation by the Vancouver Lake Watershed Partnership (VLWP) is focused on cyanobacterial blooms, and because toxics studies are still underway, for the purposes of this research plan toxic contaminant studies are supplemental and pending further investigations by EPA and Ecology. A study task for this research plan includes an initial summary of toxic contaminant study findings for Vancouver Lake once the Ecology 2010 study is completed. A second task could then be conducted that identifies needs for additional study of toxic contaminants based on the data gaps identified.

EPA conducted sediment sampling in Vancouver Lake for contaminant analysis in 2009. Of the sediment samples collected throughout the lake, four contained contaminants above the "Threshold Effects Levels" (TEL). Two of those samples were above the TEL for lead, one was above the mercury TEL and one was above the TEL for three semi volatile organic compounds. Other lake samples found concentrations of lead, copper, mercury, and beryllium at higher levels than background levels. However, no contaminants were at a level for Vancouver Lake to be considered for the Superfund National Priority List. Although PCBs were not detected in any of EPA's sediment samples, EPA planned to return in late summer to sample clams for PCBs due to the US Army Corps of Engineers' findings of high levels of PCBs in clam samples in the flushing channel in 2005. Results of the clam sampling are not yet available.

Preliminary data indicate that while toxic contaminants are present in Vancouver Lake, the levels at which they occur when compared on a national scale do not warrant immediate action. Based on the study recommendations, Ecology is planning to conduct another toxic contaminant study of Vancouver Lake in 2010 using semi-permeable membrane devices (SPMDs). These devices are used to accumulate low levels of hydrophobic organic compounds over a one-month period in order to allow quantification of those compounds that are dissolved in water and potentially available for bioaccumulation in tissues of aquatic organisms. Preliminary plans call for deployment of devices in January, May and late August in Burnt Bridge Creek, the flushing channel, and at two locations in the Lake River (near the lake and near the Columbia River). Concentrated water samples obtained from the SPMDs will be analyzed for PCBs, dioxins/furans, and chlorinated pesticides and those results will be compared to SPMD results obtained from a statewide survey recently conducted by Ecology at approximately 19 sites.

Table 5
Toxic Contaminants Studies

Study task	Description	Timeframe
Task 5.1: Analyze Existing Data.	Technical review and summary report on existing toxics data and studies. Identify any data gaps.	3 months
Task 5.2: Identify Additional Toxic Contaminant Studies	If data gaps are identified, then determine necessary supplemental studies.	3 months

Fish, Wildlife, and Habitat

The research tasks include an aquatic species survey, fish community study, and salmonid genetic study. Aquatic species population and habitat data are important for understanding how those species affect the phytoplankton community primarily through nutrient cycling (e.g., phosphorus inputs) and food web interactions (e.g., predation on zooplankton). Recent studies on migratory and resident fish and their habitat as well as wildlife species and habitats in and around Vancouver Lake are lacking. Fish population composition surveys and habitat evaluations would inform management decisions, especially as they may impact aquatic habitat and food web interactions. Studies on wildlife composition and habitat may be less critical in decisions aimed at managing cyanobacteria blooms, but are of interest to some lake users.

A waterfowl population survey will be conducted in one study year, and timed with seasonal waterfowl migration patterns. Waterfowl data can be used with literature-derived values for fecal inputs to estimate nutrient loading from waterfowl for Task 2.3.

While not directly related to cyanobacteria and algal blooms, a salmonid genetic study can be used to determine if salmonids present in Vancouver Lake originated from tributaries to the lake or the Columbia River. Knowing the origin of salmonids in the lake will be useful for determining needs for salmonid habitat protection and restoration.

Table 6
Fish, Wildlife, and Habitat Investigations

Study task	Description	Timeframe
Task 6.1: Analyze Existing Data.	Compile and review existing data. With assistance from Partnership agencies, compile all available wildlife and habitat data, including sources such as past habitat and wildlife studies and information and data from the Port's current wetland and songbird habitat investigations.	3 months
Task 6.2: Aquatic Species Survey	a: Conduct an aquatic plant survey on one occasion in late summer to map the distribution of native and exotic emergent, floating, and submersed, aquatic plant species, and measure biomass and phosphorus content of major submersed plant populations to evaluate nutrient uptake and inputs by those plants. b: Conduct a benthic invertebrate survey on one occasion in late summer to measure the density and diversity of benthic invertebrate populations for evaluating water quality impacts and fish habitat. Collect sediment samples from representative locations in the lake and analyze them for benthic invertebrate species. c: Conduct an aquatic habitat survey on one occasion in late summer to evaluate habitat conditions in the lake for aquatic plants, benthic invertebrates, and fish. This could be conducted in conjunction with the aquatic plant survey.	a: 6 months (includes planning and analysis) b: 6 months (includes planning and analysis) c: 6 months (includes planning and analysis)

Table 6 *Fish, Wildlife, and Habitat Investigations*		
	d: Conduct waterfowl population surveys on four occasions during one study year. Use the collected waterfowl data and literature values for fecal inputs to estimate nutrient loading from waterfowl for Task 2.3	d: 15 months
Task 6.3: Fish Community Study	Conduct a fish community study that samples fish in different regions of the lake at different times of the year. The number of locations and the duration of the study would be based on the anticipated geographic and temporal variability, and available budget. Fish population and health data will be collected using multiple techniques (e.g., mark and recapture method using mid-water net tows for pelagic species, beach seining for littoral species, and fish traps for benthic species), and will include fish gut analysis for assessing feeding habits.	15 months
Study task	Description	Timeframe
Task 6.4: Salmonid Genetic Study	Genetic sampling of salmonids in the lake can help identify the origins of salmon that are using the lake at various life stages.	21 months

Lake Water Quality Model

The primary purpose of the water quality model is to predict effects of lake and watershed management activities on the algae and cyanobacteria population dynamics in the lake. An initial task (Task 7.1) will be conducted to identify specific objectives for the water quality model and to select which model will best meet those objectives. Selection of an appropriate water quality model for the lake depends on various factors related to constraints by physical lake features, the amount of input data available, level of detail needed for model output, how the model will be used, and available funds. Examples of water quality models that may be used include CE-QUAL-W2, CE-QUAL-ICM, and MIKE-21. Advantages and disadvantages of these and other models will be summarized once the modeling objectives are defined and historical data are reviewed. Although the relative accuracy of each model will vary with the amount and quality of the input data, it is anticipated that the studies identified above would provide sufficient data for any of the alternative models considered. Recommendations for additional data collection, if any, will be made once the preferred water quality model is selected.

Chemical and biological data collected for the other studies can be used to calibrate a water quality component of the model. The model chosen for Vancouver Lake, once populated with the necessary water dynamic, nutrient, sediment, and biological data, would allow the Partnership to make informed restoration and management decisions, and to evaluate management alternatives for Vancouver Lake. The calibrated water quality model developed for Vancouver Lake will be used to evaluate the effects of lake and watershed management actions on the growth of phytoplankton (suspended algae and cyanobacteria) in the lake.

The model will be useful for examining effects of reduced nutrient loadings to the lake from the watershed, but will not be capable of predicting the effectiveness of watershed nutrient reduction strategies on the those loadings. The potential needs, benefits, and approaches for developing a watershed model and integrating it with the lake water quality model will be explored.

The model also will be useful for examining effects of biological populations on water quality and phytoplankton growth, but will not be capable of predicting impacts of lake and watershed management on populations of higher trophic levels (e.g., aquatic plants, invertebrates, and fish). The potential needs, benefits, and approaches for developing a comprehensive ecological model and integrating it with the lake water quality model will be explored.

Table 7
Lake Water Quality Model

Study task	Description	Timeframe
Task 7.1: Select Lake Water Quality Model	Review advantages, disadvantages, data needs, model capabilities, and costs of lake water quality models that can be used to predict the effectiveness of management options on hydrology, nutrient dynamics, water quality, and plankton populations in the lake. Select an appropriate lake water quality model based on the lake's physical characteristics, available input data, desired model output/uses, and available funds.	3 months
Task 7.2: Develop Lake Hydrodynamic Component	Develop the hydrodynamic component of the water quality model using existing data and results of the initial water dynamic studies (Tasks 1.1 – 1.3)	6 months
Task 7.3: Develop Lake Water Quality Model	Develop, calibrate, and run the Vancouver Lake Water Quality Model for two years of data collected for Tasks 1 – 6.	6 months
Task 7.4: Evaluate Management Options	Use model to evaluate effectiveness of selected management options. A watershed model may need to be developed and used to evaluate the effectiveness of watershed management options.	6 months

Summary of Lake Research Costs

The table below (Table 8) shows the approximate cost or range of costs for each research task.

Table 8 *Study Area*	Study Task	Cost
Water Dynamics Studies	Task 1.1: Physical Bathymetry	Complete
	Task 1.2: 1-D Model	Complete
	Task 1.3: 2-D Model	Complete
	Task 1.4: Identify and Acquire Water Balance Data	$350 K in Partnership funds planned for USGS study of all four study tasks.
Nutrient Budget Study	Task 2.1: Analyze Existing Nutrient Data	
	Task 2.2: Conduct Nutrient Budget Study	
	Task 2.3: Data Analysis	
Sediment Studies	Task 3.1: Analyze Existing Sediment Data.	$10 K
	Task 3.2: Conduct Sediment Studies a: Sediment Traps b: Surface Sediment Grabs c: Tributary Suspended Sediment	 a: $10 K b: $10 K c: $10 K
	Task 3.3: Evaluate Internal Phosphorus Input a: Physical Suspension b: Chemical/Microbial Release c: Biological Mechanisms	 a: $40-80 K b: $30-40 K c: $20-40 K
	Task 3.4: Investigate Lake Sediment History	$100-150 K
Food Web Interactions	Task 4.1: Study Planktonic Assemblages	Complete
	Task 4.2: Determine Rate Processes	$100 K
	Task 4.3: Larger Food Web Study	$100 K
Toxic Contaminant Studies	Task 5.1: Analyze Existing Toxic Data	$10-20 K
	Task 5.2: Identify Additional Toxic Contaminant Studies	$10 K
Fish, Wildlife, and Habitat Investigations	Task 6.1: Analyze Existing Data.	$10-20K
	Task 6.2.a: Aquatic Plant Survey Task 6.2.b: Benthic Invertebrate Survey Task 6.2.c: Aquatic Habitat Survey Task 6.2.d: Waterfowl Survey	a: $30-60 K b: $30-40 K c: $20-40 K d: $30-60 K
	Task 6.3: Fish Community Study	$100-150 K
	Task 6.4: Salmonid Genetic Study	$3 – 5k
Lake Water Quality Model	Task 7.1: Select Lake Water Quality Model Task 7.2: Develop Lake Hydrodynamic Component Task 7.2: Develop Lake Water Quality Model Task 7.4: Evaluate Management Options	$10-20 K $40-80 K $85-120 K $15-30 K

Proposed 5-Year Research Plan

A proposed 5-year research plan is shown in the attached timeline (Appendix A). In some cases a task needs to take place first because it then informs a later study. That later study may also be critical but is simply a later step. In other cases a task is listed first because it is more critical to lake decision making than a later study.

Summary

The Vancouver Lake Watershed Partnership proposed this research plan to fill data gaps that limit understanding of lake processes, particularly those that cause nuisance cyanobacterial blooms resulting in lake closures in the summer months. This is not a complete list of all that needs to be done for Vancouver Lake. Rather, this document creates a foundation from which restoration and long-term management decision can be based. These studies will result in a more focused set of questions and identify specific data gaps that once filled will inform a clear restoration strategy for the lake.

Restoring Vancouver Lake to a healthy functioning estuarine freshwater lake could take decades, but there are many important steps that can be taken now to address the most urgent problems the lake faces. This research plan proposes a data gathering strategy to begin addressing nuisance cyanobacterial blooms.