Brown AND Caldwell

NON-PRICE PROPOSAL | Prepared for
Town of Stow, Stow, MA

Consulting Services for

Lake Boon Municipal Vulnerability Preparedness Project

January 11, 2021 | ORIGINAL

Fresh Perspective

Customized Solutions

Climate Readiness

Educated Citizens

EXHIBIT A - Proposal Signature Page

Complete this page and return as a cover sheet for the completed non-price proposal.

Town of Stow RFP to Provide Consulting Services

Brown and Caldwell	Deborah Mahoney
Company Name	**Contact Person** *(Please Print)*
One Tech Drive, Suite 310	978.983.2069
Street	**Phone**
Andover, MA 01810	
City, State, Zip	**Fax**
dmahoney@brwncald.com	
Email	

Submits the attached proposal for this Request for Proposals to the Town of Stow on the authority of the undersigned and as dated below. I confirm and pledge to abide by and be held to the requirements of this RFP and its resulting contract, to perform any tasks and deliver any documents required, and to execute a Contract with the Town of Stow.

Proposer acknowledges receipt of the following addenda.*

1.	2.
3.	4.

Authorized Agent of the Contractor:

Signature ***(blue ink please)***

Deborah Mahoney

Printed Name

Client Services Manager

Title

December 23, 2020

Date

(If a corporation, attach certificate of vote or apply corporate seal here)

BROWN AND CALDWELL INCORPORATED NOV. 7, 1958 CALIFORNIA

Form must be signed by a duly authorized officer(s) eligible to sign contract documents for the firm. Consortiums, joint ventures, or teams submitting proposals will not be considered responsive unless it is established that all contractual responsibility rests solely with one contractor or one legal entity. The Proposal must indicate the responsible entity.

Contractor should be aware that joint responsibility and liability will attach to any resulting contract and failure of one party in a joint venture to perform will not relieve the other party or parties of total responsibility for performance.

** to be filled in by Proposer, if addenda are issued.*

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January 11, 2021

Town of Stow
380 Great Road
Stow, MA 01775

Lake Boon Municipal Vulnerability Preparedness Project

Dear Selection Committee,

In accordance with your request, Brown and Caldwell (BC) is pleased to submit our proposal to the Town of Stow in response to the Lake Boon Municipal Vulnerability Preparedness Project RFP. BC understands all sections and provisions outlined and has no exceptions. In addition, BC acknowledges the Questions and Answers and additional Questions and Answers posted on the Town of Stow's website from the Pre-Proposal Conference on December 21, 2020. BC offers the Lake Boon Commission (LBC) and the Town of Stow the following benefits:

National firm with local presence. BC provides world class experience and lessons from lakes throughout Massachusetts and the United States. BC is an industry-leading, professional environmental engineering and consulting firm that offers a wide range of expert services on water resources, environmental, and engineering projects. We understand each lake is different: the hydrology, the environment and the effects from climate change. We offer our national expertise to customize solutions specifically for Lake Boon. BC serves our clients with a staff of more than 1,700 professionals in over 60 offices strategically located throughout the Country, including our local Andover office. Since 1947 nationally, and for more than 20 years in Massachusetts, BC has been building a reputation for delivering innovative, simple, and economical environmental solutions to its clients.

An expert team with a fresh perspective. BC has assembled a team that is well-suited for this project. Andrew Goldberg is a local and dedicated Project Manager with extensive MVP Grant Program experience. Technical Lead, Kirk Westphal, is BC's National Water Resources Leader who not only lives on Lake Boon, but also volunteered to collaborate last year with the Lake Boon Association (LBA) to collect water quality samples, and with the LBC to develop the monitoring and modeling programs that were included in the MVP Grant Proposal that is funding this work. The project team also includes Jeff Herr, BC's National Stormwater Practice Leader with over 37 years' experience in watershed management, Clifton Bell, BC's Water Quality and TMDL Technical Leader, and Jamie Lefkowitz, who recently designed and implemented a data dashboard for officials and citizens in Newburyport, MA.

A customized approach tailored to Lake Boon and its citizens. Our proposal recognizes that the work that LBC plans to do in 2021 and 2022 is a continuation of ongoing volunteer work with LBA, an opportunity to dig deeper into data gaps and uncertainties in historic data, and explore the resilience of the lake and its management measures well into the future. Our team provides continuity in that effort because we've been involved with LBA and LBC throughout 2020 in helping to frame the MVP proposal, sampling the lake with LBA, and developing a model to better understand the Lake's hydrology. Through volunteer work, we have already developed a preliminary hydrologic model of the lake that has helped better inform us on prevailing flow pathways. This will allow more time for experimental work with future climate scenarios and management measures.

Thank you for the opportunity to present our Proposal. We hope you see the value the BC team brings with our qualified team, relevant experience, and our ability to meet your objectives. We look forward to discussing our qualifications with you, and should you have any questions, please do not hesitate to contact Andrew Goldberg at 978.620.0759.

Best regards,
BROWN AND CALDWELL

Andrew Goldberg
Project Manager

Deborah Mahoney
Principal In Charge

Section 2

Executive Summary

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Executive Summary

Why Brown and Caldwell?

We Understand the Multiple Facets of this Project – It's about Lake Boon and its People

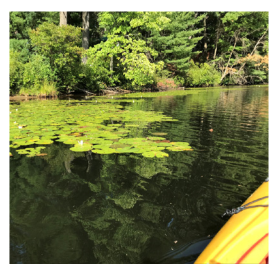
- **Every Lake Has its Own Story:** BC has worked to understand and improve nutrient-laden water bodies throughout New England and the United States. **We have learned that each lake has its own dynamics, and that while lessons from one lake may help inform decisions on another, effective water quality management relies on understanding the unique dynamics and science of each individual lake.** We worked with the Lake Boon Commission to help craft an MVP-funded program to do just that: Collect multifaceted data from the lake (flows, nutrient inputs, sediment data, and resulting water quality) that is targeted to rain events and time-of-year such that it creates a scientific narrative linking effects to their contributing and prevailing causes, then simulating these results with models that can extrapolate to future conditions in order to project the effectiveness of various management measures and both vulnerability and resilience to future climate trends.
- **This Project is a Continuation of Volunteer Work Started in 2019/2020 with LBA:** Through our work with the LBC and LBA to date, we have collaborated on a program that began in 2020 with citizen scientists collecting a year's worth of current hydrologic and water quality data. We understand that the MVP Grant program represents the continuation of this work, with funding for additional and more rigorous environmental monitoring (including sediments), development of simulation models to test future conditions, and coordination with citizens to learn about, and ultimately protect our lake. The goal is to clearly link water quality problems to their specific causes, and to recommend agreeable and cost-effective solutions, including nature-based solutions. Continuity with the LBA volunteer work in 2019 and 2020 will be essential to creating the scientific narrative of Lake Boon.

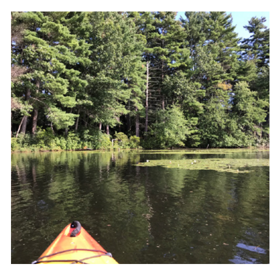
We don't know the answers yet, but we have a plan and are already on the Lake: Through Kirk Westphal's volunteer work in 2020 to help establish an affordable but comprehensive water quality sampling program with LBA, and BC's assistance with the LBC's successful MVP Grant, we have a good understanding of the lake's history over the last 40 years, and perhaps more importantly and directly the variety of its conditions over the last 2 years (beach closure in 2019, and then first brown and then green algae blooms in 2020 while phosphorus levels remained comparatively low and no beach closures were warranted). We've kayaked all four basins and we know their variety, depths, propensity for vegetation, access points, and shoreline density.


First Basin

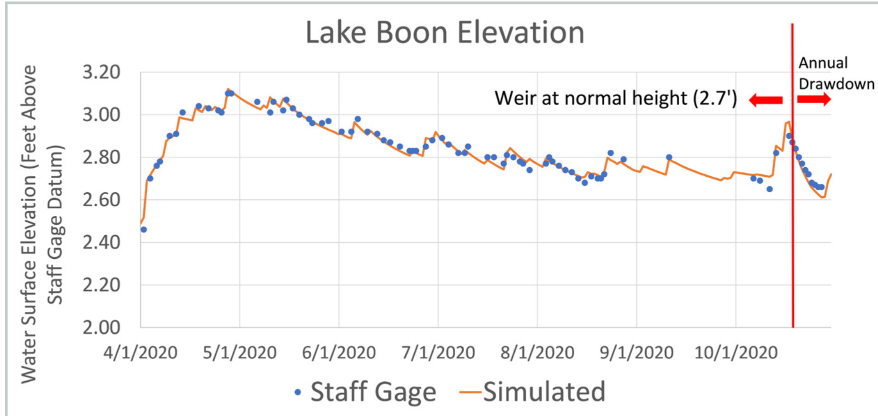

The Narrows


Second Basin


Third Basin


Fourth Basin

We have already developed a Lake Boon Hydrology Model: In collaboration with LBA with water level data from 2020, through volunteer work we have already developed and calibrated a climate-driven model of Lake Boon's hydrology, and have a sound understanding of the inflows from surface water and groundwater, as well as outflow at the weir and seepage through the stoplogs at the weir. We have accounted for evaporation and precipitation directly onto the lake and are already able to confirm with the sound science of this model that this lake is predominantly fed by groundwater (over 90% of the water that falls on the watershed appears to enter the lake via groundwater), as evidenced by the upwellings that are visible in winter. The photo below suggests upwelling of warmer groundwater springs, and the lake in winter is often speckled with these signs:



Apparent groundwater upwelling and our working model of Lake Boon's Hydrology, which confirms that Lake Boon is predominantly fed by groundwater (through flow division and visual observation of the gradual recession in lake levels after rain events).

This model does not eliminate the hydrologic modeling task – we will still present the model and its findings to LBC and LBA and continue to calibrate and validate with 2021 data, but the resources needed to develop a model can be re-allocated to broader deployment of the model to consider future climate scenarios and management measures, the principle purposes of this tool.

We understand the balance between monitoring and modeling: Many legitimate lake studies are conducted with a very heavy emphasis on field data collection, and rightly so if the questions are limited to the immediacy of a specific water quality issue. In this case, we understand that LBC wants to not only understand recent algal trends in the lake, but to provide a long-term program of solutions to guard against future climate scenarios. Warmer temperatures could increase evaporation, reduce summer inflow, and result in longer residence times in the lake, increasing the propensity for algal growth. Likewise, redistribution of precipitation to more frequent and more intense rain in the spring and fall can alter runoff dynamics and pollutant loading from the watershed surfaces. The field monitoring program that we developed with LBC for the MVP proposal results in a significant but balanced allocation of resources (including volunteer citizen scientists and substantial funding for laboratory analysis of water and sediment samples) to understand the current dynamics of the Lake so that we can identify its specific vulnerabilities. We have also included resources for modeling, not so much to compensate for actual data, but to be able to simulate future climate trends and management scenarios with confidence once the models are able to reproduce current conditions. **We learn about today's issues with the field data, and we learn about future resilience and management efficiencies with the models.**

A Flexible Approach: While we believe that the tasks successfully funded through the MVP program will achieve these goals, we also understand the need for adaptive management of not only our environmental resources, but also the projects that support them. **To that end, while we have addressed the scope tasks as outlined, we have also highlighted several opportunities to adapt the proposed scope of work if conditions warrant, much as we did in volunteer consultation with LBA in 2020 when a short-lived algae bloom occurred while phosphorus levels were low, reorienting our attention from phosphorus samples to chlorophyll-a.** If, in 2021, we see algae blooms develop, we may wish to reallocate some of our sampling resources to identification of the algae to better understand its organic composition (for example). We do not anticipate that adaptations in either the monitoring or modeling associated with this work to have significant impact on costs, but rather, would offer opportunities for modest reallocations toward work that can help better illuminate conditions as they evolve, or create room for even more room for exploratory future scenario evaluation.

Our Proximity to Lake Boon: Our proposed Technical Lead, Kirk Westphal, lives on Lake Boon and has already established a good working relationship with David Gray and others within the LBA and LBC throughout 2020 in planning the sampling program, adapting to conditions to capture specific events, and evaluating data from the lake. This, coupled with our involvement in the successful MVP grant, will allow a very smooth transition into the MVP program – a continuation of ongoing collaborative work rather than a ramp-up into something new.

Our Work Ethic: **Recognizing both climatic and social shifts, BC developed guidance documents called "LENSES" in 2020, which are intended to guide ALL of the water planning work we do**, and even if issues such as **climate adaptation**, **resilience** (to all varieties of shocks, such as pandemics and people spending more time at home), or **social equity**, are not explicit in our scopes of work, these issues WILL BE addressed in our processes, recommendations, and solutions. For Lake Boon, our work ethic goes hand in hand with MVP principles and LBC's own commitment to environmental resilience and social justice.

Section 3

Understanding, Approach, and Methodology

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Understanding, Approach, and Methodology




Four Seasons on Lake Boon. Photos courtesy of Kirk Westphal and Alex Townsend.

Understanding

Lake Boon is a remarkable resource in the towns of Stow and Hudson, and by discharging into the Assabet River, is part of a much larger regional water resource system of the SuAsCo Watershed (Sudbury/Assabet/Concord Rivers), and ultimately the Merrimack River Watershed. Locally, it affords residents opportunities to swim, boat, fish, and walk around its borders with astonishing views of its natural beauty. Like all lakes and rivers, however, it is vulnerable to the influence of humans, and this study is aimed at improving the balance between human interactions with the lake and its overall health.

Originally a resort community well outside of Boston, the lake was ringed with summer cottages which have since mostly been renovated into 4-season homes. While people can enjoy the lake and its surroundings in all four seasons, the year-round population density has brought with it some risks to which the lake is vulnerable. Specifically, high nutrient loads into the lake from runoff (which can carry fertilizers and organic matter such as pet waste and leaves) and from private septic systems (which can distribute nutrients into the largely spring-fed lake via groundwater) have resulted in occasional Harmful Algae Blooms (HABs). In 2019, for example, the levels of nutrients in the lake were high enough to create an algae bloom that raised enough concern about human toxicity that the lake was temporarily closed to swimming.

Our Technical Lead, Kirk Westphal, is a Lake Boon resident and has worked throughout 2020 as a volunteer with the Lake Boon Association and Lake Boon Commission to collect water quality samples of the lake, formulate a comprehensive monitoring program of lake water quality and flow for future years, better understand the lake hydrology, and assist the Lake Boon Commission with its successful Municipal Vulnerability Preparedness (MVP) grant proposal. He is personally vested in the success of this project, as he and his family value the lake for its aesthetic beauty, its abundance of good fish, its calm waters for swimming and kayaking, and the astonishing array of wildlife supported by the aquatic and terrestrial habitat around the lake.


Our Technical Lead, Kirk Westphal, lives on Lake Boon and loves the wildlife and calm waters. Photos courtesy of Kirk Westphal.

Lake Boon divides itself into four basins connected by narrow waterways. The deepest point of the lake is in the First Basin, measuring approximately 21' when full, and just beyond the public beach. Most of the inflow to the lake occurs through groundwater or shallow soil pathways, but one notable exception is the creek flowing into Monahan's Cove in the second basin, which drains the nearby Charter Oak Golf Course. The Third and Fourth Basins are much shallower – approximately 5-6', and marshier than the rest of the lake.

Multiple studies have been completed on the lake to try to determine the prevailing sources of nutrients that cause algae blooms, but most are 20-40 years old and findings may not reflect current conditions, particularly with regards to development and population. Perhaps more problematic to understanding the scientific dynamics of this lake today and into the future is the fact that the historic reports do not agree on representative levels of nutrients in the lake, nor the prevailing source(s). While all reports agree that phosphorus concentrations in the lake vary significantly year to year and month to month (from barely detectable, or less than 0.01 mg/l to 0.08, 0.15, and even 0.52 mg/l in one case, all of which can be compared to a general lake health guidance level of approximately 0.025 mg/l, which guides certain regulatory decisions), they do not agree on the relative source contributions:

- CDM in its 1986 study suggested that **septic systems** contribute between **0% and approximately 80%** of the lake's phosphorus, and it is hard to recommend potentially expensive solutions when there is this range of uncertainty.
- Massachusetts DEQ in a 1980 study suggested that septic loads could range from **0% to approximately 50%** of the lake's phosphorus loads, again hard to pin to confident recommendations on source reduction.
- DEP in its 2002 Total Maximum Daily Load (TMDL) study attributed **32%** of the phosphorus in Lake Boon to septic systems.
- In a 1999 study, ESS concluded that most of the flow into the lake is from surface runoff, suggesting that septic system loads may be less prevalent than **surface runoff** loads (not all reports agree on this – the lake is widely understood to be primarily groundwater-fed, and BC's preliminary assessment affirms this).

All these reports were good reports, and very useful in helping people understand the water quality in Lake Boon. **What was missing from earlier studies was the confident and consistent relative attribution of phosphorus to its sources – they range from suggesting that septic system loads can dominate the lake to suggesting the opposite, that runoff loads dominate. None of them attribute much potential for lake sediments recycling to contribute phosphorus. This study aims to overcome the gaps in our understanding of our lake through targeted science: sampling and modeling with both spatial and temporal variations aimed at identifying sources as they respond to their natural environment and climate conditions.**

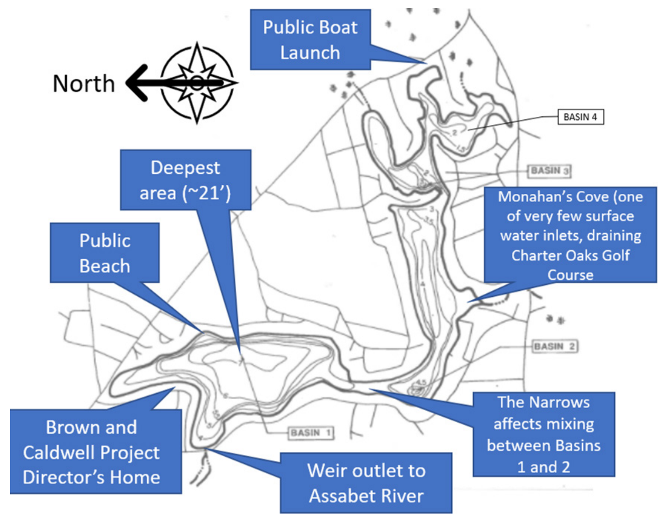


FIGURE 1 // Lake Boon and Key Features. (Map from CDM Report: "Diagnostic / Feasibility Study, Lake Boon – 1987" annotations added in blue)

Couple this with the fact that LBA grab samples and laboratory analysis for phosphorus throughout 2020 tended to be much lower than the historic numbers (often below or just barely above the laboratory detection limit), and we can see why we need targeted year-over-year measurements (started in 2020 and planned through 2022 with this project) to understand this variability and respond with a meaningful management plan.

Without this improved understanding of phosphorus sources, any attempted solutions to reduce the potential for algae blooms will be partially blind, and likely cost ineffective. For this reason, **the most important purpose of this study is to improve our understanding of the unique dynamics of Lake Boon so that we can manage its problems effectively - it is not just like any other lake in Massachusetts.** It is largely spring-fed with deep areas that thermally stratify but dominated by shallower areas that are well mixed and well oxygenated. In 2020, Lake Boon Association found that the deep areas of the First Basin go anoxic, which means that sediments could play a key role in recycling legacy nutrients back into the water column.

Our understanding of the risks posed to Lake Boon, current and future, stem from lingering uncertainties in past studies that can be addressed with targeted lake sampling and simulation models that are driven by climate variables. These risks include both **current conditions and potential future conditions driven by climate change** and must be clearly addressed with this work.

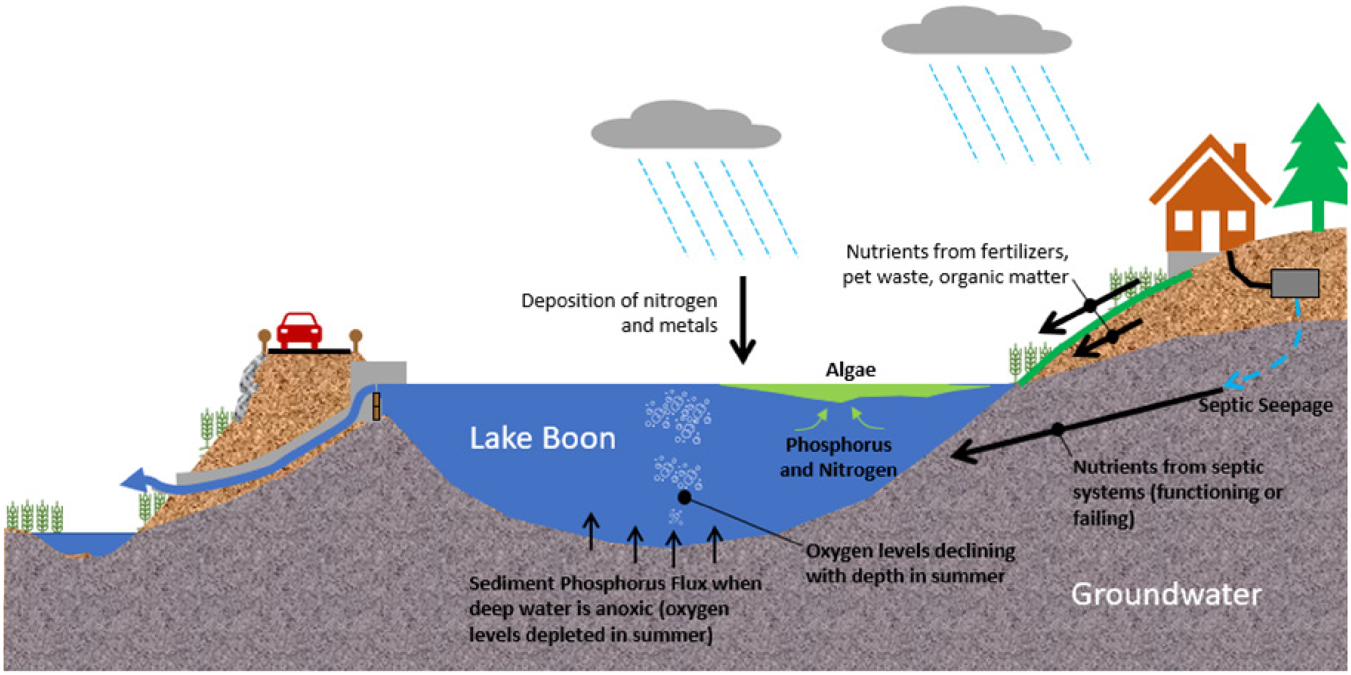


FIGURE 2 // **Phosphorus Loading Pathways: This figure illustrates the pathways for phosphorus to get into Lake Boon. For Algae to grow in Lake Boon, two nutrients must be present in sufficient concentrations: Phosphorus and Nitrogen. In most freshwater lakes, there is always an abundance of nitrogen because of its persistence in groundwater and deposition from rainfall. There is not always enough phosphorus, but when there is, it can combine with the available nitrogen to grow algae. This is called a "Phosphorus-Limited Lake," meaning that phosphorus is the controlling nutrient, and management of phosphorus to bring it below concentrations that would permit aggressive combination with nitrogen can be effective ways to reduce the potential for algae blooms.**

Priorities for Understanding Lake Boon's Unique Dynamics

In order to understand the unique dynamics of Lake Boon, it will be important to fill in several of the data gaps in the current body of knowledge:

- The balance between surface water and groundwater flows and nutrient loads and the effects of these loads on lake health
- The actual (measured) impacts of sediment as they recycle phosphorus into the water
- The climate vulnerabilities of the lake if left unmanaged, and in response to specific management alternatives
- The current state of cultural eutrophication (organic productivity accelerated by human activities) in the lake
- Historic Management Practices

Each of these is discussed below:

Balance between surface water loads and groundwater loads: Prior reports were inconclusive about whether nutrient-laden runoff or groundwater rich with nutrients from septic systems are principally to blame for past algae blooms. CDM, in its 1987 report on Lake Boon, suggested that the lake's water inflows are dominated by groundwater contributions (approximately 80%), but ESS in its 1999 report suggested that only 10% of the lake's phosphorus originates in groundwater. While both may be true, when taken together they are entirely inconclusive, especially noting that CDM's report cited phosphorus contributions from septic systems (via groundwater) as between 0% and 80% of the total phosphorus load to the lake, which is inconclusive. It may be that both groundwater and surface water contribute significant enough loads to cause algae blooms, but under different conditions or different times of year. **Targeted sampling (by month, and before and after rain events) and clear hydrologic representation of the inflows and outflows at Lake Boon will be key to understanding this balance, reconciling inconclusive findings of past reports, and better understand the lake's variability year to year, or month to month.**

Lakes can experience different types of plant and algal growth, each of which tend to have different drivers and controls. Both natural and invasive rooted plants (e.g., pondweed, fanwort, and milfoil) favor quiescent waters with shallow depths and soft bottom sediments. Because rooted plants can obtain nutrients from the sediment, they tend to be limited by water clarity, water depth, and grazing rates rather than by nutrient availability. The scientific and lake management literature shows little record of successful reduction of macrophytes by external nutrient controls, and management measures tend to focus on top-down controls such as harvesting, dredging, herbicide application, or biological controls (e.g.,, stocking of triploid carp).

In contrast, algae growth in lakes is typically strongly controlled by nutrient availability, in addition to other factors such as water clarity, temperature, and hydraulic residence time. Longer residence times provide more opportunity for algae to accumulate without being flushed from the water body. In most freshwater lakes, phosphorus is in shorter supply (relative to algal needs) than other nutrients such as nitrogen, and so algae growth tends to be phosphorus-limited. This is probably the case in Lake Boon, as evidenced by low phosphorus concentrations under most conditions. Additional monitoring can help confirm whether phosphorus-limiting conditions predominate in Lake Boon, or whether nitrogen also plays a role under certain conditions.

Phosphorus in lakes can be derived from both external and internal sources. External sources include precipitation, stormwater runoff, groundwater inputs, and septic systems. Internal sources include releases from the bottom sediment and internal within the water column itself. Thus, in order to determine the best manner to control or reduce phosphorus availability, it is important to identify the major internal and external sources and quantify those sources in a mass balance. A phosphorus mass balance should be based on accurate, representative monitoring data and integrated with the hydrologic budget. It can also be developed at different temporal scales to distinguish between: (1) seasonal average conditions; and (2) shorter-term pulses that temporarily increase nutrient availability and fuel nuisance blooms. Such pulses might be caused by wet-weather events or wind-driven suspension of nutrients from bottom sediments.

The monitoring and modeling approach presented in the scope of work is designed to provide a strong understanding of both nutrient sources and in-lake water quality dynamics. This will provide the scientific bases for selection of effective control and protection measures.

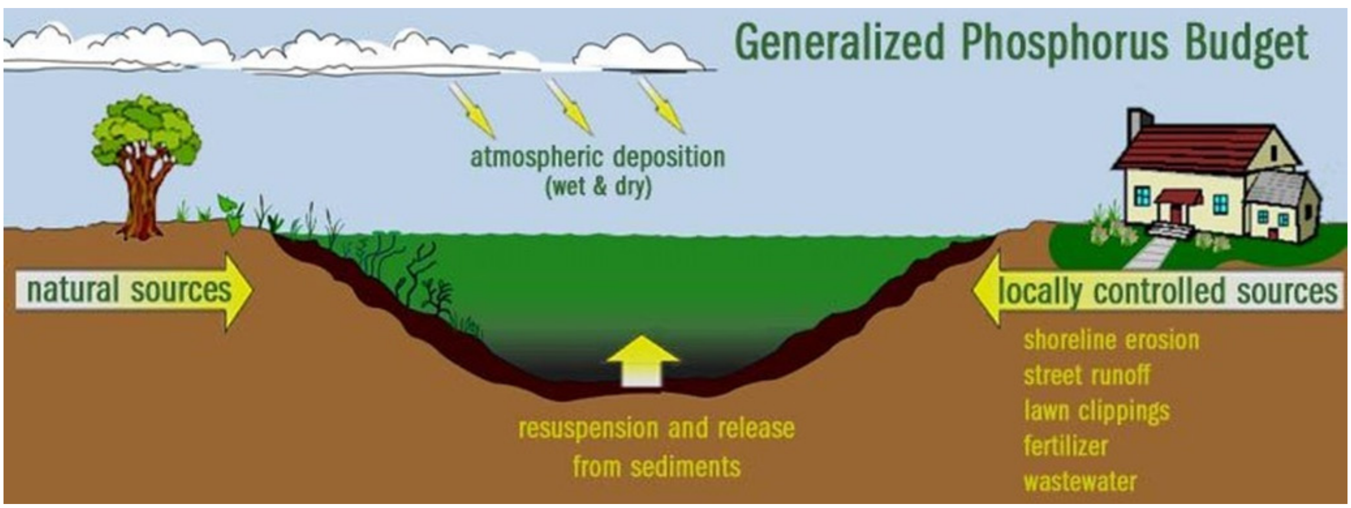


FIGURE 11 // Modeling will quantify the relative contributions of phosphorus loading from various pathways, taking into consideration both natural sources and local factors like septic systems and fertilizer use. Source: Heger (2017)

Sediment Recycling: An often-overlooked source of phosphorus to lakes can come from the sediment in deep areas. Some earlier reports (ESS 1999, and CDM 1987) dismiss sediment loads as contributing only about 1% of the total phosphorus in the water, but it appears that this was speculative and was never verified. Work by our Technical Lead, Kirk Westphal, in the nearby Assabet River just downstream of the Lake Boon discharge (for the US Army Corps of Engineers) suggested, with the help of laboratory measurements, that phosphorus loads from sediment in this region can be much more significant. **We must use this study to conclusively determine the degree to which sediments contribute to Lake Boon's phosphorus load. This can be done through specialized laboratory measurements.**

In 2020, the Lake Boon Association with its newly purchased YSI probe detected very low levels of dissolved oxygen throughout the deep zone (approximately 20' – 21') in the First Basin, near the swimming beach. **Our Project Director assisted LBA Lead David Gray during some of these measurements, as an LBA volunteer, and this experience emphasized how important it will be to understand the spatial extent of this anoxic zone in the summer (how many acres), and to couple this with actual laboratory measurements of phosphorus release from sediment in the anoxic zone.** On its own, low oxygen does not cause or encourage algae growth, but when water just above the sediment goes anoxic (very low oxygen levels, as observed in 2020), it can cause phosphorus that previously settled out of suspension to unbind from iron molecules and come back into the lake. The deep area in the First Basin spans many acres, and if the anoxic conditions are prolonged in the summer, this may be a significant source of phosphorus.

It is important to understand the science of temperature and oxygen variations in the water column. In the summer, warm air heats the upper layer of water (the epilimnion) and it becomes less dense than colder lower layers. Because of different densities (a good analogy is oil and water), the layers do not mix well, and the lower layers (metalimnion in the middle, or transitional area, and hypolimnion in the lowest layer) are left fully unexposed to surface air that can re-oxygenate the water naturally. Oxygen levels in the hypolimnion, then, are depleted by decaying matter in the sediment which consume oxygen, and are not replenished with surface air. The graphs to the right in the figure below illustrate this phenomenon very consistently throughout history at Lake Boon, with three separate studies all showing similar patterns from 1979 (Massachusetts DEQ), 1986 (CDM), and 2020 (Lake Boon Association, assisted by our proposed Technical Lead, Kirk Westphal). In the warm months of July and August, water temperature starts to drop at depths from 10-15 feet, and oxygen levels at the bottom of the lake (hypolimnion) are reduced to nearly nothing. An example below in a cooler month (the profile collected by LBA in September of 2020, shows a more consistent distribution of temperature and oxygen levels, meaning that between August and September of 2020, the lake “turned over,” and as densities equalized the lake returned to a vertically well-mixed water body where all water can circulate and become reoxygenated. **Understanding this summer stratification and autumnal turnover pattern is vitally important in assessing the health of Lake Boon.**

It is important to remember, however, that phosphorus does not originate in the sediment – it arrives there from runoff or groundwater in previous times (called “legacy phosphorus”). Hence, management of phosphorus in sediments can be controlled either by improving oxygen levels, or by the very same measures aimed at land-based nutrient loads, which contribute to next year’s sediment load potential. **In past reports, sediment contributions have been presumptive – we aim to measure them directly and have already engaged with two of the very few laboratories in New England who specialize in these services to formulate a plan for Lake Boon:** The Woods Hole Group, and SMAST (Water quality laboratory at UMass-Dartmouth). We will be recommending these labs to the LBC.

Climate Vulnerabilities: Understanding the problems and risks as they exist today will be an enormous step forward for the Lake Boon community, when compared to past studies that did not necessarily agree on the lake’s dynamics. This is just the beginning. In order to recommend management measures that are likely to be resilient to future trends in rainfall and temperatures, and to understand how natural conditions can potentially worsen the risk of algae blooms, this study must yield tools that can explore the sensitivity of Lake Boon’s phosphorus loads, flushing rates, and temperatures to future trends in precipitation intensity, volume, distribution through the year, and air temperatures. Three risks specifically must be examined:

- **More intense rain in the spring and fall**, which may wash higher loads of fertilizer and decaying leave matter into the lake, elevating available phosphorus
- **Longer and more frequent dry periods during the summer**, which can lead to longer residence times (slower flushing), and more time for algae to grow in the lake after washing in during the spring and continually leaching through septic discharge to groundwater
- **Warmer air temperatures**, which will lead to warmer water temperatures, which is known to increase algae growth potential.

BC worked directly with the LBC to help draft the 2020 MVP Action Grant proposal from which this work will follow. We recognize that solving today’s problems through a better understanding of the lake’s unique dynamics is just one part of the problem, and that vital to the long-term health of the river is to understand, manage, and mitigate the risks that future climate trends could exacerbate the loads into the lake and the algae growth patterns within it.

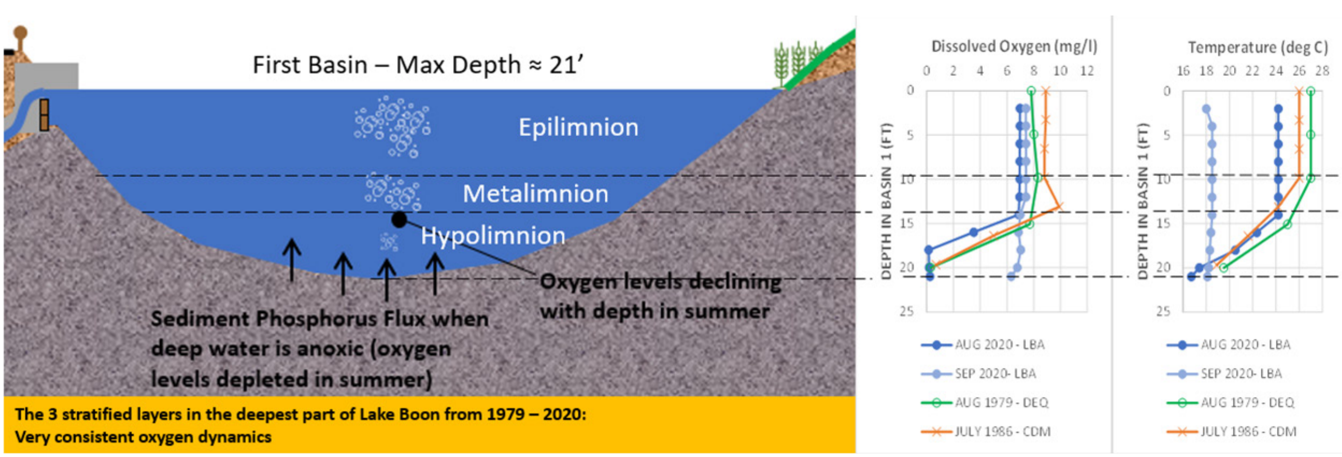
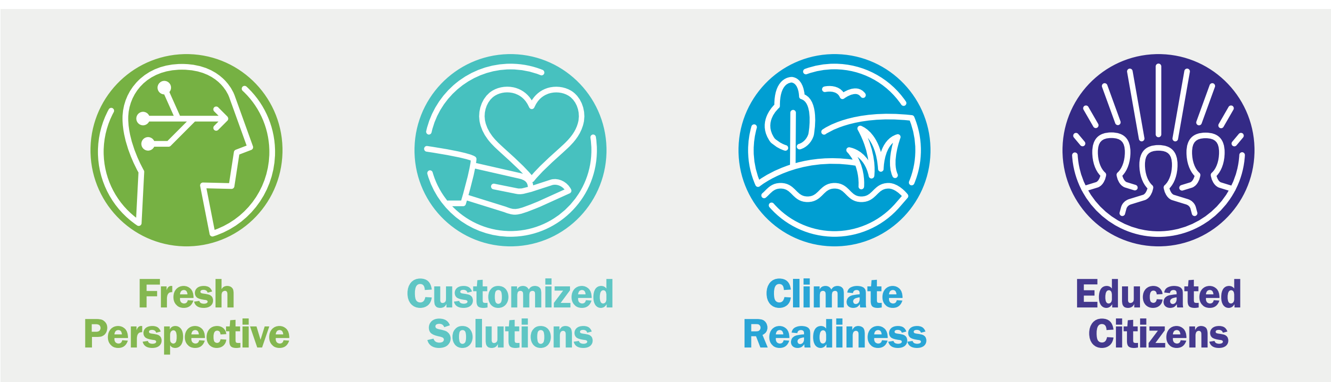


FIGURE 3 // Data Sources: Boon Pond Diagnostic/Feasibility Study, Massachusetts DEQ (1980), Diagnostic/Feasibility Study, Lake Boon – CDM (1987), and Lake Boon Association Volunteer Sampling Collaboration - David Gray and Kirk Westphal (2020).

Current Trophic Status: An early indication of the health of Lake Boon will be the application of a reliable indicator of trophic status. Eutrophication occurs when a water body becomes over-enriched with nutrients in a state where they can grow into harmful algae, deplete the water of oxygen, and pose toxic threats to both people, fish, and wildlife. “Cultural Eutrophication” occurs when human activities and presence accelerate or dominate the nutrient enrichment of a water body and help accelerate biological productivity of algae. Water bodies are classified on a spectrum of eutrophication states, from **oligotrophic** (good water quality) to **mesotrophic** (moderate biological productivity and fair water quality) to **eutrophic** or **hypereutrophic** (high rates of biological productivity resulting in poor water quality). Understanding Lake Boon’s current trophic state will be essential in recommending solutions, as some contemporary solutions are aimed at preventing eutrophication before it happens, while others seek to manage it once it occurs. **Our approach will include an assessment of Lake Boon’s current state so that we can better target effective management measures**.

Historic Management Practices: Historically, LBC and LBA have collaborated on encouraging best management practices within the watershed, including incentivized septic maintenance through group rates, education about lawn and leaf care, in-lake weed-treatment, and annual drawdown over the winter to reduce growth potential of shallow rooted macrophytes in the spring and summer. What is missing is an attempt to quantify the effectiveness of these practices. Through simulation models, we will aim to better understand the potential for proper septic maintenance and/or upgrades, and non-point source pollution management (fertilizers, pet waste, leaves, etc.). We will also work with LBC to better understand the potential impacts of the annual weed treatment and lake drawdown by linking recent practices to nutrient levels observed in the lake (incorporating the annual weed characterization reports that are supplemental to this project into our collective body of knowledge).

Approach



In the spring of 2020, BC’s Water Resource Director, Kirk Westphal, who lives on Pine Point Road on Lake Boon’s First Basin, began discussing lake water quality as a volunteer with the Lake Boon Association, and subsequently offering guidance to the Lake Boon Commission on a water quality and flow sampling program for 2020, and funding strategies for extended study of the lake into 2021 and beyond. BC subsequently volunteered time to collaborate with the LBA and LBC on the successful Municipal Vulnerability Preparedness (MVP) Grant, from which this project is derived. Our approach and methodology will carefully reflect the scope developed for the MVP process, which is aimed at four key elements:

Fresh Perspective

A fresh and local perspective on the unique dynamics of Lake Boon, its hydrology, and its nutrient loading patterns through targeted water quality sampling and companion simulation models driven by climate variables that can help clarify current risks and explore future risks. Part of the fresh perspective needs to be a more foundational examination of the lake's hydrology – that **without a dynamic understanding of flow and how it behaves seasonally on the surface and beneath it, we cannot even begin to make qualified assessments about water quality.** Supplementing this fresh perspective will be targeted, current water quality samples that reflect the lake's response to rain, dry periods, and different months in the year, as well as the contribution of phosphorus from the sediments – a largely presumptive impact until now. **Our Project Director developed a sediment phosphorus flux model for the Assabet River just downstream of the Lake Boon discharge (for the US Army Corps of Engineers) and is intimately familiar with the potential for sediment to be a prevailing source of nutrients, and how to represent this quantitatively.** His work was published in the American Society of Civil Engineers Journal of Environmental Engineering in 2013. **And because our Project Director lives on the lake, he can observe fluctuations in lake levels, clarity, and algae concentrations with his own eyes, every day and be ready to nimbly adapt sampling plans if needed as conditions evolve through 2021 and 2022.** His immediately local presence also assures his vested interest in the success of this study – this project requires far more than applying lessons learned elsewhere – together, we need to learn the dynamics of Lake Boon and target solutions at the sources of the problems to improve the health of our lake and community.

Customized Solutions

Customized solutions for Lake Boon, based on a more definitive understanding of the balance of nutrient loads between fertilizers and organic matter in surface runoff, subsurface groundwater flow that carries septic discharge, and sediment that can release entrained nutrients under certain conditions, we will target effective management practices Lake Boon. We will draw on successes from other lakes in New England and elsewhere but will not begin with any presumptions about what's right or best for Lake Boon. **Many similar studies recommend presumptive treatments for Harmful Algae Blooms (HABs) and focus on the manifestation of the problem (algae growth from nutrients in the water) rather than the source of the problem (the nutrient loads themselves). Our approach will use robust monitoring and modeling techniques to identify the root cause of these issues, and while we will certainly consider solutions that have been successful elsewhere, we will also focus on recommending nature-based solutions tailored for the needs of Lake Boon to help manage the nutrient loads themselves, and not just their impacts.**

One key theme in our approach will be to identify the current trophic status of Lake Boon (see earlier description on eutrophication states). A long-standing method used to estimate the trophic status of a lake can be helpful, though not fully conclusive. Named after its researcher, the Vollenweider Method for evaluating the trophic status of a lake is a very useful first step in a lake water quality study, as it provides initial screening into the extent of problems, and subsequent guidance toward effective management (preventative or abatement). The method requires the use of three pieces of information, all of which we have now in some form, and each of which will be improved upon over the course of the field work in this study.

In short, eutrophication status can be correlated to mean lake depth, average residence time of water, and annual phosphorus load into the lake. We know the lake depth from past bathymetric studies. We know from 2020 measurements the outflow of the lake and with a hydrologic model already in progress with BC, can compute average residence times. From past reports and recent years of phosphorus sampling by LBA, we can develop a range of annual phosphorus load projections **to determine what range on the eutrophication spectrum best describes Lake Boon today. Knowing this up front can better inform sampling priorities and management plan recommendations.** Prior to beginning the water quality modeling, we will assess the trophic status of Lake Boon, and this will help inform us on the level of detail we may or may not need for the water quality modeling and interpretation.

Climate Readiness

Climate Readiness: Many similar studies are content to rely on qualitative impacts of future climate conditions as posing neutral, mild, moderate, or severe risks to current environmental problems. While useful, we pose the proposition that this understanding is not enough to support decisions that could be costly, and a more quantifiable understanding of climate risks will be very helpful. **You will see that the simulation models that we have already started to develop for Lake Boon as part of our work on the MVP proposal and volunteer work with the LBA are climate-driven models, which means that they are driven by the fundamental hydrologic drivers that are critical to understanding a natural water system, daily rainfall and temperature.** By basing our models on these climate variables, we will be able to examine a broad range of potential future conditions in precipitation and air temperature (which affects evaporation and water temperatures) by changing precipitation and temperature inputs to explore a range of plausible future climate conditions and their likely impact on flows, loads, and water quality in Lake Boon. **We have learned that exploring a range of plausible climate futures offers a far more confident assessment of vulnerabilities than projecting a "most likely" climate future and grounding recommendations in a single hypothetical.**

Educated Citizens

Educated Citizens: Citizen scientists will be a driving force behind a successful project. Our team will coordinate with LBA volunteers to train citizen scientists to properly collect water quality samples for laboratory analysis, and this force of dozens of local citizens who care about our water will be key to our understanding of the lake, and will also share their experiences with friends and family. BC will support the LBA and LBC and the project Steering Committee in public meetings, offering our technical assessments of the lake and bringing to bear our national expertise in building agreements on pathways forward for solving environmental problems.

Key to success in projects such as this is the application of "simple but confident" tools. This includes both the water quality sampling, and the simulation modeling. We worked with the LBC to outline a sampling program that is affordable, practical, and comprehensive in time and space to isolate sources of phosphorus and their impacts on lake water quality, without requiring any excessive and expensive enumeration of the algae varieties themselves (we believe in identifying the problem at the source, and then recommending solutions targeted both at the source (loads) and their impacts (the algae itself) – In this sense, more specific enumeration of algae varieties may be a good follow-up grant opportunity when it comes time for implementing recommended solutions). With models, we will use a proven tool for watershed hydrology that is rooted in the practical application of academic research, but which avoids the cumbersome and often confusing problem of over-parameterization. Our simple watershed model uses just four parameters to help distinguish surface runoff from shallow soil moisture and groundwater flows, and our Project Director has applied this successfully for other lakes and reservoirs in Massachusetts, including for the Massachusetts Water Resources Authority (MWRA) in another published paper that was awarded "Best Practice Oriented Paper" by the ASCE Journal of Water Resources Planning and Management for its simple approach to understanding complex water systems. Application of simple but proven tools is not only cost-effective, but it will also improve our collective confidence in understanding our lake.

Lastly, our approach is flexible and adaptive to evolving conditions. The sampling program that we developed with LBC and LBA for the MVP proposal is a solid framework for capturing the lake's response to rain (fast runoff and then slower groundwater flows), and also to seasonal trends (longer term persistent loads and how they vary). Having coordinated and overseen water quality sampling programs since 2002 in Massachusetts in the Merrimack Basin, Assabet Basin, and Blackstone Basin, we know that the only thing of which we can be certain is that conditions will be different in 2021 than they were in 2019 and 2020. BC worked in close partnership with LBC and LBA to structure the sampling program for 2020, 2021, and 2022 to target event-driven and seasonal phosphorus and algal dynamics. We may find, however, that during the monitoring we see curious spikes or anomalies in one parameter that warrant a closer look, or stronger statistical correlation with other parameters. This was the case in 2020, as some surprisingly high conductivity measurements along the shoreline suggested elevated loads from nearby septic systems – perhaps worth a closer look, and as first brown algae, then green algae appeared, and encouraged us to reallocate some lab funds to chlorophyll-a instead of only total phosphorus.

We may wish to re-allocate sampling and lab resources to investigate findings like this. Our sampling program will be grounding in the structure of the proposed plan that we developed with LBC and LBA in preparation for the coming years, but we will evaluate cues and clues as they are obtained to determine if focus should shift to other areas of interest. We want to be sure that each data point is collected for a reason – the sampling plan we developed with you for the MVP proposal accomplishes this without collecting extraneous data that might be useful only at a more academic level. However, we look forward to reviewing results as they are available and discussing with LBC any appropriate adaptations to the sampling plan that may be wise. For example, we may discuss opportunities with LBC and LBA to adapt the monitoring program in the following ways (without changing level of effort), based on actual 2021 data findings:

1. If we see high conductivity in certain shoreline areas, this may be a clue that we should trade some phosphorus samples for nitrogen because of suspected prominent septic loads to better determine if septic leaching is indeed a localized source of surplus nutrients (nitrogen is a better indicator of localized septic loading than phosphorus).
2. If we witness an algae bloom, we may re-allocate phosphorus, chlorophyll-a, and cyanotoxin measurements more immediately upon observing the bloom to better understand the levels that cause it.
3. If we see algae growing while total phosphorus levels are seemingly small, we may wish to divide some phosphorus samples into organic and inorganic phosphorus to understand how much is truly available to support growth (conversely, we may do the same if we see high total phosphorus levels without corresponding algae blooms.) It may be wise to do this for a few samples anyway, and we will discuss this with LBC.
4. If we begin to see algae even in small quantities, or phosphorus levels above 0.025 mg/l, which is a guidance level for healthy lakes, we might suggest taking a few diurnal oxygen measurements (morning and evening) to help determine if organic productivity is pronounced even before the appearance of an algae bloom – high organic productivity can be indicated by oscillations of 1-2 mg/l (or more) of dissolved oxygen as respiration of organic matter (photosynthesis and the production of oxygen) can dominate by day while decay (oxygen consumption) can dominate by night. (In fact, we may be wise to plan on this regardless of what else we find).
5. If nitrogen levels are found to be as expected early in the sampling season (always abundant enough to support organic growth), we may de-emphasize nitrogen sampling and shift more emphasis on the correlation between oxygen, chlorophyll-a and phosphorus in order to better understand indicators of impending algae issues.
6. If we see algae blooms repeatedly after severe rainstorms, as were reported by residents in 2020, we may refocus efforts to better capture phosphorus in direct runoff, especially in the small tributary that drains the Charter Oak Golf Course into Lake Boon.
7. If we see different types of algae blooms, as we did in 2020 (first brown algae, then later green algae), we may reallocate some of the funding for chlorophyll-a to better understand the type of algae that is growing, and how it correlates with nutrient concentrations. We may also recommend some specific tests for phytoplankton to better understand the composition of the algae in the lake.
8. If we see that nutrient and oxygen levels are consistent between the First and Second Basins, we may assume that the Narrows and its boat traffic effectively mix the two basins, and for analytical purposes treat them as one, and reduce sampling in one basin to get a more dispersed or more frequent sample set in the other. On the other hand, if we see persistently different concentrations in the two basins, we will want to model and evaluate them separately (but with connectivity that can support transport and diffusion of nutrients between basins). The same is true with the Third and Fourth basins. Through our volunteer work with the LBA in 2020, we observed data that suggested fairly consistent levels of total phosphorus between the first and second basins, and fairly consistent oxygen levels in the upper levels of the lake. We will want to confirm this in 2021.
9. There are several ways to measure the contributions of phosphorus from sediment into the water column, and our team is experienced with both.

   Sediment Method 1: In nearby Indian Lake in Worcester, BC worked with a laboratory to measure the amount of phosphorus bound to the sediment, and was able to quantitatively estimate a bulk annual contribution of approximately 9% of the total phosphorus in the lake attributable to sediment contributions.

   Sediment Method 2: In the nearby Assabet River, our Technical Lead, Kirk Westphal, once helped direct a study that relied on laboratory measurements in which sediment cores were extracted and oxygen was slowly depleted under lab conditions while increasing phosphorus levels were measured in the canister just above the sediment core. This provided insight into the rate of phosphorus exchange from the sediment, which allowed simulation of management measures year-over-year in response to reductions in land-based loading.

   We will work with LBC and LBA to define the most appropriate method for Lake Boon. Method 1 is simpler and likely less expensive, but relies on some mathematical extrapolation. Method 2 provides more dynamic insight into actual rates of phosphorus exchange with different levels of oxygen in the overlying water, and may better help on defining how much phosphorus enters the water under different conditions and different times of year. In preparing the MVP Grant proposal, we worked with two of the only qualified laboratories in New England for sediment analysis (The Woods Hole Group, and SMAST (School for Marine Science and Technology) laboratories at UMass-Dartmouth to ensure that LBC could set aside sufficient funding allowances for sediment analysis, and they have expressed their support for the project and willingness to work with LBC.

In other words, while the proposed monitoring program that we developed with you is targeted at event-driven phosphorus dynamics and seasonal phosphorus dynamics, our science-based approach will include watching for clues to consider course corrections without changing our overall heading or level of effort.

Methodology

We have included more detail about our methods and deliverables in our section on the Scope of Work, but listed here are some key tenets of our methodology for better understanding Lake Boon's multi-faceted dynamics (both water flow and phosphorus), and recommending appropriate, resilient, and cost-effective measures to improve the health of the Lake that citizens and officials can understand and support:

1. **Trust the Science:** We come to collaborate with you with no preconceived notions about the most effective solutions. Other studies have evaluated the water quality in the lake but have left uncertainty as to the relative sources of phosphorus, water flow, and even the long-term prognosis for the lake. We will let the science guide us, and will offer you our expertise in organizing, interpreting, and extrapolating information in the site-specific setting of Lake Boon, both in its current state and for its future.
2. **The Foundation is Data:** While much of our work with you will involve simulation modeling and climate forecast assessments, there is no substitute for actual data. We have worked with LBA and LBC throughout 2020 to craft a well-rounded yet cost-effective water quality sampling program for continuation into 2021 and 2022. While we will keep an eye out for reasons or opportunities to adapt the program, we believe that foundationally it will help us understand the sources of pollutants and their impacts in the lake much more clearly than we do today, because the program is designed to capture the lake's response to rain events, prolonged dry periods, and basic seasonality in a way that prior studies did not do. **The data from the lake will be the most useful tool in deducing the relative sources of phosphorus and guiding recommendations for management, which is why we worked with LBC and LBA to allocate a significant portion of the MVP funding to laboratory analysis, and to mobilize a force of dozens of citizen scientists to help capture the vital information just beneath the waves.** The modeling and climate analysis will build on this to provide extrapolation, clarity of the system's dynamics, "what-if" analysis of management measures, and a testbed for future climate risks and resilience.

   We will measure phosphorus levels before and after rain events, after long periods of dry weather, and at targeted locations such as the inlet of the small tributary that drains the Charter Oaks Golf Course. This will help determine if loads and concentrations in the lake are episodic (event-based), or more continual (groundwater or sediment-driven). We will certainly compare what we measure to standard literature values for land-based loading, but we understand that Lake Boon's dynamics are its own, and will rely principally on the data we collect from its waters.
3. **Know the Hydrology:** Far too many lake studies are conducted with annual flow estimates, which are far too coarse to understand storm response, monthly variability, and pollutant residence times. Previous reports on Lake Boon disagree on the relative contribution of flows from surface water and groundwater, and a better understanding of this is absolutely critical, since the two primary suspected sources of phosphorus each reach the lake through different hydrologic pathways: Fertilizers and organic matter such as leaf litter and pet waste through surface runoff, and septic system leachate through groundwater.

   As a volunteer with the Lake Boon Association through 2020, Kirk Westphal, our proposed Technical Lead, developed a hydrologic model of Lake Boon that was calibrated to 2020 readings by the LBA of the water elevation at the discharge weir. The model is a simple spreadsheet model that segregates rainfall into evaporation, runoff and shallow soil flow, groundwater inflow, and direct precipitation onto the water surface, resulting in a predicted daily change in lake level by applying a water balance approach to all inflows and outflows of the lake. With this tool, we have a significant head start on the MVP project (Task 3b is the Hydrologic Modeling). Our hydrologic tool is ready, has been calibrated to 2020 data to the point at which it explains 96% of the variability in lake levels (The correlation coefficient of simulated to measured data, R2 = 0.96 - typically, a model that explains 80% of the variability in an environmental variable is considered useful and reliable).

- **Model Input:** Daily Precipitation and Daily Min/Max Temperature
- **Simulated Flows:** Groundwater inflow, Surface water inflow, Evapotranspiration from the soil/plants, evaporation from the lake itself, direct precipitation onto the lake, see page from the weir, and outflow over the weir to the Assabet River.
- **Model Output:** Resultant daily lake level and all computed flows

We will validate the model to data collected through 2021, but you will see we have a great start in understanding the lake's hydrology. The figures below illustrate the basic flows simulated by the model, and the result of calibration to lake levels throughout 2020:

By accurately reproducing the rise and fall of the lake on a daily basis over time in response to rainstorms and dry periods, we can be reasonably confident that the model is accurately segregating surface water flow ("fast response") from groundwater flow ("slow response"). By seeing the simulated lake level rise quickly in response to rainstorms we know we have a good representation of the fast runoff response, and by seeing the lake level gradually decline after the rises due to storms, we know that we are faithfully representing the slower groundwater response, and can therefore separate these flows for subsequent association with pollutants from different sources.

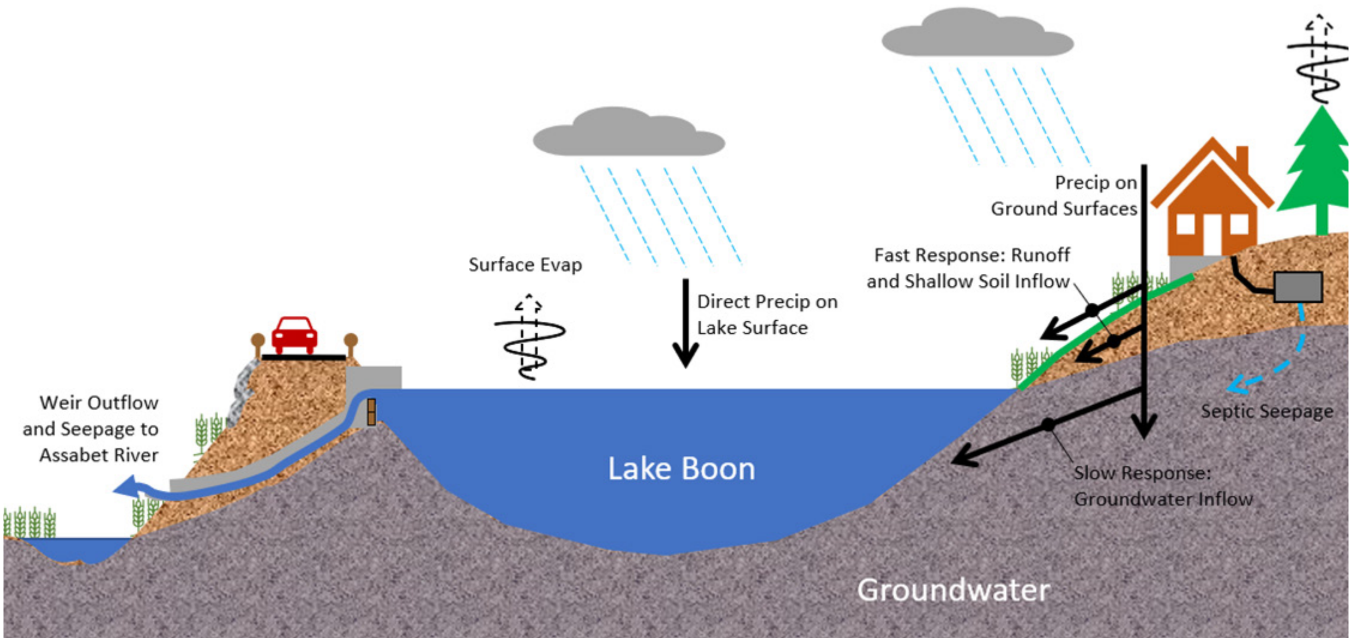


FIGURE 4 // **Schematic Diagram of Flows simulated by the Hydrologic Model developed by Kirk Westphal through volunteer time with the LBA in 2020.**

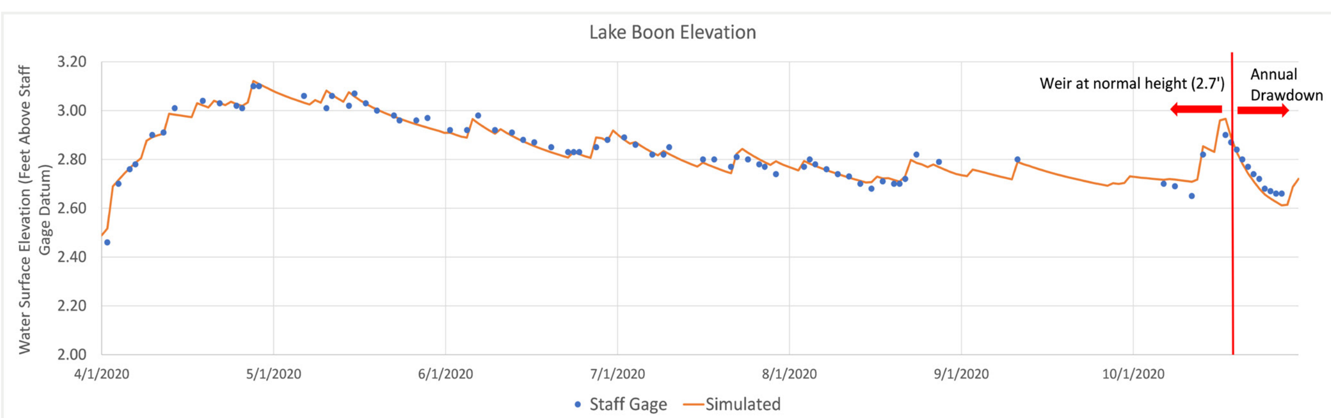


FIGURE 5 // **Performance of the Lake Boon Hydrologic Model developed by Kirk Westphal through volunteer time with the LBA in 2020: Our Model Predicts 96% of the Variability of Lake Levels as Measured at the Outlet Weir – A Strong and Confident First Step in Improving our Knowledge of THIS LAKE's Unique Dynamics.**

What we have learned to date with this preliminary analysis is that more than 90% of the rain that falls onto the land area of the Lake Boon watershed likely reaches the lake by groundwater – a fundamental key to understanding flow and nutrient dynamics, and a certain clarification of some of the earlier reports which relied on annualized numbers and estimation techniques instead of event-driven and climate-driven modeling.

4. **Simplify - Apply Simple but Proven Tools:** Many models of natural systems are complex and over-parameterized, leaving more questions than answers with respect to what they are trying to represent. The hydrologic model shown above for Lake Boon uses a spreadsheet and only 4 parameters to segregate groundwater and surface water flows and limitations on total storage of water in these realms. Anybody in the LBC or LBA can look through it and learn about our lake. **Our Technical Lead, Kirk Westphal, has applied it for many of the MWRA's reservoirs, and incorporated its use into a paper published by ASCE's Journal of Water Resources Planning and Management which was received an award for "Best Practice Oriented Paper."**

   Our approach to water quality modeling is similar. Before conducting any simulation, we will apply the well-established Vollenweider Evaluation to determine the likely trophic state of the lake. This time-tested approach (also used by Kirk Westphal for MWRA reservoirs) uses data available today to determine whether the lake is vulnerable to eutrophication (nutrient enrichment, algae growth, oxygen depletion, and poor overall water quality). By comparing annual phosphorus loads from LBA's 2020 data and previous studies with known lake depth and computed residence time from the hydrologic model, we will have a statistically valid understanding of the lake's trophic status, and this will guide both the level of detail needed in further modeling, and also ultimately the management measures themselves.

   Based on the findings of the eutrophication analysis, we will develop either a spreadsheet-based nutrient balance model which will couple directly with the hydrology model, or apply a standard water quality model for lakes such as CE-QUAL. Such tools can become complicated if applied in multiple dimensions but we will assume (from data, known boat traffic, etc.) that each basin is sufficiently well mixed within themselves and can apply the simpler 1-dimensional water quality equations. Phosphorus inflows, lake concentrations, and outflows will be simulated to the point that the model can be used to validate understanding of relative sources, assess climate vulnerability by changing precipitation and temperature variables, and ultimately serve as a testbed for the efficacy of recommended management measures.

5. **Incorporate Climate from the Start:** It is easy to view this study as simply an assessment of recent Harmful Algae Blooms (HABs) in Lake Boon. It is much more than that. It is a long-term vulnerability and resilience study, focused not just on observed issues in recent years, but aimed at building preventative, mitigative, and abatement measures that will endure through a broad range of potential climate futures. In many studies, this is a qualitative afterthought. **Our approach builds in climate from the start – our hydrology model (results shown above for 2020) uses daily precipitation and air temperature as its inputs, the two most significant climate variables to consider for future projections. By calibrating to today's conditions with tools built with climate variables in mind, we can experiment with different rainfall and temperature patterns to see how the lake's hydrology, pollutant loading, and algae potential might change in the future based on a range of predictions for how precipitation and temperatures may change in Massachusetts.**

6. **Adapt:** We already know that 2020 was not like 2019 with respect to algae in the lake. 2019 produced a significant algae bloom that caused the Board of Health to close the lake to swimming. 2020 produced a short-lived brown algae bloom and a second mild algae bloom in 2020, but neither resulted in dangerous levels of cyanotoxins, or even exhibited unusually high levels of phosphorus. Our Approach (above) outlines many ways we might recommend adapting the water quality sampling program to conditions that manifest themselves in 2021 and 2022. We want to be sure that each data point is collected for a reason – the sampling plan we developed with you for the MVP proposal accomplishes this without collecting extraneous data that might be useful at a more academic level. However, we look forward to reviewing results as they are available and discussing with LBC any appropriate adaptations to the sampling plan that may be wise. **It helps that our Program Director lives on the lake, and can respond immediately to observed changes in lake quality if appropriate.**

7. **Clear Statement on Sediment:** Earlier reports on Lake Boon pay only passing attention to sediment, claiming that it produces less than 1% of the total phosphorus in the lake. This may be true, but it remains somewhat speculative and has not, to our knowledge, been verified in a laboratory. **For this program to be successful, we must be able to state definitively whether or not sediment contributes high levels of phosphorus when the lake stratifies in the summer and oxygen is depleted (drawing phosphorus back into the water from molecular bonds in the sediment).** Our program director recognized the importance of this on the work he did with the US Army Corps of Engineers on the Assabet River just downstream of the Lake Boon discharge, showing that sediment phosphorus flux in this area can be a significant contributor to total loads. He also developed simple modeling equations that, if necessary, can be built into

the water quality model (work was published in ASCE's Journal of Environmental Engineering in 2013). We know from 2020 measurements with LBA that the lake becomes anoxic in its deepest zones, which covers many acres. **By extracting sediment cores and reproducing depleted oxygen level in the laboratory, we will be able to make a definitive statement on the relative impact of Lake Boon's sediment on its phosphorus load.**

8. **Combine Models and Monitoring to Assess Lake Boon's Health:** Lake studies often over-rely on either field work or desktop analysis to unwrap the mysteries of a water body. We understand how to appropriately balance monitoring and modeling for Lake Boon. There is no substitute for actual field data, and a fleet of citizen-scientist volunteers and a substantial financial commitment for laboratory analysis is already being orchestrated by LBC and LBA to collect data. We will use this data to create the baseline narrative of Lake Boon:

   From the Data Itself:

   - What are the prevailing loads during different times of year?
   - What are their ranges of impacts?

   We will also use the data to calibrate models so that we can begin to address questions about the future:

   From the Models:

   - How effective are different management alternatives likely to be in reducing loads?
   - How effective are in-lake treatments likely to be in reducing organic productivity?
   - How will various future climate trends affect the potential for organic productivity in the lake?

> We will engage Jeff Herr and Mike Milne, BC's senior-most leaders in lake health assessment with experience in Massachusetts and across the US in focusing on nutrient reduction in lakes.

9. **Resilient Solutions:** We understand that the historical algae blooms in Lake Boon are not the only problem at hand – this project aims to protect the lake from future blooms amidst conditions in climate and land use that are uncertain. From our experience in reducing algae potential in lakes and water bodies in New England and across the US, we will recommend both source-reduction measures and in-lake measures as necessary, but one of the most important criteria of any management measure is that it be resilient – it must offer lasting value in the face of changing climate conditions. To this end, we will place heavy emphasis on nature-based solutions such as buffer strips and creative landscaping, which, year-over-year can help reduce nutrient loads into the lake both from surface and groundwater. The annual drawdown is already a nature-based solution and we can evaluate how this can complement a portfolio of alternatives into the future. We will also work to identify alternatives that rely in part on social behavior (septic maintenance, lawn care, etc.), where resilience can only be built in through an educated citizenry and a community-based commitment to collectively manage our watershed over time for the betterment of the lake. Persuasion, in this case, begins with science – our approach will help identify the prevailing sources of nutrients and educate citizens on how they can best help reduce the loads. As a community, then, we will act resiliently.

10. **Educate Citizen Scientists, Officials, and Citizens**: Our proposed approach provides multiple opportunities to engage and educate the public about the Lake's water quality throughout the entire project duration and through multiple formats. Engagement of the community is critical element of this project, as watershed stewardship will be an important pathway towards improving water quality regardless of the identified root causes of impairments. We will begin the project with multiple virtual meetings to discuss historic and present-day water quality issues, the process for collecting and interpreting data to identify root causes of and using simulation models to project climate vulnerabilities. These venues will also offer opportunities to provide education and messaging on "no regrets" watershed stewardship actions that preserve and improve water quality (homeowner actions such as lawncare and landscaping practices, septic maintenance, leave and pet waste, etc.). As we collect data with Citizen Scientists, we will provide training through in-person methods and provide on-going quality control and feedback, as needed, either through virtual or in-person methods, making effective use of health and safety plans and procedures that keep our team and volunteers safe from the spread of COVID-19.

    We will learn more about the Lake through modeling and we will develop and deploy an online dashboard and other tools to communicate findings with the Stakeholder Committee and the public. Information will be published such that all members of the community have access to it, and it will be presented in a clear and easily interpretable manner, (you can find an example in our Scope section) as we've done with data dashboards for other communities in Massachusetts.

    As our team works with the Stakeholder Committee to prioritize recommendations, we will also develop educational materials in print and electronic formats that explain the role of individuals in improving water quality, as well as information about how the long-term Plan will address future vulnerabilities. In combination, these strategies will be effective in educating the public, officials, volunteers, and the Steering Committee about risks and the most effective strategies to preserve water quality in Lake Boon. To the extent needed, our team stands ready to help facilitate agreements on decisions and pathways forward, as we have broad and successful experience in building consensus on water management plans across the country.

Section 4

Scope of Services

Fresh Perspective

Customized Solutions

Climate Readiness

Educated Citizens

Scope of Services

The BC Approach

The BC team, consisting of experienced water resources engineers, limnologists, and environmental scientists, has reviewed the scope of work provided in the request for proposals and we are confident that our approach will result in an effective Plan that identifies and addresses the root causes of impairments, improves water quality in Lake Boon, improves resiliency, and educates the public. Details of the task are described below.

Scope of Services

1. Introduction to Lake Boon and Community
2. Monitoring Program
3. Modeling and Analysis
4. Lake Health Assessment
5. Alternatives Assessment
6. Public Engagement
7. Dashboard Web Tool
8. Recommendations

FIGURE 6 // Service Tasks

Task 1. Introduction to Lake Boon and Community

Objectives

A. Gather and synthesize available information about Lake Boon and the surrounding area – past, present, and future. This includes land use, water quality, hydrology, and potential future climate trends.

B. Support the facilitation of project meetings with the Lake Boon Commission and the Public and solidify project goals and approach.

A. Data Gathering and Synthesis

BC's team will review prior water quality studies of Lake Boon and other available data, as described below, and summarize key findings in a presentation and report that we will share with the Public and the Stakeholder Committee.

There are other data sources that may be useful to begin retrieving early in the project. Since many existing studies are 20-40 years old, our team will gather relevant information about changing land use patterns and development practices around the Lake, which may provide insights on how these changes correlate with changes in water quality. Our team will make effective use of staff and volunteer time by leveraging publicly available spatial data, including datasets accessed from the Towns of Hudson and Stow and from MassGIS, which can be used to visualize historic conditions, existing conditions, and data gaps. Additionally, the team will retrieve historic climate data from Northeast Regional Climate Center (NRCC) and the most up-to-date climate forecasts, including precipitation and temperature projections from NOAA Atlas 14 Volume 10. These data will be used to assess vulnerabilities based on climate trends, which may include increased algal growth from changes in runoff, flushing patterns, residence time, evaporation, and water temperature.

Findings will be presented at the Kickoff meetings, described below, to guide additional data gathering efforts and future analyses. Gathering and synthesizing available data at the onset of the project will also assist with the modeling tasks, as described in Task 3, and lead to improved selection and prioritization of management alternatives, as described in Tasks 5 and 8. Our reporting will included (at a minimum, the following):

1. Summary of reports from the last ~40 years (CDM, ESS, MADEQ, TMDL, etc.) with respect to annual hydrologic flows.
2. Summary of these reports estimates of total annual phosphorus contributions from various sources (groundwater, surface water, deposition, sediment, etc.)
3. Summary of historic monthly variability of phosphorus in various locations in Lake Boon, where available
4. Summary of other key water quality indicators, such as Total Suspended Solids, Dissolved Oxygen, Nitrogen, etc.
5. Summary of available information from LBA's recent sampling of phosphorus, cyanotoxins, dissolved oxygen, chlorophyll-a, etc. (~2019 / 2020)
6. **A discussion of the VARIABILITY in the numbers above, which have rendered it difficult to identify prevailing nutrient sources and address algae potential at its source, not just after a bloom.**

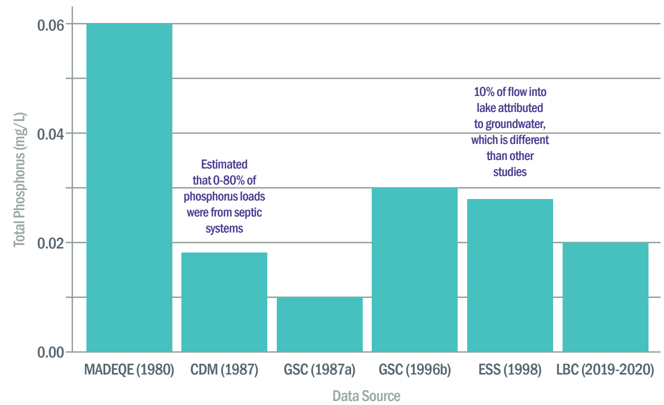


FIGURE 7 // **Wide range in phosphorus concentrations and inconclusive and contradictory findings on predominant sources of phosphorus loading from historic reports.**

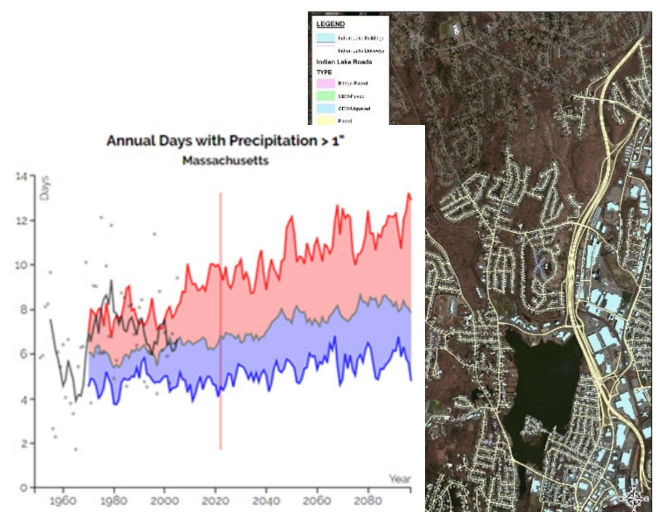


FIGURE 8 // **Our team will use the latest climate projections for Massachusetts to model projected impacts on the Lake Health (left) and publicly available datasets to assess how watershed management practices have changed over time (right).**

7. A discussion of how earlier reports justifiably backed into their estimates on sediment phosphorus contributions (which is standard practice without laboratory measurements, as suggested in the MVP Grant to be able to make more conclusive statements about the specific relationship between sediment and phosphorus in Lake Boon).

8. Comparison of historic hydrologic records and precipitation to projected trends in precipitation and temperature over at least the next 50 years, with specific references for how this information can be used in Tasks 3 and 5 to evaluate the sensitivity of Lake Boon's water quality to a range of plausible climate trends, and to evaluate the potential effectiveness of various management measures of phosphorus control, both now and under future climate conditions.

B. Kickoff Meetings

BC's technical team will support the facilitation of kickoff meetings with the Steering Committee and the Public to discuss project goals, the approach, and future public outreach and community engagement opportunities. Our team will develop a presentation that describes the findings of the above sub-task (including prior studies, climate trends, and vulnerabilities), proposed technical approach, and key points for engaging with the Stakeholder Committee and the Public. During the Stakeholder Committee meeting we will also present and solicit options for aspects of the technical approach, such as dashboarding tools and public engagement process, and facilitate a discussion and build consensus on desired outcomes for this project. Given the importance of Lake Boon to the surrounding community, we understand project goals may extend beyond maintaining and improving water quality, improving resilience to vulnerabilities to climate change, and educating the public on water resources issues. These project goals will be incorporated into other aspects of the project including the design of an effective monitoring program, selection of alternatives, and prioritization of recommended alternatives.

Deliverables: Presentation and Report summarizing past studies, data gap analysis, the case for the current study, and the approach for the current study. We will share this information at two kickoff meetings, one with the Steering Committee and one with the public, both held virtually.

Task 2. Monitoring Program

Objectives

A. Develop a robust and adaptable sampling plan that will inform the water quality study.

B. Train volunteers on the Plan and sampling procedures.

A. Monitoring Plan

The Monitoring Program will include relevant water quality parameters, details on the timing and frequency of sampling, and recommended monitoring locations to identify prevailing sources of pollution and associated impacts. The plan will draw upon our understanding of the Lake's hydrology and will be adaptable to improve the value of data collection efforts as conditions evolve. For example, monitoring timing and frequency can be adjusted to collect data pre- and post-storm events. Our team will also prepare the Plan in a manner that is also flexible to changing conditions and findings from analysis of water quality data, so that if anomalies are detected or if correlation is established, data collection efforts can focus where there is the most value. Please refer to the Potential Adaptations Call-out on page 22.

TABLE 9 // Our Team's Recommended Sampling Plan

Sampling Plan from RFP as Originally Recommended by BC (with locations added as necessary)				Plan		
Parameter	**Locations (New Info)**	**Frequency**	**Purpose**	**Lab or In-Situ**	**Collected By**	**New Thoughts**
Outflow	At Dam Weir	Every other day	Inform water budget and calculate phosphorus leaving the lake	In-Situ	LBA and Consultant (during daily walk – no time charges)	Can be manual checks of visual staff gage or we can consider automated level sensor
Precipitation	Rain gage at Lake Boon, correlate with USGS gage in Acton	Daily	Understand total water entering lake through watershed	In-Situ and online	LBA: In-Situ Rain Gage Consultant: online NCDC data	We have seen very strong correlation between LBA and the NCDC Acton gage: Will continue to compare, considering averages for very large values

Sampling Plan from RFP as Originally Recommended by BC (with locations added as necessary)				Plan		
Parameter	**Locations (New Info)**	**Frequency**	**Purpose**	**Lab or In-Situ**	**Collected By**	**New Thoughts**
Total Phosphorus (annual pattern)	**Basin 1** • Deep area near beach • Both coves • Near narrows **Basin 2** • Near Narrows • Monahan's Cove • Deep zone • East end **Basin 3** • Center **Basin 4** • Center Inlet stream from Charter Oaks Golf Course and other if flowing	Monthly	Better understand annual pattern of accumulation and depletion – separate seasonal loads to help ID sources	Lab	Volunteers	As conditions evolve this may warrant more or less attention, with reallocations to/from others.
Total Phosphorus (dry/wet weather)	Same as above	During same month in growing season, after 7 dry days, day after 0.5" or more of rain: Spring/ Summer/Fall	Better understand relative contributions of phosphorus load from runoff and septic systems	Lab	Volunteers (Consultant to help forecast and coordinate with LBA)	The frequencies are listed as goals, and consultant will coordinate with LBA to forecast and prepare as practical, with some expected variations due to weather patterns
Dissolved Oxygen **Temperature**	Same locations as TP (vertical profiles only in deep areas)	Monthly, also to help establish areas coverage of anoxic zone	Understand aquatic impacts of TP, and whether the lake stratifies / turns over	In-Situ	LBA Lead to delineate 21-deep zone in Basin 1 Volunteers to collect measurements	We recommend vertical profiles in the deep zone in Basins 1 and 2 each month (21'-deep zone in Basin 1 to be delineated by LBA with depth-finder). Other locations, measurements 2' below surface only
Conductivity	Shoreline Survey (around lake perimeter, as close as safe/practical to shore)	Monthly	Determine locations of any septic "hot spots"	In-Situ	Volunteers and authorized operator of LBC Boat.	We may alter our Phosphorus and Nitrogen plans if we see spikes – Use of the LBA YSI Sonde recommended. Consider using LBC Boat
Chlorophyll-a	**Basin 1** • -Deep area near beach **Basin 2** • -Deep zone **Basin 3** • Center **Basin 4** • Center	Monthly	Understand lake trophic state and potential cyanotoxin risk in recreational areas	Lab	Volunteers	We will use this to help determine the overall productivity, compare it to the MA guidelines of ~15 ug/l (ppb), and help determine trophic status of lake as well as TP warning signs

Sampling Plan from RFP as Originally Recommended by BC (with locations added as necessary)				Plan		
Parameter	**Locations (New Info)**	**Frequency**	**Purpose**	**Lab or In-Situ**	**Collected By**	**Notes**
Sediment Phosphorus Flux	**Basin 1** • Deep area near beach **Basin 2** • Deep Zone **Basin 3** • Deepest location **Basin 4** • Deepest location	Preferably in August/ September when the lake is naturally stratified, but this is not essential, as the labs can re-create anoxic conditions in the overlying water	Understand if elevated levels of Phosphorus are released if stratified	In-Situ Core Collection, Lab Analysis	Specialty Laboratories Recommend Woods Hole Group / SMAST – Umass Dartmouth	We have coordinated with Woods Hole Group and SMAST (UMass Dartmouth) to help LBC estimate costs for 4 sediment core samples. As noted in proposal, we offer 2 alternative methods, both of which our team is familiar with
Nitrogen	**Basin 1** • Deep area near beach • Alternating coves **Basin 2** • Monahan's Cove • Deep Zone **Basin 3** • Center **Basin 4** • Center	Monthly	Can help identify septic "hot-spots", and can help understand P:N Ratio, which can help indicate toxicity characteristics	Lab	Volunteers	We recommend including the full array, but only at limited sites/ frequencies as noted: Nitrate, Nitrite, Ammonia, TKN. If we find homogenous and consistent results, we can consider reallocating
TSS	Same as Nitrogen	Monthly	Can help identify non-algal turbidity	Lab	Volunteers	Can also help distinguish the algal impact on Secchi depth.
Secchi Depth	Same as DO Measurements	Monthly	Indicator of turbidity	In-Situ	Volunteers	Use in conjunction with TSS to help understand the contribution of algae to overall turbidity
Cyanotoxins	Same as Chlorophyll-a	2X per month	Indication of toxicity	In-Situ	Volunteers	Could use field test kits that indicate presence/ absence above key thresholds

Opportunities for Innovative Enhancement — Continuous Monitoring

Our team can support the deployment of smart sensors to enhance the monitoring program. Smart sensors continuously record surface water parameters, such as water level, temperature, and conductivity, and send the data automatically to internet-based cloud storage, where users can view, download, transfer the data, and incorporate it into dashboards. The sensors are similar to handheld meters however, they run continuously on battery power and can be deployed temporarily or permanently in the lake. Smart sensors can supplement the volunteer data collection effort, as they are available for many of the parameters of interest for this study, and prices for the sensors and associated communications hardware vary. A particularly good application of continuous monitoring would be to install a water level sensor on the dam weir. These measurements would provide information about the hydrologic response of the lake and improve model calibration. Data collected from smart sensors can be integrated with volunteer-collected data in the dashboard environment that BC will design and deploy, making all monitoring data accessible to the project team in one location. The hardware cost for deploying smart sensors ranges from $600-1,500/station for parameters such as temperature and water level to $5,700-6,500/station for dissolved oxygen and TSS. Any funding for this innovation would need to be balanced with other laboratory and field priorities, or coordinated with LBA annual funding outside the MVP program.

Sediment Sampling

There are several ways to measure the contributions of phosphorus from sediment into the water column, and our team is experienced with both. Two things are important to recognize about the science of sediment phosphorus flux. First, sediments do not generate phosphorus, but collect it from land-based loads that settle out, or from decaying organic matter (potentially including aquatic weeds after treatment). Hence, a solution like dredging does not solve the long-term problem – it only removes the last few years of phosphorus deposition. Second, while there is always an exchange of phosphorus between the water and the sediment (sometimes into and sometimes out of the sediment), water that is depleted of its oxygen in its lower layer (as happens in Lake Boon in the deep area of the First Basin), instigates the breakage of molecular bonds between phosphorus that has bound to iron and rapidly increases the phosphorus that is available to return into the water.

Sediment Method 1 – Quantifying Phosphorus Amount: In nearby Indian Lake in Worcester, BC worked with a laboratory to measure the amount of phosphorus bound to the sediment, and was able to quantitatively estimate a bulk annual contribution of approximately 9% of the total phosphorus in the lake attributable to sediment contributions.

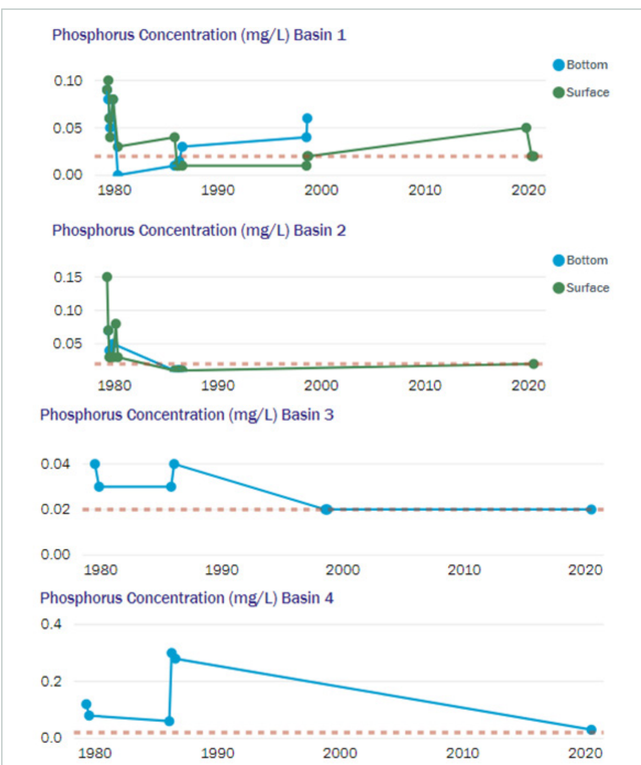


FIGURE 10 // Historic Phosphorus Data by Sampling Station, (data from LBA prepared using an interactive dashboard BI). Note that the goal of the 2002 TMDL study is to reduce total phosphorus concentrations to 0.020 mg/l. Note that recent levels in 2020 are generally in alignment with TMDL goals. Data sources: Prior reports listed on LBA website and LBA data collected by David Gray and Kirk Westphal in 2020.

Potential Adaptations to the Field Sampling Program, as Conditions Evolve

1. If we see high conductivity in certain shoreline areas, this may be a clue that we should trade some phosphorus samples for nitrogen because of suspected prominent septic loads to better determine if septic leaching is indeed a localized source of surplus nutrients (nitrogen is a better indicator of localized septic loading than phosphorus).
2. If we witness an algae bloom, we may re-allocate phosphorus, chlorophyll-a, and cyanotoxin measurements more immediately upon observing the bloom to better understand the levels that cause it.
3. If we see algae growing while total phosphorus levels are seemingly small, we may wish to divide some phosphorus samples into organic and inorganic phosphorus to understand how much is truly available to support growth (conversely, we may do the same if we see high total phosphorus levels without corresponding algae blooms.) It may be wise to do this for a few samples anyway, and we will discuss this with LBC.
4. If we begin to see algae even in small quantities, or phosphorus levels above 0.025 mg/l, which is a guidance level for healthy lakes, we might suggest taking a few diurnal oxygen measurements (morning and evening) to help determine if organic productivity is pronounced even before the appearance of an algae bloom – high organic productivity can be indicated by oscillations of 1-2 mg/l (or more) of dissolved oxygen as respiration of organic matter (photosynthesis and the production of oxygen) can dominate by day while decay (oxygen consumption) can dominate by night. (In fact, we may be wise to plan on this regardless of what else we find).
5. If nitrogen levels are found to be as expected early in the sampling season (always abundant enough to support organic growth), we may de-emphasize nitrogen sampling and shift more emphasis on the correlation between oxygen, chlorophyll-a and phosphorus in order to better understand indicators of impending algae issues.
6. If we see algae blooms repeatedly after severe rainstorms, as were reported by residents in 2020, we may refocus efforts to better capture phosphorus in direct runoff, especially in the small tributary that drains the Charter Oak Golf Course into Lake Boon.
7. If we see different types of algae blooms, as we did in 2020 (first brown algae, then later green algae), we may reallocate some of the funding for chlorophyll-a to better understand the type of algae that is growing, and how it correlates with nutrient concentrations. We may also recommend some specific tests for phytoplankton to better understand the composition of the algae in the lake.
8. If we see that nutrient and oxygen levels are consistent between the First and Second Basins, we may assume that the Narrows and its boat traffic effectively mix the two basins, and for analytical purposes treat them as one, and reduce sampling in one basin to get a more dispersed or more frequent sample set in the other. On the other hand, if we see persistently different concentrations in the two basins, we will want to model and evaluate them separately (but with connectivity that can support transport and diffusion of nutrients between basins). The same is true with the Third and Fourth basins.

Sediment Method 2 – Quantifying Phosphorus Exchange: In the nearby Assabet River, our Technical Lead, Kirk Westphal, once helped direct a study that relied on laboratory measurements in which sediment cores were extracted and oxygen was slowly depleted under lab conditions while increasing phosphorus levels were measured in the canister just above the sediment core. This provided insight into the **rate of phosphorus exchange from the sediment**, which allowed simulation of management measures year-over-year in response to reductions in land-based loading.

Our team will work with LBC and LBA to define the most appropriate method for sediment sampling in Lake Boon.

B. Plan Implementation and Training

Our team is experienced at conducting water quality monitoring and sampling and will provide volunteers with training on sampling techniques and protocols to improve data integrity, reliability, and overall quality while maintaining safe conditions. We will provide up to two training sessions for volunteers to learn about grab sampling and in-situ monitoring procedures and quality assurance protocols. We envision that an initial training will be conducted in-person, and as necessary, coordinate with the Stow and Hudson Boards of Health on proper COVID-19 protection practices and incorporate protocols into a Health and Safety Plan that keeps their and our teams' safety at top priority when implementing the monitoring program. We will also provide follow-up training and coordination support through up to two additional virtual meetings. We will use the follow-up training to improve the monitoring process and revise the Plan to adapt to changing conditions, as needed.

Our team will review and validate water quality data collected and recorded through this monitoring program to assess data quality. The team will provide timely guidance to volunteers on abnormal or unexpected results and validate these data. We budgeted for one four-hour in-person training and up to 12 hours for review and quality control of data and follow-up training for specific needs that arise throughout the project. We can work with the Stakeholder Committee to accommodate more training time, if warranted.

Note that this sub-task achieves the scope item described in the RFP Task 6A (volunteer training).

C. Quality Assurance Plan

We will develop a Data Quality Plan for the project. We understand that this work is undertaken on behalf of concerned citizens of the Lake Boon Community, and the Commission and Association that represent them, and that this study is not to be used to assess regulatory compliance. As such, a Quality Assurance Program Plan (QAPP) approved by USEPA and MADEP is not required, but our team will provide similarly comprehensive and specific guidelines, procedures, and recommendations to help ensure the scientific quality and credibility of the data collected. Our Data Quality Plan will include:

A. Field and Lab SOPs (Standard Operating Procedures) for each type of constituent to be measured
B. Calibration and operation requirements for in-situ monitors to be used by Citizen Scientist volunteers
C. Requirements for duplicate and blank samples to help assure laboratory quality, which will be based on quantities/percentages of total samples previously approved by USEPA and MADEP for other programs (even though this work is not for regulatory purposes).
D. Chain of Custody requirements to document transactions between volunteers, LBA coordinators, drivers, and laboratories
E. Data logging procedures (envisioned as a collaborative practice between our team and LBA) to help ensure consistency in nomenclature, precision, units, timeliness, location and management of master files, copies, etc. We have worked with numerous mobile data collection applications such as Fulcrum and ArcGIS Collector and can provide recommendations and technical assistance to LBA in setting up the forms for data collection. These applications make it easy to integrate GPS location, photos and timestamping into the data collection process.

Deliverables: Monitoring program including QA protocols, initial in-person volunteer training and sustained remote support, on-going review and quality control of water quality monitoring data.

Task 3. Modeling and Analysis

Objective

Select appropriate tools for modeling the spatial and temporal dynamics of Lake Boon and develop a model for projecting future conditions.

Basis of our Approach

We understand that the most instructive diagnostic information for Lake Boon's current health and risks will be the recent years of focused, contemporary sampling of water quality conducted by LBA/LBA from 2019-2022 (including the sampling through this MVP grant program). However, what this information can tell us about the conditions and risks in the lake today cannot necessarily be extrapolated to future conditions in a way that will help ensure the long-term resilience of the lake. **Our team will develop a model to assess the efficacy of targeted management measures for today's problems and to study the risks to water quality as the climate becomes warmer and rain and droughts patterns change.**

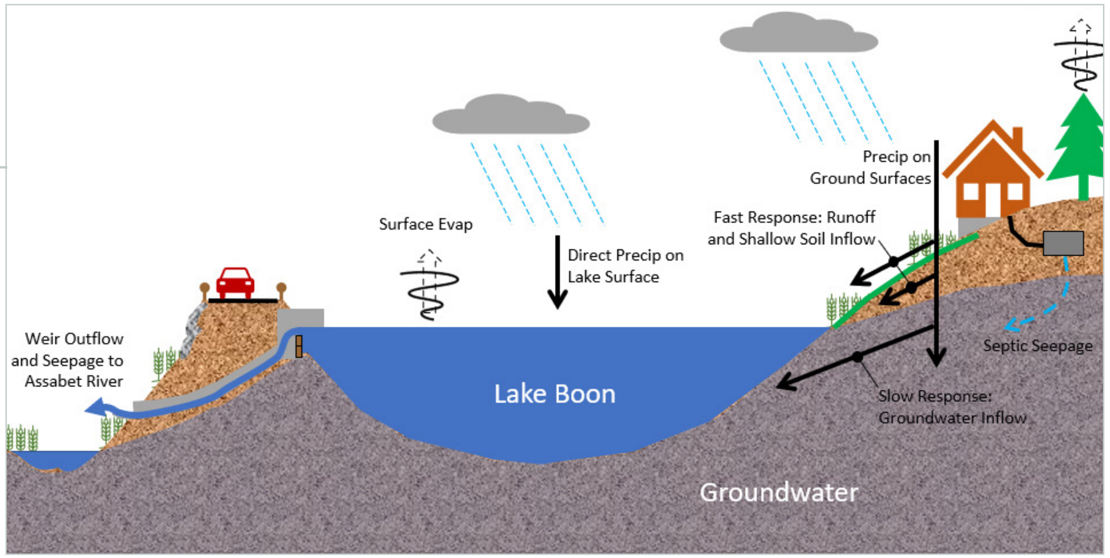
We propose a 3-step process to modeling Lake Boon. The 3 steps that we propose are discussed below, and represented in Figure 11.

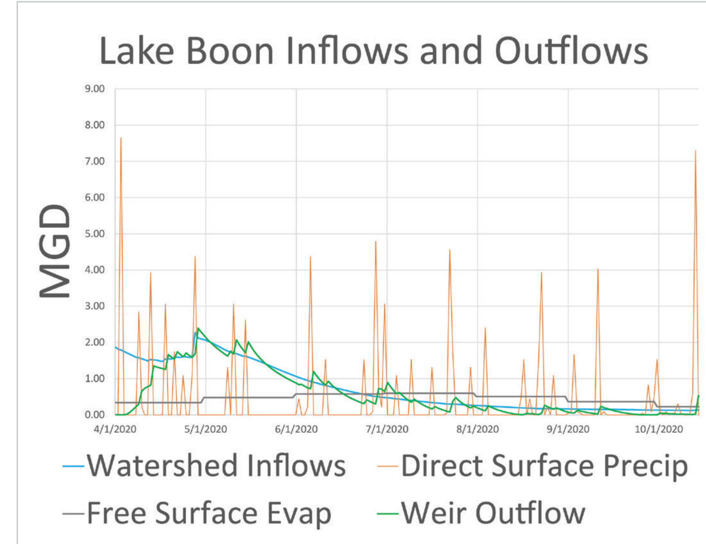
1 Hydrology Model *(Our Team Has Already Developed the Hydrology Model and Calibrated it to 2020 LBA Lake Levels)*

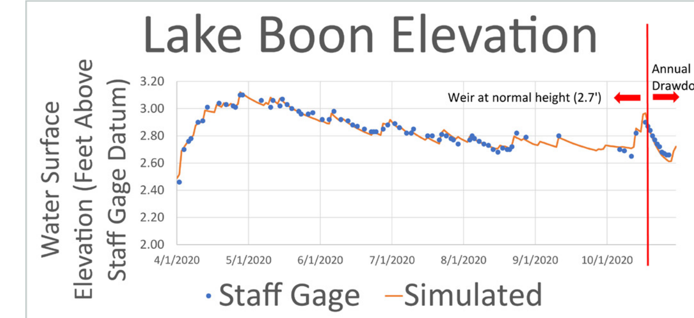
Spreadsheet model of inflows and outflows already developed by Kirk Westphal with LBA

Inputs:

- Daily Precipitation (in)
- Daily Min/Max Temp (deg C) *(can be historic or future climate scenarios)*







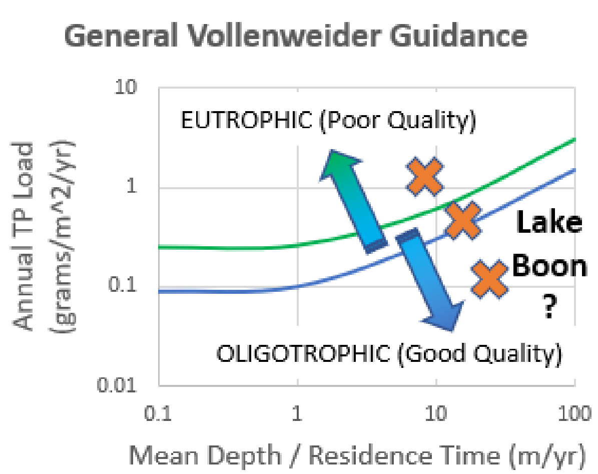
Outputs:

- Surface Water Inflows
- Surface Precipitation
- Weir Outflow
- Groundwater Inflows
- Evaporation
- Lake Level

2 Two-Step Eutrophication Screening

1. Vollenweider Method Inputs:

- Annual Phos Load (from LBA/Reports)
- Residence Time (from Hydrology Model)
- Mean Depth and Lake Surface Area



2. Long-Term TP Concentration Inputs:

Long Term TP Conc. (mg/l)	Likely Trophic Status
<0.01	Oligotrophic (Good quality)
0.01-0.02	Mesotrophic (Ok for Rec, Habitat degraded)
0.02-0.05	Eutrophic (poor quality)
>0.5	Hypereutrophic (uses severely diminished)

Trophic Status

More Eutrophic: Detailed CE-QUAL type model

Less Eutrophic: Simple Spreadsheet Model

Water Quality Model of Lake Boon: Phosphorus, Nitrogen, Oxygen, Organic Growth

Outputs:

- Prevailing Loads
- Potential Management Impacts
- Sensitivity to Climate Change
- Potential change in Trophic Status
- Risk Levels for Future Action

3 Water Quality Modeling

Scenarios:

- Today's Conditions
- Impacts of Measures
- Sensitivity to Climate

Inputs:

- Septic # and Rates
- Runoff Load Rates
- Sediment Rates
- Nutrient Cycling Rates

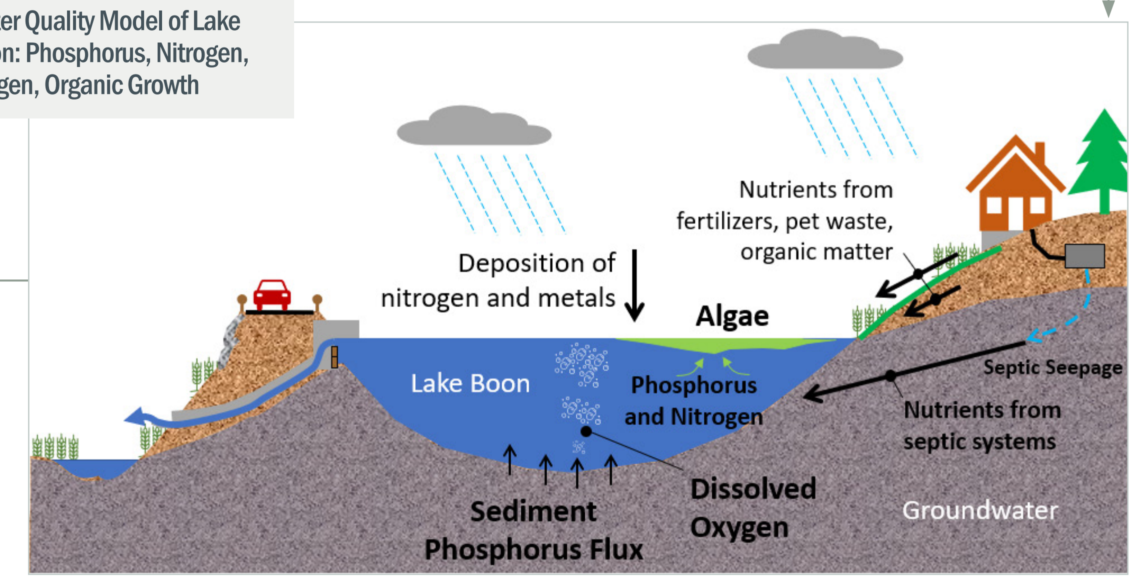


FIGURE 11 // Proposed Modeling Steps for Lake Boon

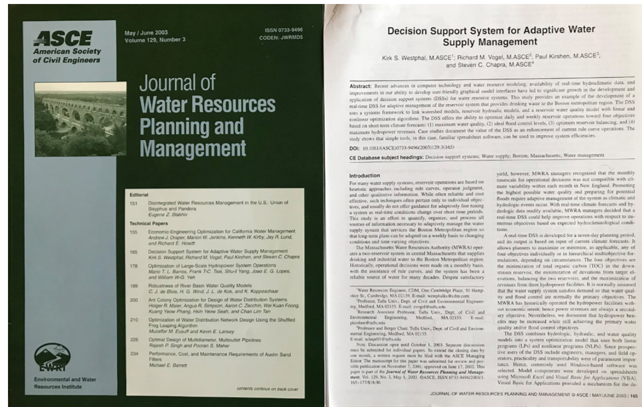
Step 1: Hydrologic Modeling:

Several key aspects of our model are worth highlighting, because they speak directly to the aim of this project.

The model is driven by daily data, which allows us to examine the response of the lake to specific storm events, something that earlier studies did not necessarily do. Targeting effective management measures MUST be grounded in understanding the immediate effects of storms, and the longer-term effects of sustained droughts and groundwater flows and depletion. This cannot be done at an annual scale, and even a monthly scale is too coarse to capture event dynamics. Our model is daily – the perfect time scale for understanding Lake Boon.

As previously discussed (see pages 13-15), our Team as already developed a hydrologic model. As part of this project, we will calibrate and further refine the model. The model already suggests that more than 90% water flowing into Lake Boon from land sources is through groundwater, and with this quantitative basis, we have a great start on better understanding this lake. (See Figure 12 for a preliminary evaluation of the distribution of inflows and outflows from the lake from the model calibrated to 2020 data). The model will be further calibrated and validated to 2021 lake level measurements as part of this study.

The model is developed in an Excel spreadsheet, so it is shareable and others (LBA, LBC, Citizen Scientists) can explore it on their own and with some basic instruction, experiment with different scenarios since the inputs are limited to three columns in the spreadsheet.



Our Technical Lead, Kirk Westphal, published a paper based on the same hydrologic model that he adapted to Lake Boon for this proposed work. In 2003, it was awarded "BEST PRACTICE-ORIENTED PAPER" by ASCE's Journal of Water Resources Planning and Management. Now our team is using this model for Lake Boon.

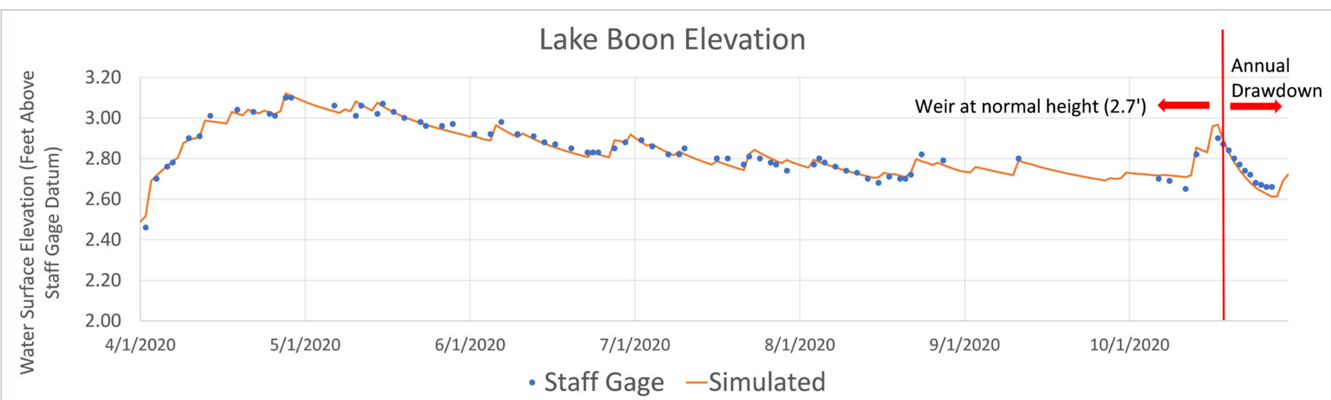


FIGURE 12 // Our Team already has a working, calibrated hydrologic model of Lake Boon, developed through our Program Director's volunteer efforts with the Lake Boon Association.

Step 2: Screening For Eutrophication Potential: Our team will determine the trophic status of the lake using the Vollenweider method. This will inform the management decisions and the type of water quality modeling that should be conducted in step 3. Our team will use the following data in estimating the trophic status:

- Lake Mean Depth (available from past studies)
- Lake Surface Area (available from past studies – approximately 160 acres)
- Residence Time in the lake (available from our team's hydrologic model, already developed)
- Annual Total Phosphorus Load into the lake (available from past studies and recent LBA sampling)

The figure on the following page illustrates how these factors can be combined into a two-dimensional grid to determine where Lake Boon resides in the spectrum of potential eutrophication.

Step 3: Dynamic Water Quality Modeling: Developing a robust model of Lake Boon will provide a clear understanding of the relative impacts of various sources of pollution and flows into and out of the Lake. Our team is experienced with a modeling software at various range of complexity, from flexible and simple spreadsheet-style tools to complex proprietary water quality and watershed models. Since this tool will be used to identify, develop, and test the effectiveness of a wide range of strategies that improve overall water quality, it is of critical importance to select the right type of tool for Lake Boon.

3A. Tool Selection

To guide the selection of an appropriate modeling tool (or set of tools) that will be useful for Lake Boon, the Team will complete diagnostic assessments of the lake's trophic condition (Vollenweider Evaluation) and trophic state index, which provide information about the in-lake phosphorus concentrations over time and provide information about the primary productivity in a lake, respectively. These assessments will be completed by incorporating data gathered through Task 1 and Task 2 into a basic spreadsheet tool simulating the Lake's hydrologic patterns, which BC began developing in a volunteer capacity.

Building upon previous tasks, the team will then recommend a specific water quality modeling approach for Lake Boon. Potential modeling approaches range from relatively simple spreadsheet models or mass balance-based models (e.g., BATHTUB) to complex, multi-dimensional models (e.g., WASP, CE-QUAL-W2). The table below lists some of the major differences in modeling approaches, with associated data requirements. Our preliminary judgement is a relatively simple, mass balanced-based model will meet the project objectives. Because shallow lakes do not typically experience strong vertical stratification, a one- or two-dimensional model will serve (Note that we have observed vertical stratification in the deep area of Basin 1 and can make accommodations there in the model). However, the model should have sufficient spatial resolution to distinguished between major basins of the lake, if monitoring data shows they are not well mixed. The model should also have sufficient temporal resolution to distinguish long-term or seasonal conditions with shorter-term conditions under which blooms might develop. Hence, one option might be spreadsheet-based dynamic model, built by adding a nutrient mass balance to the hydrologic model already created. The Team will consider this among other options and provide a clear explanation of the capabilities and limitations of the recommended modeling approach.

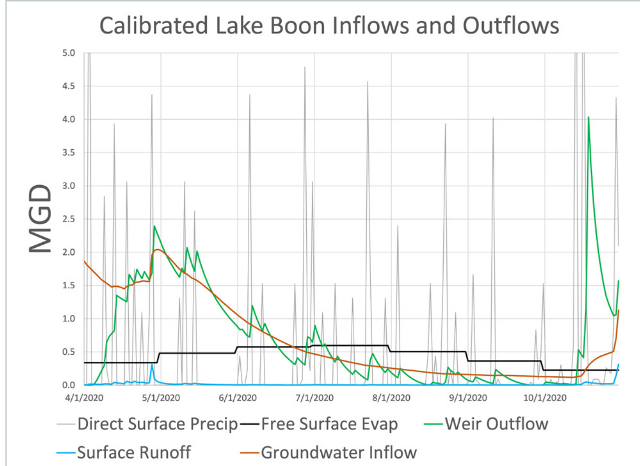


FIGURE 13 // Calibrated model of Lake Boon Inflows and Outflows in 2020, Developed by Kirk Westphal in volunteer collaboration with LBA data: Note how groundwater inflow appears to dominate surface runoff significantly – this will be very important for accurate water quality modeling.

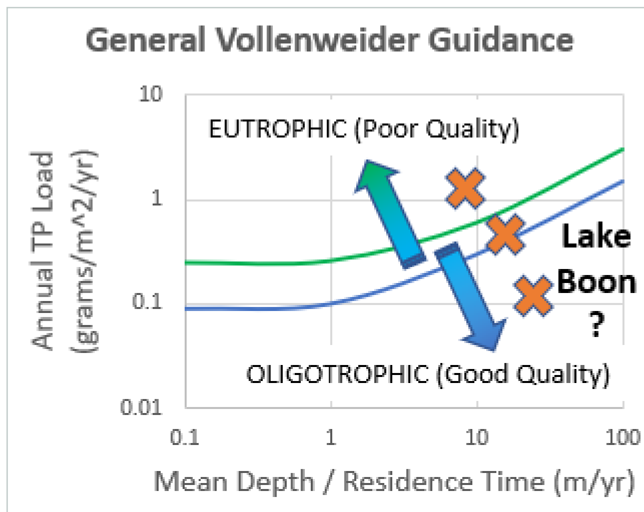


FIGURE 14 // Eutrophication potential using available data: We will need to determine where Lake Boon falls on this graph – it will inform management measures and the detail with which we proceed with more dynamic water quality modeling.

TABLE 15 // Comparison of Modeling Approaches

Model Element	Simpler	More Complex
Spatial Resolution	Zero or one-dimensional	Two or three-dimensional
Temporal Resolution	Steady state	Dynamic
Watershed Loading	Mass-balance of major hydrologic fluxes	Complex representation and modeling of specific watershed sources
In-Lake Water Quality	Empirical relations	Detailed chemical/algal algorithms

Our team will recommend an appropriate modeling tool or set of tools that can replicate current hydrologic conditions, phosphorus dynamics, and sensitivity to management measures and climate change and communicate with the Steering Committee.

3B. Model Development

Regardless of the modeling approach taken, the model will require a basic mass balance that quantifies the major sources of nutrients (primarily phosphorus) to Lake Boon. This turn will require knowledge of the extent of different sources with the Lake Boon watershed, and their associated loading rates. The BC team will create the phosphorus mass balance using a combination of mapping data, literature sources, information from available databases, and data collected specifically for this project. Estimates of phosphorus loading rates by land use/cover types are available from various sources (e.g., USGS SPARROW models, previous MDEP TMDL studies) and can be adjusted based on monitoring results. The number of septic systems can be estimated from parcel data, and the nutrient loading rate by systems can be estimated from regional studies (e.g. Heufelder and Mrozcka (2004) from the Massachusetts Alternative Septic System Test Center). Loading rates from atmospheric deposition can be estimated using data from the National Atmospheric Deposition Program (NADP).

Sediment Modeling: In past studies, loads from sediments have been frequently treated as an unknown variable, and once other phosphorus loads were measured or estimated, the difference between the total load and the sum of estimated loads was simply attributed to sediment. In the Assabet River, this led to an enormous overestimation of sediment influence on water quality in which the US Army Corps of Engineers was ready to dredge the river. A team led in part by Kirk Westphal was called in to determine the true extent of the issue and found that nutrients in the sediment replaced themselves almost every year or two, hence dredging would have only a year's worth of benefit and the problem was better addressed by reducing land-based loads. Likewise, in some of the historical studies of Lake Boon, the contributions of sediment have been estimated to be very small because when land based loading estimates were considered with their uncertainty bands, there was not much left over to attribute to sediment. We need to measure sediment contribution directly in the lab and will incorporate findings into water quality modeling. Our team has previously engaged with Woods Hole Group and SMAST at UMass Dartmouth, two specialty labs that we could recommend to the Steering Committee.

Once the sediment laboratory measurements are complete, our team will incorporate an accurate representation of sediment phosphorus flux in the model to better understand its monthly and annual contribution to the total phosphorus in the lake. If the LBA/LBC wishes to evaluate how future sediment management strategies (e.g., reducing land-based loads, oxygenating deeper areas of the lake) may impact the Lake, our team will develop another simple, dynamic model of the sediments. For a discussion of this sediment model, please see Figures 16 and 17. **The reason this model could be useful is not to help understand the sediment dynamics today (we'll get that from the lab), but to understand the sensitivity of sediment phosphorus loads to potential management measures, and to climate change (changes in loads, duration of oxygen depletion, etc.).** Because it can be programmed in a spreadsheet, it can be easily added as a module to a spreadsheet-based water quality model of the lake or, as it was for the Assabet River, used as a companion tool to a highly-parameterized water quality model.

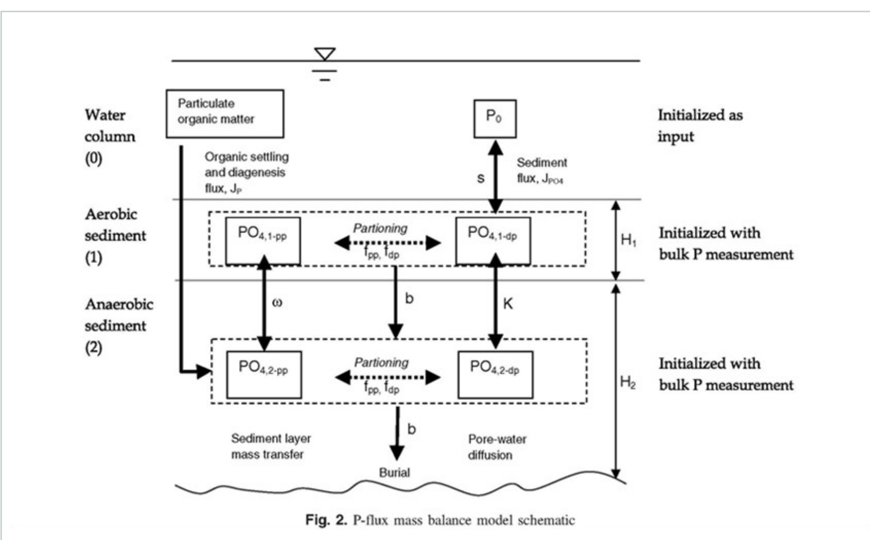


FIGURE 16 // Sediment Phosphorus Flux Spreadsheet Model co-developed by Technical Lead Kirk Westphal for the Assabet River, which could be adapted to Lake Boon if needed (From ASCE Journal of Environmental Engineering, January 2013, Vol 139, No 1., page 37.)

FIGURE 17 // Paper co-authored by Technical Lead Kirk Westphal on Sediment Flux Modeling and Laboratory Analysis.

Land-Based Loads: Some water quality studies rely on detailed watershed models to estimate non-point source pollution running off the land from sources such as fertilizers, pet waste, and other organic detritus. Our team has found that this can be counterproductive in that it is frequently requires complex models with many parameters which can lead to more uncertainty than clarity and consume a great deal of time with little benefit. We will focus our modeling efforts on the hydrology of the lake, whose dynamics until now have not been well understood, and on the water quality modeling of the lake itself. There is sufficient literature data on ranges of values we can use for septic system load, nutrient loads from various land uses (which we'll have from Town GIS databases, etc.). **More importantly, the sampling program that BC developed with the LBC as part of the MVP grant proposal includes dry and wet weather sampling events, and we can use actual in-lake comparisons before and after rain to determine phosphorus contributions from runoff more accurately than any land-based pollutant loading model. Furthermore, we will sample directly from the tributary draining the Charter Oak's Golf Course into Monahans's Cove to understand nonpoint source nutrient loads from that heavily fertilized subwatershed.**

3C. Climate Vulnerability Analysis

Our model will incorporate state-of-the-art climate forecasts for Massachusetts, retrieved and summarized through Task 1, to identify and evaluate vulnerabilities to future climate conditions. As discussed above, the Lake may be sensitive to changes in air temperature and precipitation volume and intensity, two variables that are used our modeling. While the RFP requests a 10-year outlook on impacts of climate on the Lake health, we recommend also incorporating climate projections for additional periods in the future. In our experience, many communities want to **also look at the impacts of climate change for the middle and the end of the century**, since climate projections for 2030 are similar to climate patterns experienced today, while trends diverge in later years. Our team will select likely future climate conditions at multiple points in the future (e.g.: 2030, 2050, and 2070) and evaluate how projected likely and extreme climate patterns will impact hydrology and flow dynamics, pollutant loading, water quality, eutrophication potential, management activities. Our team will share preliminary findings with the Steering Committee for feedback.

Our approach to modeling is summarized in the following table:

TABLE 18 // Summary of our 3-step Modeling Plan

Physical Phenomena	Proposed Modeling Tools	Data Sources	Current Status
Lake Bathymetry, Watershed, and Lake Hydrology	Spreadsheet model referred to as the "ABCD" model for its four governing parameters – Separates surface water and groundwater inflows based on climate inputs and watershed features. Can be used for daily, weekly, or monthly modeling using current and future climate conditions. *	• LBA Precipitation Data, corroborated with NOAA/NCDC Climate Center in Acton, MA • Daily air temperature from NOAA/NCDC Climate Center in Worcester • Climate projections (NOAA Atlas 14)	Model is fully developed and calibrated to LBA measurements of lake level in 2020. Will further calibrate & validate to 2021 data
Lake Trophic Status	Vollenweider Model	• Prior reports on Lake Boon for depth and area • Prior reports and current monitoring for phosphorus loads • Hydrologic Model (above) for residence time	Ready to estimate on day 1 and refine as more TP data are collected.
Land-Based Pollutant Loads	No dynamic modeling needed. We will incorporate Lake Boon Monitoring Program Data and literature values into the water quality model.	• Phosphorus concentrations in the lake before and after storms • Phosphorus in the tributary draining Charter Oak's Golf Course • Literature values for septic loading • Town and publicly available GIS data	Phosphorus data from LBA in 2020, supplemented with data from the proposed monitoring in 2021 and beyond.
In-Lake Water Quality Modeling and Climate Vulnerability Projections	Simple spreadsheet model if lake is reasonably healthy, more complex (CD-QUAL) type model if detail is required. Can supplement with spreadsheet model of sediment dynamics developed by Kirk Westphal.	• LBA/LBC Sampling Data • Prior reports on bathymetry • Sediment lab results • Ranges of literature values for phosphorus reaction dynamics • Climate projections (NOAA Atlas 14)	Will wait to see indications of trophic status and discuss with LBC/LBA to determine best water quality modeling approach based on data and current lake status.

**The ABCD Hydrologic Model is described well in 2 papers, one in which our Technical Lead Kirk Westphal applied it to the MWRA Water Supply Reservoirs (the paper was awarded "Best Practice-Oriented Paper" for 2003 by ASCE's Journal of Water Resources Planning and Management":*

1. Westphal, K.S., R.M. Vogel, P. Kirshen, and S.C. Chapra (2003). "Decision Support System for Adaptive Water Supply Management." ASCE Journal of Water Resources Planning and Management, May/June 2003, pg. 165-177.

2. Alley, W.M. (1984). "On the Treatment of Evapotranspiration, Soil Moisture Accounting, and Aquifer Recharge in Monthly Water Balance Models. Water Resources Research, Vol 20, No. 8, Pages 1137-1149.

Deliverables: Detailed hydrological and nutrient model of the lake and scenario analysis of future climate conditions

Task 4. Lake Health Assessment

Objectives

Clearly explain the current water quality conditions in Lake Boon and future vulnerabilities identified through the modeling and analysis task.

Our team will develop a report that clearly visualizes and interprets trends that comprise the overall health of Lake Boon. These components include several important considerations such as aquatic habitat, how the Lake can be enjoyed by the public, and climate vulnerability. Data collected through the water quality monitoring program and modelling efforts, Tasks 2 and 3, will provide insights on how the health of the Lake has changed over time and how climate patterns and watershed stewardship practices may affect risks to the Lake's health in the future. Findings from scenarios modeled in Task 3 will be summarized in this report.

Since these findings provide the foundation for identifying and prioritizing management decisions (as described in Task 5 and 8), our team will leverage capabilities of the dashboard developed through Task 7 to present clear visualizations of these data, resulting in improved engagement with decision-makers.

While regulatory compliance is not the primary focus of this study, we suggest incorporating a regulatory compliance perspective into this assessment of Lake health. Achieving water quality standards established by Massachusetts Department of Environmental Protection is a desired outcome of efforts to minimize predominant sources of pollution entering Lake Boon. Comparing current and projected water quality in Lake Boon to the State's water quality standards may provide a meaningful set of comparisons for measured and projected water quality conditions. Since regulations are intended to protect the environment and public health, water quality thresholds provide a useful benchmark for measuring success. Aspects of water quality standards can also be integrated into the dashboard web tool, as detailed in Task 7.

Deliverables: Water Quality Health Assessment Report

Task 5. Alternatives Assessment

Objectives

Develop recommendations that address the root causes of water quality impairments in the Lake.

A. Development of Alternatives

Our team will develop a set of alternatives that may be beneficial to improving the health of Lake Boon. We will

BC and many other organizations have studied many lakes in Massachusetts, the Northeast, and across the country. It would be easy, even tempting, to directly associate cause-and-effect relationships (and even management measures) observed at other nearby lakes with the issues experienced at Lake Boon and its water quality. However, each lake has its own story. Lake Boon's dynamics are different than any other lake in Massachusetts. Its depth is different, its hydrology and residence time is different, its sources of nutrient loads are different, its sediment dynamics are different. The methods prior studies used to incorporate the Lake's unique characteristics are why these previous studies disagree on prevailing sources of nutrients, total annual loads, and recommended management techniques. We will take the time to assess Lake Boon through this and prior tasks so that we can target the source of the issues, and not only the effects. We want to limit nutrient inputs, and not simply react to algae blooms when they occur.

consider actions that were recommended through previous studies (including the Phosphorus TMDL for Lake Boon), relevant actions that are used for managing surface water bodies like Lake Boon locally in New England (including nature based solutions, in-situ lake management strategies, and non-structural controls like stormwater management and zoning policies), and relevant innovative strategies that were successfully implemented in other regions. To prevent future algae growth, we will evaluate hypolimnetic oxygenation, alum-based treatments, and other in-lake preventative measures, as guided by the monitoring, sediment analysis, and modeling. To reduce nutrients at their source, we will examine stormwater controls, incentivized septic maintenance, public education on property management, potential zoning regulations, buffer strips and alternative landscaping of lawns, etc. We will focus most heavily on the sources identified as "prevailing" through the comprehensive monitoring and modeling. We will engage Brown and Caldwell's top national experts, Bill Faisst and Mike Milne to consult with LBC on viable and promising technological and societal alternatives based on their successful experience in reducing algae blooms in many other lakes. Our team will present these initial set of alternatives to the Steering Committee at a workshop, for feedback and input, prior to scoring, as described below. During this workshop, we will discuss the set of alternatives, the root cause(s) each alternative addresses, their expected effectiveness and impacts, and strategies for scoring.

Consensus-building Expertise

Our team includes Kirk Westphal, who has successfully facilitated decisions on environmental management plans with groups of stakeholders of differing opinions across the US, including the Connecticut State Water Plan (getting four regulatory agencies, environmental NGOs, and Water Utilities to agree), and a Water Settlement Agreement between two Indigenous Tribes and the State of Oklahoma. We stand ready to assist as needed (through public engagement) in building consensus on a path forward using our technical expertise, ability to work socially with stakeholders to explain pros and cons of various alternatives, and most importantly, build a portfolio of solutions that addresses the needs of everyone.

B. Scoring of Alternatives

Each alternative will be scored based on the criteria established at the workshop described in the above sub-task. The model developed through Task 4 provides a robust analytical framework for evaluating many different types of benefits, particularly those related to aquatic health and water quality. Quantitative scores, such as concentration of phosphorus, can be incorporated into the scoring directly from modeling results or literature values. Other types of scoring that rely on qualitative or subjective measures, such as type of management strategy (i.e.: nature-based versus chemical or physical treatment) can be scored with input from the Stakeholder Committee.

Deliverables: Spreadsheet of alternatives and scores

Task 6. Public Engagement

Objective

Engage and educate the entire community through public presentations, volunteer trainings, and Stakeholder Committee workshops about the project.

We recognize the importance of public engagement early in and throughout the duration of the project. To ensure that there are sufficient opportunities for input and feedback, BC integrated aspects of the multi-tiered public engagement program into other Tasks within this scope. The complete Public Engagement Program is described in the table below. Concretely, training of Citizen Volunteers on water quality monitoring will be accomplished through Task 2. Facilitation of consensus-building workshops for identifying objectives, discussing metrics and scoring, and prioritizing management alternatives, will be achieved through Tasks 1, 5, and 8, respectively.

TABLE 19 // Tasks and Public Engagement Opportunities

Task	Public Engagement Opportunities
1. Introduction to Lake Boon and Community	Steering Committee – Kickoff Public Meeting - Kickoff
2. Monitoring Program	Training (in-person) to volunteers Training and feedback to volunteers (virtual, on-going)
3. Modeling and Analysis	Periodic Steering Committee updates
4. Lake Health Assessment	Periodic Steering Committee updates
5. Alternatives Assessment	Steering Committee - Alternatives Development & Screening Steering Committee - Alternatives Scoring and Prioritization
6. Public Engagement	Educational Materials in multiple languages
7. Dashboard Web Tool	Steering Committee
8. Recommendations	Steering Committee – Review of recommendations

Through this task, we will work collaboratively with the Stakeholder Committee to develop public education and outreach materials. We recognize that many public education and outreach materials about watershed stewardship activities (leaf litter cleanup, septic maintenance, fertilizer reduction) are available from non-profit associations, watershed groups, and public agencies (MassDEP and EPA), which can be adapted to reach a broad audience, including those that are a part of historically marginalized groups. To communicate in a manner that is accessible to all members of the community our project team will develop public-facing compelling and materials with visuals and explanations that are clear and understandable to the public. Our team can provide translations of these education and outreach procedures; however, we recommend that translation of these educational materials into Portuguese and Spanish is completed as a part of the in-kind service match of the MVP Action Grant.

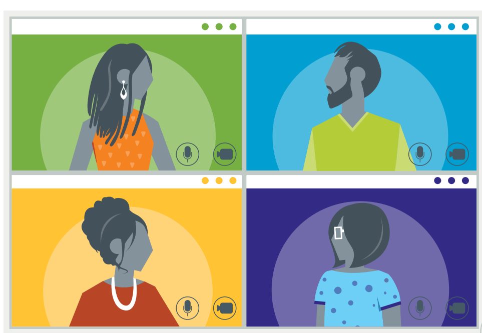


FIGURE 20 // Our team is prepared to facilitate project meetings virtually and in-person, once conditions allow for safe gathering.

Adapting to Changing Times

BC prides itself at being a virtual company, meaning that we can bring all the tools and resources of a national company to the team dedicated to this project. These capabilities include Zoom, Microsoft Teams, WebEx, and Box software that can be used to facilitate collaboration, information sharing, and virtual engagement. The past year have proven that even the most complex projects can advance using these platforms, and we are committed to identifying the blend of strategies that promote safety and quality.

Deliverables: Volunteer training on the monitoring program (see Task 2), Consensus building workshops and coordination meetings (see Task 5), support with developing education and outreach materials suitable for reproduction or online use, and Project Management / Grant Administration support.

Task 7. Dashboard Web Tool

Objectives

Create a portal for uploading and viewing data and visualizing current conditions in Lake Boon.

Water quality data is at the center of this project. Our team will work with the Steering Committee to select an appropriate platform for developing a web-based portal that meets the needs of this project and keeps future needs in mind. Our team has experience developing portals using a variety of tools, which seamlessly integrate with a variety of data sources and are easily accessible by key stakeholders. We would recommend using a suite of Microsoft products that seamlessly integrate with one another, including PowerApps, for mobile-enabled forms and web-based data collection; SharePoint, for online file storage and data management; and Power BI, for dashboard development and online publishing. Alternatively, our team can combine any of these tools with ESRI products, including ArcGIS Survey123 for forms and entry of data collected in the field using the YSI meter and reported from laboratories; ArcMap and ArcGIS Online, for mapping; and ESRI Operations Dashboards for web-based data visualizations. Collectively, the set of selected tools will allow volunteers to efficiently upload sample data and lab reports, search and filter for relevant documents and data, provide opportunities for quality control and quality assurance of data at multiple points prior to publishing, and develop intuitive and customizable dashboards. These products offer security options for multiple levels of access and Our team will work with the Stakeholder Committee to properly configure and communicate access for internal users that will be submitting and others that will view data.

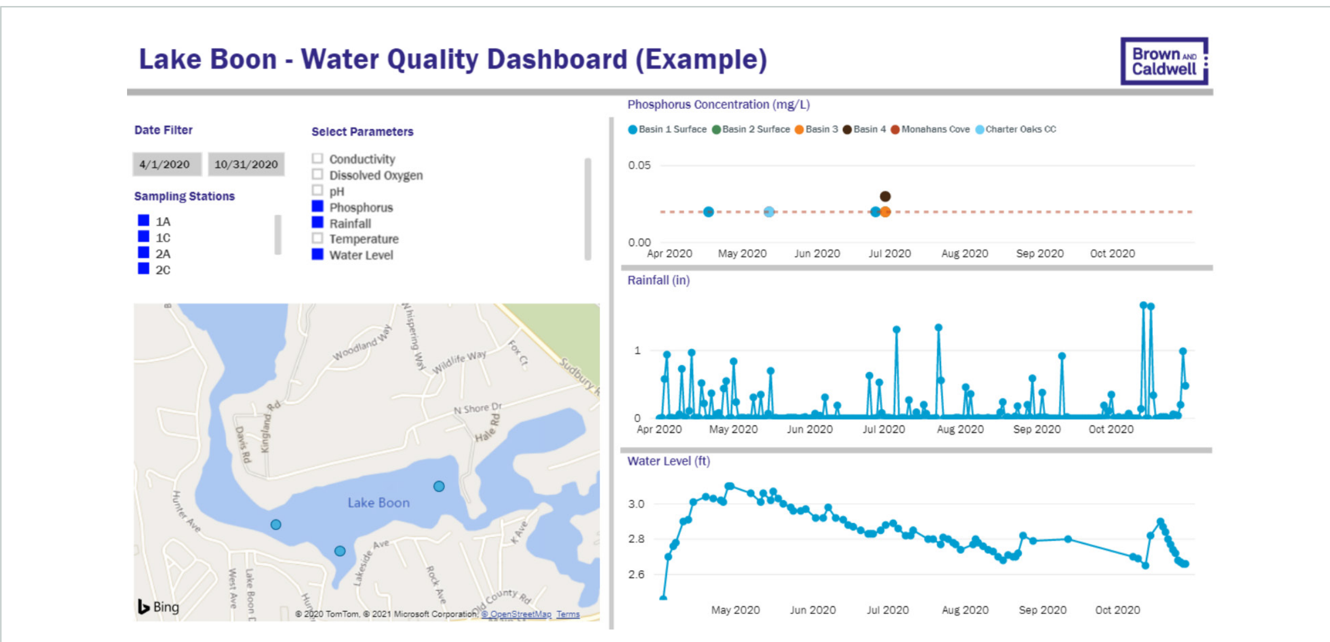


FIGURE 21 // Our team prepared this example interactive dashboard using data collected through our volunteer collaboration with LBA. This dashboard provides data filtering capabilities by date, location, and parameter and can update seamlessly in the background as data is uploaded via mobile or web-based forms.

Our team members, Andrew Goldberg, Matt Davis and Jaimie Lefkowitz have developed data collection, data management, and dashboards tools through a variety of relevant projects will guide our recommendations for Lake Boon. To illustrate our understanding of the needs of Lake Boon and the mapping, querying, and visualization capabilities of this tool, our team developed a conceptual design of key components of this dashboard using Microsoft's Power BI, which can be implemented immediately for use on this project and enhanced for more advanced analytics over the duration of the project through collaboration between the team, the Steering Committee, and Water Quality Monitoring Program volunteers.

We also understand that volunteers and the Steering Committee will have valuable input on the design, interpretability, and functionality of these tools. We will work collaboratively with these stakeholders and solicit feedback early and often in the development of these tools, can explore the details of water quality datasets and so that dashboard present data in a transparent, simple, and clear manner tailored to the needs of those that are supporting the project. Our team will provide an educational fact sheet on how to access and use each of the selected these tools, as they are developed.

BC will host the data and dashboard tool within our secure cloud environment for the duration of the project (through June 2022), providing flexibility in what information is published at various points in the project. The dashboard can be embedded into an existing project website or linked to and accessed separately from existing websites. We can work with the Steering Committee to transition the dashboard to be hosted by the community or can continue hosting the dashboard after the end of this project (through a separate agreement).

We envision that this Dashboard tool will accompany the Lake Boon Health Assessment Report, prepared in a prior task, and can also be used to prioritize alternatives, as described below.

Deliverables: Development of a set of data collection, data management and sharing, and dashboard tools and instructions for use by volunteers, the Stakeholder Committee, and the public.

Task 8. Recommendations

Objective

Prepare a prioritized list of defensible recommendations that address the current root causes of pollution in Lake Boon and address future vulnerabilities related to climate and watershed stewardship practices.

The culmination of this project is developing an implementation plan that will achieve multiple management goals established by the Steering Committee for Lake Boon. The implementation plan recommendations will consist of a prioritized set of alternatives, as developed through Task 5, as well as the methodology and findings used to develop these recommendations.

Our team will provide the Steering Committee with a transparent and clear process for comparing benefits and prioritizing a wide range of watershed management and lake management alternatives. Our process will engage stakeholders in establishing management goals and measures of success for Lake Boon, which will likely include improving water quality (minimizing the prevailing causes of pollution and mitigating the impacts of pollution entering the Lake), recreational opportunities, aesthetics, resiliency to vulnerabilities caused by climate change, implementation of nature based solutions, among others. We will then use a tool that incorporates all these goals and measures the combined benefits of each proposed alternative. The benefits of this tool are that it provides:

- Transparency in how alternatives are compared by providing access to all information used in the analysis
- Incorporates uncertainty of future conditions, promoting the selection of alternatives that suit both the most likely scenarios and mitigate against the most extreme situations
- Defensibility in the prioritization of alternatives by addressing typical limitations of traditional analytical approaches, which introduce bias and skew in comparing qualitative and quantitative ways of measuring benefits.

We will conduct a workshop with the Steering Committee to discuss and solicit input on the recommended set of alternatives and the implementation schedule that will address the objectives developed through prior workshops. Following this workshop, our team will present the implementation plan along with the methods and findings of prior components of this project in a report, which will be presented to the Stakeholder Committee for comment. Our team will incorporate comments and issue a final report.

Deliverables: Final report providing best assessment of lake study results and prioritized recommended solutions/actions.

Section 5

Schedule of Services

Fresh Perspective

Customized Solutions

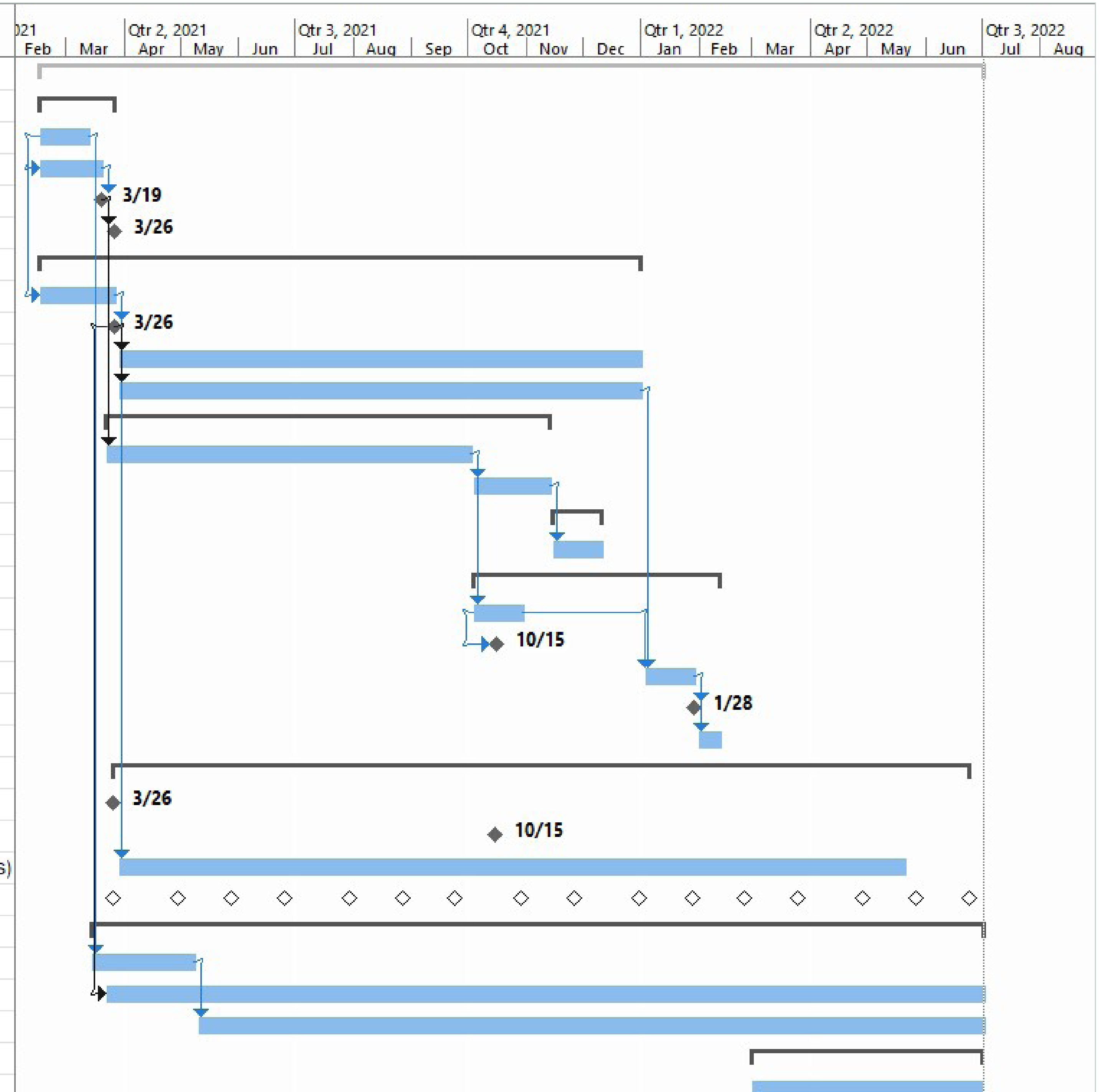
Climate Readiness

Educated Citizens

Schedule of Services

Our team understands the schedule drivers associated with the Monitoring Program as well as the requirements of the MVP Grant Program. Our team is ready to begin this work and will work closely with the Steering Committee to meet all deadlines and complete this project by June 2022.

WBS	Task Name
0	**Lake Boon Municipal Vulnerability Preparedness Project Schedule**
1	**Introduction to Lake Boon and Community**
1.1	Data Request
1.2	Report & Presentation
1.3	Steering Committee Kickoff
1.4	Public Meeting
2	**Monitoring Program**
2.1	Develop monitoring program
2.2	Volunteer training (in-person)
2.3	QAQC/Sustained Volunteer Feedback
2.4	Water quality data collection
3	**Modeling and Analysis**
3.1	Detailed hydrological and nutrient model (current conditions)
3.2	Climate change evaluations
4	**Lake Health Assessment**
4.1	Report on current and future risks for humans and aquatic habitat
5	**Alternatives Assessment**
5.1	Alternatives Development & Screening
5.2	Steering Committee Workshop - Alternatives Development & Screening
5.3	Alternatives Scoring
5.4	Steering Committee Workshop - Alternatives Scoring & Prioritization
5.5	Alternatives Prioritization & List
6	**Public Engagement**
6.1	Volunteer Training (see Task 2.2)
6.2	Alternatives Prioritization Workshops (see Tasks 5.2 & 5.5)
6.3	Public Education and Outreach (including information on watershed stewardship actions)
6.4	Project Management & Progress Reporting Support
7	**Dashboard Web Tool**
7.1	Development data collection, storage, and dashboard platforms and instructions
7.2	Secure access to data platforms for volunteers
7.3	Hosted public-facing dashboard
8	**Recommendations**
8.1	Report



Section 6

Sub-consultants

Fresh Perspective

Customized Solutions

Climate Readiness

Educated Citizens

Sub-consultants

BC does not propose any sub-consultants or subcontractors.

Section 7

Certificate of Insurance

Fresh Perspective

Customized Solutions

Climate Readiness

Educated Citizens

Certificate of Insurance

ACORD®

CERTIFICATE OF LIABILITY INSURANCE

5/31/2021

DATE (MM/DD/YYYY): 5/15/2020

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INSURER C : Lloyds of London	
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INSURER F :	

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THIS IS TO CERTIFY THAT THE POLICIES OF INSURANCE LISTED BELOW HAVE BEEN ISSUED TO THE INSURED NAMED ABOVE FOR THE POLICY PERIOD INDICATED. NOTWITHSTANDING ANY REQUIREMENT, TERM OR CONDITION OF ANY CONTRACT OR OTHER DOCUMENT WITH RESPECT TO WHICH THIS CERTIFICATE MAY BE ISSUED OR MAY PERTAIN, THE INSURANCE AFFORDED BY THE POLICIES DESCRIBED HEREIN IS SUBJECT TO ALL THE TERMS, EXCLUSIONS AND CONDITIONS OF SUCH POLICIES. LIMITS SHOWN MAY HAVE BEEN REDUCED BY PAID CLAIMS.

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A	X COMMERCIAL GENERAL LIABILITY; CLAIMS-MADE; X OCCUR; GEN'L AGGREGATE LIMIT APPLIES PER: POLICY; X PRO-JECT; LOC; OTHER:	N	N	37CSEQU1172	5/31/2020	5/31/2021	EACH OCCURRENCE	$ 2,000,000
							DAMAGE TO RENTED PREMISES (Ea occurrence)	$ 2,000,000
							MED EXP (Any one person)	$ 10,000
							PERSONAL & ADV INJURY	$ 2,000,000
							GENERAL AGGREGATE	$ 4,000,000
							PRODUCTS - COMP/OP AGG	$ 4,000,000
								$
A	AUTOMOBILE LIABILITY; X ANY AUTO; OWNED AUTOS ONLY; SCHEDULED AUTOS; X HIRED AUTOS ONLY; X NON-OWNED AUTOS ONLY	N	N	37CSEQU1173	5/31/2020	5/31/2021	COMBINED SINGLE LIMIT (Ea accident)	$ 2,000,000
							BODILY INJURY (Per person)	$ XXXXXXX
							BODILY INJURY (Per accident)	$ XXXXXXX
							PROPERTY DAMAGE (Per accident)	$ XXXXXXX
								$ XXXXXXX
	UMBRELLA LIAB; OCCUR; EXCESS LIAB; CLAIMS-MADE; DED; RETENTION $			NOT APPLICABLE			EACH OCCURRENCE	$ XXXXXXX
							AGGREGATE	$ XXXXXXX
								$ XXXXXXX
B D	WORKERS COMPENSATION AND EMPLOYERS' LIABILITY Y/N; ANY PROPRIETOR/PARTNER/EXECUTIVE OFFICER/MEMBER EXCLUDED? (Mandatory in NH) N; If yes, describe under DESCRIPTION OF OPERATIONS below	N / A	N	37WNQU1170 37WBRQU1171	5/31/2020 5/31/2020	5/31/2021 5/31/2021	X PER STATUTE; OTH-ER	
							E.L. EACH ACCIDENT	$ 2,000,000
							E.L. DISEASE - EA EMPLOYEE	$ 2,000,000
							E.L. DISEASE - POLICY LIMIT	$ 2,000,000
C	PROFESSIONAL LIABILITY	N	N	LDUSA2000482	5/31/2020	5/31/2021	$2,000,000 PER CLAIM & AGGREGATE	

DESCRIPTION OF OPERATIONS / LOCATIONS / VEHICLES (ACORD 101, Additional Remarks Schedule, may be attached if more space is required)

CERTIFICATE HOLDER

15422942
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SPECIMEN

CANCELLATION

SHOULD ANY OF THE ABOVE DESCRIBED POLICIES BE CANCELLED BEFORE THE EXPIRATION DATE THEREOF, NOTICE WILL BE DELIVERED IN ACCORDANCE WITH THE POLICY PROVISIONS.

AUTHORIZED REPRESENTATIVE
Joseph M Agnello

ACORD 25 (2016/03)

Section 8

Experience

Fresh Perspective

Customized Solutions

Climate Readiness

Educated Citizens

Experience

Brown and Caldwell

BC is among the most stable firms in the business with more than 73 years of continuous employee ownership. We are one of the largest environmentally-focused firms and a leader in adapting state-of-the-art approaches to safeguard drinking water, maintain sanitary systems, improve vital infrastructure, and restore habitats to keep our communities thriving. We offer full-service engineering, construction, program management, and science and research services. **Our bottom line is the success of our clients.**

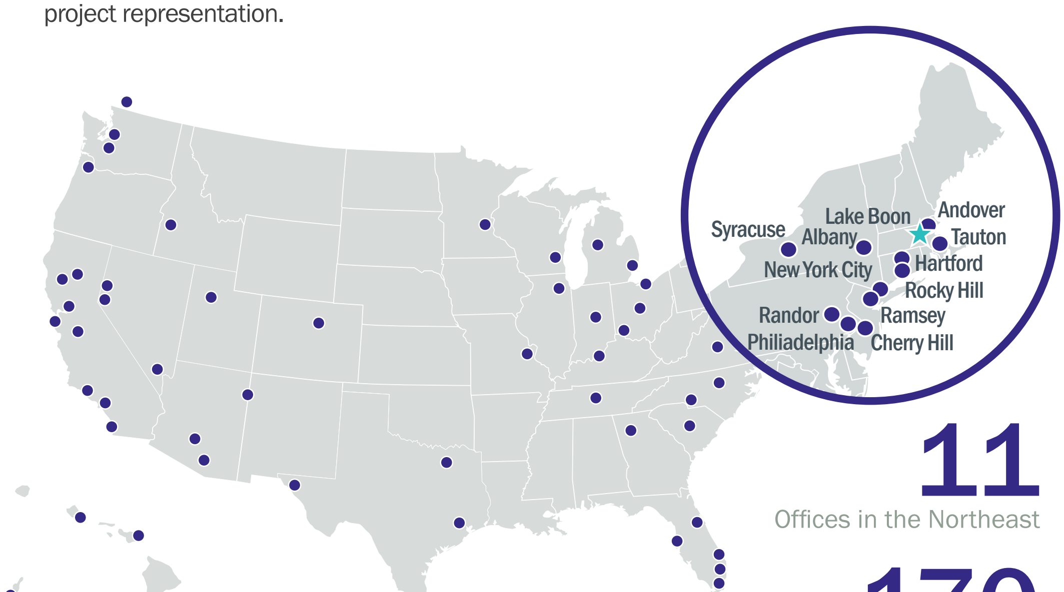
BC is comprised of nearly 1,700 professionals in over 60 offices throughout North America and the Pacific, creating solutions to help municipalities, private industry, and government agencies successfully overcome their most challenging water and environmental obstacles.

We are passionate about delivering exceptional service, collaborating with clients, adding value through innovation, and building relationships that produce extraordinary outcomes. This passion dates to Ken Brown and Dave Caldwell, who, since founding the company in 1947, stood out for their ability to solve engineering challenges, apply technology to emerging environmental problems, and serve their community.

Service, great technical solutions, innovation. These are the qualities our founders carried forward as the world changed and the company grew into what it is today. Now, these qualities are just as important – essential, really – to BC and to our clients.

BC is committed to making a positive impact on the communities and environments where we work, live, and play. Employees support our local communities through individual volunteerism and donations, as well as coordinated activities with their officemates and client partners.

BC's projects cover all aspects of water engineering, including planning, modeling, condition and risk assessments, design, rehabilitation, engineering construction services and resident project representation.



11
Offices in the Northeast

170
Professionals in the Northeast

Year Established // 1947

Business Type // Corporation - California, November 7, 1958

Parent Relationships //
Brown and Caldwell LLC
Brown and Caldwell Constructors
Brown and Caldwell Ohio, LLC
Brown and Caldwell Consultants Canada Ltd.
Eckenfelder Engineering P.C. (dba Brown and Caldwell Associates)

Office Locations // 60+ Offices Nationwide

Headquarters // 201 North Civic Drive, Walnut Creek, California 94596

Local Office // One Tech Drive, Suite 310, Andover, MA 01810

Customer Base // BC's clients include local, state, and federal governments, as well as many Fortune 100 companies.

Ownership // BC is 100% employee-owned.

General Character of Work // BC is the largest engineering consulting firm solely focused on the U.S. environmental sector.

Years Experience in Work Similar in Character and Scope // 73 years as both Contractor and Subcontractor. BC was founded on water and wastewater plant and infrastructure projects.

BC has earned the trust of our clients by meeting their increasing demands for reliable, high-quality water supplies, while simultaneously preserving the integrity and quality of water resources.

By completing more than a thousand successful water-related projects, we have established expertise that encompasses literally the entire life cycle of water resources. We have extensive experience with data collection, evaluation, and interpretation methodologies; numerical and analytical modeling techniques; and clear and concise presentation and document preparation.

References, project experience, and team experience are presented on the following pages. BC's team members were key contributors to each of these projects, and brought a wealth of knowledge, technical expertise and lessons learns. The proposed project team will provide the same commitment and deliver exceptional results to Lake Boon.

TABLE 22 // Similar Projects

	Project	Client	TMDL	Water quality sampling	Water quality modeling	Bathymetric survey	Nature-based solutions	Hydrologic modeling	Sediment sampling	Phosphorus reduction	Climate change	Public outreach	Lake management	Dashboard/web portal
References / Experience	Indian Lake Study 1	City of Worcester, MA	●	●	●			●		●			●	
References / Experience	Indian Lake Study 2	City of Worcester, MA	●	●		●			●	●			●	
References / Experience	Water Quality Management of the Cocheco River	City of Rochester, NH		●		●	●			●		●		
References / Experience	Water Quality Early Alert System	Merrimack Valley Planning Commission		●	●			●				●		●
Additional Select Experience	Lake Quinsigamond Water Quality Study	City of Worcester, MA	●	●									●	
Additional Select Experience	Spanaway Lake Management Plan	Pierce County, WA		●	●		●	●	●				●	
Additional Select Experience	Stormwater Detention Study	Boston Water Sewer Comission	●				●			●	●			
Additional Select Experience	Lake James Monitoring and Alternatives Analysis	City of Virginia Beach, VA	●	●	●		●	●		●		●	●	
Additional Select Experience	MS4 Permit Compliance	Town of Brookline, MA	●	●			●			●				
Additional Select Experience	Lake Whatcom Phosphorus TMDL	Whatcom County, WA	●		●		●	●		●			●	
Additional Select Experience	Waughop Lake Management Plan	City of Lakewood, WA		●	●			●	●	●		●	●	
	Fort Point Channel Study	Boston Water Sewer Comission		●	●	●		●						
	Braintree Stormwater	Town of Braintree, MA		●										
	Budd Inlet Study	LOTT (Olympia, WA)		●	●	●		●	●					
	Canterbury Brook GI Study	Boston Water Sewer Comission					●			●				
	BWSC On-Call Services	Boston Water Sewer Comission		●			●			●				
	Coes Reservoir Study	City of Worcester, MA				●							●	
	Merrimack River Integrated Decision Framework	Merrimack Valley Planning Commission								●	●	●		
	Integrated Water Management Plan	City of Portland, ME	●		●		●	●		●	●	●		●
	Portland Resiliency Plan	City of Portland Bureau of Environmental Services						●			●	●		
	NPDES Permit Negotiation for Phosphorus	Greater Lawrence Sanitary District			●					●	●			

Indian Lake Phase 1 and Phase 2

City of Worcester, MA

Indian Lake – Phase 1

BC played a key role with one of the first communities in Massachusetts scheduled to receive new NPDES stormwater discharge permits for their Municipal Separate Storm Sewer System (MS4). Worcester's permit requires that they develop a plan to assess and reduce phosphorus loads for waters within its boundaries with a Total Maximum Daily Load (TMDL). The City has five lakes affected by this permit and identified Indian Lake as the first to evaluate.

The first phase of the project included evaluating historic water quality data for the lake and performing stormwater runoff and baseflow quantity and quality monitoring. The water was collected at each of the major tributary inflows to the lake and analyzed for a number of parameters ranging from alkalinity to total phosphorus. Lake surface water quality monitoring was also performed.

The project also included extensive hydrologic modeling, the development of watershed phosphorus loads, and creating a nutrient limitation model for the lake. The model incorporated phosphorus load reductions from existing stormwater "Best Management Practices" (BMPs). After the modeling was completed, BC performed an evaluation of structural (including green infrastructure) and non-structural BMPs to reduce phosphorus loads to the lake.

For the evaluation of structural BMPs, BC selected two reliable and high phosphorus removal efficiency BMPs, green infrastructure (bioretention) and coagulant treatment. A field analysis was performed to identify the best potential locations for project construction. Conceptual designs were completed for several different scenarios using both types of BMPs.

Bioretention resulted in the lowest life cycle cost per pound of phosphorus removed and was therefore recommended for implementation. Bioretention will also increase green space, habitat and recreational opportunities. BC recom-mended a phased approach with monitoring to assess lake water quality improvement to distribute the cost over many years and avoid building unnecessary elements. BC proposed the design of a demonstration bioretention project to acquaint the city and citizens with green infrastructure.

Indian Lake – Phase 2

After the completion of Phase 1, BC performed another study of Indian Lake. BC mapped sediment depths throughout the lake, measured the amount of phosphorus in the sediments and performed investigations in the watershed of a tributary brook to identify sources of excess phosphorus. The study had several important findings for the manage-ment of the lake. It found that the phosphorus stored in the sediments constituted only about 9 percent of the phosphorus that was bioavailable in the lake. It also found areas tributary to the brook that had elevated levels of phosphorus, pointing the way towards potential source controls that could reduce phosphorus loads in the lake.

Project Owner

City of Worcester, MA

Reference

Jon Gervais
Environmental Manager

E | gervaisjp@worcesterma.gov

P | 508.799.1484

Project Dates

August 2011 - October 2012

October 2015 - May 2019

Key Staff

Matt Davis

Jeff Herr

Glenn Haas

An analysis of sediments in Indian Lake found that they contribute about 9 percent of the available phosphorus in the lake.

Water Quality Management of the Cocheco River and Impoundments

City of Rochester, NH

The Cocheco River flows approximately 10 miles between the cities of Rochester and Dover in southern New Hampshire. The river alternates between free-flowing segments and impoundments formed by historical mill dams. The City of Rochester discharges both treated wastewater effluent and stormwater to the Cocheco River. The City has both a regulatory and stewardship-based interest in understanding and protecting the water quality of the river and its impoundments. The nutrient dynamics of the system have been of special interest due to regulatory agencies' interest in phosphorus and nitrogen controls.

Since 2015, BC has assisted the City in both the scientific and engineering aspects of protecting the Cocheco River system. BC performed detailed water quality monitoring to help the City understand how nutrients are transported through the river-impoundment system, and the degree to which they affect beneficial uses. This information was used to support planning effort and negotiations with regulatory agencies regarding the proper levels of nutrient control. BC engineers also performed studies and design to optimize nutrient removal at the City's wastewater treatment plant.

Leading with Strong Water Quality Science

Our consistent vision has been to address regulatory proposals with the best scientific information available, including the collection of new data if necessary. Examples of project components include:

Sophisticated Water Quality Monitoring: BC designed and implemented a comprehensive monitoring program to diagnose the status of nutrient-related conditions in the Cocheco River and impoundments. This including sampling of other lakes and rivers to understand how the Cocheco system compares with other regional water bodies.

Documenting Biological Responses: In conjunction with water quality monitoring to water quality, BC characterized the status of algae, plants, and benthic macroinvertebrates in the Cocheco River system. This involved in-stream algal/plant surveys, monitoring of cyanobacteria, and interpretation of biological data from multiple agencies.

Planning with Stakeholders: BC represented the City in multiple forums to ensure that the scientific results were properly translated for permitting and planning. This including negotiations with regulatory agencies, service on the New Hampshire Water Quality Standards Advisory Committee, and dialogues with the Piscataqua Region Estuaries Partnership.

Benefits

BC and the City have demonstrated that the Cocheco River assimilates nutrients well and fully support beneficial uses. Process controls at the City wastewater treatment plant have significantly reduced nutrient discharges. The combined effect of this engagement to date has been preservation of the City's voluntary approach to nutrient removal, avoidance of unnecessary capital projects, and increased confidence in the City's water quality protection measures.

Project Owner

City of Rochester, NH

Reference

David Green
Chief Operator, Department of Public Works

E | david.green@rochesternh.net

P | 603.335.6942

Project Dates

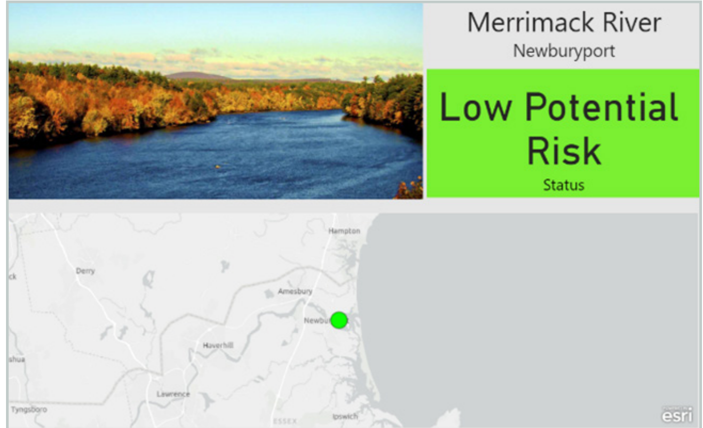
August 2017 - April 2018

Key Staff

Clifton Bell

Water Quality Early Alert System

Newburyport, Massachusetts



The Merrimack Valley Planning Commission set up an early alert system to inform river users of potential water quality concerns in Newburyport, Massachusetts.

Key Challenges

The Merrimack River runs through multiple communities in densely populated northeast Massachusetts, eventually reaching the Atlantic Ocean in coastal Newburyport. The river and coastal estuary are regional resources for recreation, commercial activity, drinking water, and aquatic habitat. Several communities also operate combined sewer systems that occasionally discharge permitted combined sewer overflows (CSOs) to the river during wet weather. Newburyport and the Merrimack Valley Planning Commission wanted a way to alert river users of the risk of bacteria contamination from CSO discharges.

Digital Solution

BC developed a tool that uses public data—such as CSO alert emails, streamflow, and precipitation—to predict the near-term risk of elevated bacteria levels downstream caused by CSO discharges. The tool ingests the public data automatically and runs an advanced prediction algorithm, based on site-specific travel time and bacteria decay parameters, and produces a daily risk status alert. The daily alert is shown on a BC Blue dashboard and sent to a public-facing website so that river users can check the risk of contamination.

Project Benefits

The early alert system provides Merrimack River communities with a valuable resource to:

- Inform the public about CSO impacts on water quality
- Enable appropriate recreational activities on the river
- Provide advance notice of specific water quality concerns in the river
- Support additional water quality data collection by nonprofits and volunteer forces

Project Owner

Merrimack Valley Planning Commission

Reference

Lane Glenn
President, Northern Essex Community College, Representative of the Merrimack River District Commission

E | lglenn@necc.mass.edu

P | 978.476.2932

Project Dates

February 2020 - July 2020

Key Staff

Kirk Westphal

Deborah Mahoney

Adrian D'Orlando

Jamie Lefkowitz

"The entire staff at Brown and Caldwell, and particularly Water Resources Leader Kirk Westphal, have been outstanding, essential partners to the work of the Merrimack River District Commission as we have formed an interstate collaboration of elected officials, government agencies, scientists, environmental organizations, educators, business and industry representatives, and municipal leaders and created an "Integrated Framework for Decision-Making" along the river that is already leading to critical environmental, recreational, and economic goal-setting and regional initiatives. Kirk and the B&C team are not only knowledgeable environmental experts; they are diplomatic engagers of community partners, highly skilled group facilitators and process engineers, and outcomes-driven planners. In short, they know their stuff, are professional and collegial, and will help you get things done. I highly recommend them."

— Lane A. Glenn
President, Northern Essex Community College, Representative of the Merrimack River District Commission

Lake Quinsigamond Water Quality Study

Shrewsbury, MA

This study investigated the water quality conditions in Lake Quinsigamond. Lake Quinsigamond is long, narrow, freshwater lake located between Worcester and Shrewsbury, MA in the Blackstone River Watershed. Lake Quinsigamond has a 475-acre surface area. Its watershed is approximately 15,100 acres. Lake Quinsigamond has dense nonnative vegetation and is showing signs of eutrophication. The cause of these conditions is thought to be related to elevated levels of nutrients in the Lake, particularly total phosphorus (TP). In 2002, The Massachusetts Department of Environmental Protection (MassDEP) developed a TP Total Maximum Daily Load (TMDL) for Lake Quinsigamond. The TMDL states that the average annual TP load to the lake needs to be reduced by 25% in order to reduce algal blooms and meet water quality standards.

This study collected water quality data from Lake Quinsigamond and from its principal tributaries (e.g., streams and stormwater outfalls that flow into it) from 2015 – 2018 during both dry weather and wet weather conditions. Parameters measured included total nitrogen, total Kjeldahl nitrogen, nitrite/nitrate, total phosphorus, orthophosphate, soluble phosphorus, alkalinity, total suspended solids, hardness, total arsenic, total copper, total lead, chlorophyll-A, E. Coli, pH, temperature, conductivity, turbidity, dissolved oxygen and oxygen reduction potential.

Inflows flow rates were measured in the stream and storm drains discharging to the lake.

Lake Quinsigamond discharges over a weir. The flow rate over the dam was estimated by measuring the water surface height over the weir (via a permanent staff gauge) and calculating the flow rate using weir flow rate equations. Manual flow measurements over the weir were also performed using a handheld velocity sensor in order to validate the accuracy of the flow rates calculated with the weir flow rate equation. This validation process resulted in some adjustments to the coefficients in the weir flow rate equation in order to improve its accuracy.

The Study shows that the Lake is making is significant progress towards meeting the goals of the TMDL. The average of the in-lake TP samples was below the TMDL target of 0.012 mg/L, and all of the in-lake surface samples were below the target. The Study also found that the Lake was thermally stratified at the deeper sites, but conductivity, pH and turbidity remain relatively similar across depths. The information developed by this Study will help the City of Worcester further refine their lake management activities to continue the improvement of water quality conditions in the Lake.

Project Owner

City of Worcester, MA

Project Dates

August 2016 - June 2019

Key Staff

Matt Davis
Jeff Herr
Colin O'Brien
Glenn Haas

Spanaway Lake Management Plan

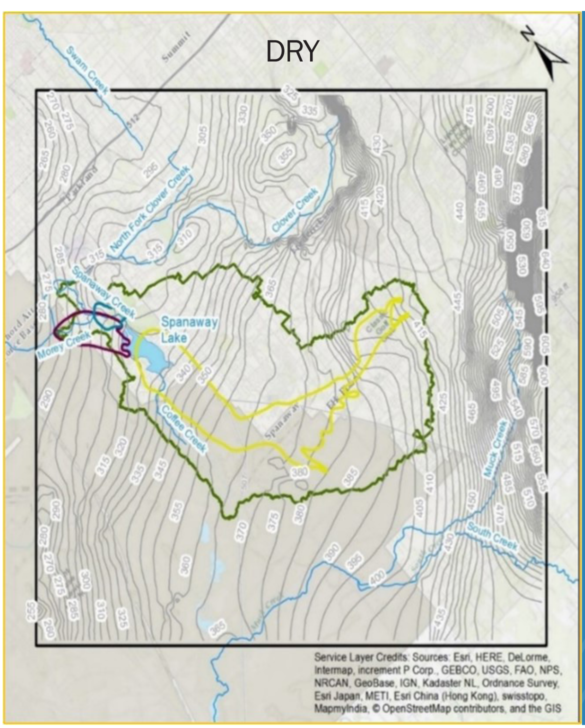
Pierce County, WA

BC led development of the Spanaway Lake Management Plan. The lake is ringed by homes and a large, popular park with a swimming beach. There are more 4,000 septic systems and 1,000 stormwater infiltration facilities in the Spanaway Lake watershed. The primary concerns are toxic cyanobacteria blooms and fecal bacteria. BC designed a comprehensive monitoring program that included creek water quality monitoring, storm event monitoring, lake water quality monitoring, groundwater monitoring, lake-bed sediment sampling, and continuous lake, outflow and lake elevation monitoring. BC used the monitoring results together with flow and geochemical modeling to estimate current and future phosphorus loads from septic systems to the lake. The results were used to develop a lake nutrient budget, evaluate the current trophic status and predict future trends based on predicted phosphorus loads to the lake. BC estimated current and future phosphorus and fecal bacteria loads from septic systems and stormwater infiltration systems to the lake using a spreadsheet model that accounts for attenuation and transport in the vadose zone and groundwater upgradient of the lake over time. BC evaluated a wide range of potential in-lake and watershed control measures and recommended a combination of hypolimnetic oxygenation and alum injection to control phosphorus and cyanobacteria in the lake. BC also evaluated a range of funding options for capital and O&M costs.

Project Owner
Pierce County, WA

Project Dates
March 2014 - December 2016

Key Staff
Mike Milne
Bill Faisst
Jeff Herr



BC used MODFLOW to simulate groundwater flow and evaluate potential pollutant sources to lake in dry and wet years.

Stormwater Detention Study

Boston, MA

The City of Boston experiences flooding during large storm events. Climate change is expected to lead to more flooding as the frequency and intensity of storms increase. The Boston Water and Sewer Commission (BWSC) contracted with BC to design resilient stormwater flood mitigation solutions that are climate-ready and use nature-based approaches.

BC developed solutions that use open space in the City to temporarily store stormwater during large storm events. This temporary storage reduces the rate and volume of stormwater discharging to the stormwater system during large storms. After the storm recedes and the downstream stormwater system has capacity, the stormwater stored in the detention sites would be released in a controlled fashion back to the stormwater system.

The stormwater detention sites include a variety of settings: wetlands, ponds, a golf course, and a park. All of the stormwater detention sites have characteristics that make them well-suited for temporarily storing stormwater: a ready supply of stormwater, available space for storage, and the ability to connect the stormwater source to the storage area and downstream drainage system. Moreover, the areas downstream of the stormwater detention sites experience flooding during extreme rainfall events, so the stormwater detention sites have the potential to provide much-need flood protection.

In addition to helping mitigate flooding in Boston, the stormwater detention sites have the potential to provide additional environmental, water quality, educational, and recreational benefits. Many of the sites have the potential to remove phosphorus from stormwater using natural treatment processes. Stormwater from the stormwater detention sites ultimately discharge to the Charles River which has a phosphorus impairment. The US Environmental Protection Agency (EPA) is requiring BWSC to reduce the phosphorus load in stormwater discharged to the Charles River by 62 percent. Treating stormwater at the detention sites would reduce phosphorus loads to the Charles River and help to meet the phosphorus reduction target. Many of the sites also present opportunities for restoring wetlands, removing invasive species, and stabilizing streams. Creating new boardwalks, footpaths and providing educational signage will provide recreational opportunities and help educate site visitors about BWSC's efforts to use open spaces for temporary stormwater detention and reduce flooding. There is even an opportunity to increase stormwater storage at a golf course irrigation pond. This will not only provide flood protection but will also provide additional water for irrigation. While originally conceived for flood mitigation, it is important to stress that the stormwater detention sites provide multiple co-benefits that can make an important contribution to the environment and the quality of life of the people in Boston.

Project Owner

Boston Water and Sewer Commission

Project Dates

September 2018 - Ongoing

Key Staff

Matt Davis

Jeff Herr

Lake James Monitoring and Alternatives Analysis

City of Virginia Beach, VA

Lake James is a former borrow pit that is used for flood control and is also considered a recreational asset by the surrounding community. The lake experiences periodic cyanobacteria blooms that are both unsightly and cause measurable cyanotoxin levels. The City of Virginia Beach retained BC to monitoring the lake water quality and develop remedial alternatives. The monitoring study revealed that the lake was impacted by high nutrient discharges from a former landfill, but also that the lake has geomorphic and hydraulic characteristics that favor algal blooms. BC developed conceptual designs of several remedial alternatives, including both treatment of the landfill leachate, hydraulic diversions, constructed wetlands, and an in-lake aeration system. BC has also assisted in communicated study results to the residents.

Project Owner
City of Virginia Beach, VA

Project Dates
July 2018 - August 2018

Key Staff
Clifton Bell

MS4 Permit Compliance

Town of Brookline, MA

BC is providing multiple stormwater activities to the Town of Brookline, MA through an on-call engineering services contract. Completed activities included a review of their stormwater program and their ability to comply with the 2018 MS4 general permit and updating their legal authority and their stormwater regulations as a result of that review. BC also updated their GIS impervious cover layer and used that information to develop a stormwater utility fee program. Currently BC is assessing traditional BMPs and innovative alternatives methods for reducing the amount of phosphorus in the stormwater discharges by as much as 50% to comply with the Charles River Phosphorus TMDL.

Project Owner
Town of Brookline, MA

Project Dates
February 2014 - Ongoing

Key Staff
Matt Davis
Andrew Goldberg
Deborah Mahoney
Jeff Herr
Glenn Haas

Lake Whatcom Phosphorus TMDL

Whatcom County, WA

Lake Whatcom is the primary water supply for approximately 100,000 people in and around Bellingham, Washington. Dissolved oxygen concentrations in the lake have been declining and algal blooms have caused taste and odor problems for the water supply. BC has been helping Whatcom County address Lake Whatcom TMDL issues in the Lake Whatcom watershed since 2008. BC performed detailed evaluations of watershed (HSPF) and lake response (CE-QUAL-W2) models used to develop phosphorus reduction targets and provided technical support for TMDL dispute resolution. BC designed a long-term tributary monitoring programs that has collected more than 3,000 samples from 30 tributaries, the results of which have been used to calibrate a new watershed load model. BC is now leading a reassessment of the TMDL, which involves using the new watershed model, together with an updated and recalibrated CE-QUAL-W2 model, to simulate DO in the lake and develop updated phosphorus allocation and reduction targets. The reassessment also includes quantification of P-load reductions from County stormwater treatment facilities, street sweeping, and homeowner incentive programs.

Project Owner
Whatcom County, WA

Project Dates
October 2008 - December 2020

Key Staff
Mike Milne
Clifton Bell

Waughop Lake Management Plan

City of Lakewood, WA

BC led development of a plan to improve water quality in a lake with a long history of toxic blue-green algae problems. The lake is the centerpiece of a very popular City park. The project involved monitoring lake water, stormwater, groundwater, and lake bottom sediment; SOD and nutrient flux monitoring, development of water and nutrient budgets; evaluation and selection of lake management measures; and stakeholder involvement. BC recommended a phased approach involving whole-lake alum treatment and potentially dredging. The City began alum treatment in 2020.

Project Owner
City of Lakewood, WA

Project Dates
April 2014 - April 2017

Key Staff
Mike Milne
Bill Faisst
Jeff Herr

A team with **proven solutions.**

Integrating technical expertise with industry specialists to deliver solutions for your project.

TECHNICAL LEAD
Kirk Westphal, PE

SENIOR ADVISORS
Bill Faisst, PhD, PE
Jeff Herr, PE
Mike Milne

PROJECT MANAGER
Andrew Goldberg

PRINCIPAL IN CHARGE / PUBLIC ENGAGEMENT
Deborah Mahoney

PROJECT ENGINEER
Adrian D'Orlando, EIT

WATER QUALITY EXPERT
Clifton Bell, PE

FIELD COORDINATOR
Colin O'Brien, EIT

REGULATORY ADVISOR
Glenn Haas

QA/QC
Matt Davis, PE

DASHBORAD ADVISOR
Jamie Lefkowitz, PE

What clients say about Kirk Westphal:

Kirk brings incredible intelligence and insight to TRWD's water supply planning. He knows state-of-the-art techniques and can distill complex modeling and analysis to simple conclusions and illustrations that our governing board and our technical staff can understand. He has been a central player in taking our water supply planning to the next level."

— Dan Buhman
Assistant General Manager, Tarrant Regional Water District, Texas

Leadership Team

We are providing a proven leadership team committed to Lake Boon. Kirk Westphal and Andrew Goldberg will deliver a **fresh perspective** and **customized solutions** that impart **climate readiness**, while **educating the citizens** of Lake Boon.

Kirk Westphal, PE

Technical Lead

Kirk Westphal has 28 years of professional experience as an engineer and water resource planner, leading clients, technical teams, stakeholders, and regulators through consensus-based decisions processes. He has directed regional water supply plans, Integrated Resource Plans (IRPs), statewide water plans, water quality management plans for lakes and rivers, water system resiliency plans, climate vulnerability studies, and risk-based drought management plans.

Relevant Expertise

- Watershed Hydrology
- Integrated Resource Plans
- Water Quality

Technical Lead, Kirk Westphal is prepared to continue to bring his expertise to Lake Boon

"Kirk's unique combination of engineering and planning skills, experience, abilities and knowledge in the field of water has adeptly led and guided the Connecticut Water Planning Council toward successful completion of state's first Statewide Water Plan. Leading numerous groups and committees, including the Policy and Science & Technical subcommittees, Kirk led his team to address every question, comment and challenge that has been presented and through actively listening to all sides of an issue has skillfully drafted the State Water Plan. His carefully structured, creative approach toward Plan development under considerable regulatory time constraints has earned the respect of all Stakeholders including winning over many long-time doubters in the water planning process. Kirk's skilled leadership and experience with other states is greatly appreciated by all involved with Plan development, and we look forward to an approved and implementable Connecticut State Water Plan."

— Lori J. Mathieu, Public Health Section Chief Drinking Water Section, Connecticut Department of Public Health

Andrew Goldberg

Project Manager

Andrew is a water resources planner and project manager with five years of experience serving municipal clients in New England. He has managed a wide variety of projects related to water quality, stormwater management, integrated water resource planning, risk and resiliency, alternatives analyses, and capital improvement plans. Andrew is knowledgeable and experienced with the Municipal Vulnerability Preparedness program.

Relevant Expertise

- Project Management
- Modeling, Data Analysis, and Visualization
- Dashboard Development

Key Personnel

Bill Faisst, PHD, PE

Senior Advisor

Bill has more than 45 years of diverse experience as project director, project manager and project engineer in water resources planning (including multiple lake and reservoir water quality assignments), the planning, design and construction of water and recycled water supply, treatment and distribution facilities; numerous effluent outfalls; and wastewater collection, pumping and treatment facilities.

Jeff Herr, PE

Senior Advisor

Jeff has over 37 years of environmental engineering experience in watershed and stormwater management, surface water monitoring and assessment, and stream and lake restoration. He has successfully completed over 200 stormwater and surface water quality projects including over 50 regional stormwater retrofit projects for public entities. Mr. Herr is a Diplomate, Water Resources Engineer, American Academy of Water Resources Engineers, and is a registered Professional Engineer in multiple states. Jeff has been instrumental in several of our New England projects, including the following featured projects: Indian Lake Phase 1 and Phase 2, Lake Quisigamond Water Quality Study, Stormwater Detention Study for Boston Water and Sewer, and the MS4 Permit Compliance Project in Brookline

Mike Milne

Senior Advisor

Mike has 40 years of professional experience in water resources management, including stormwater quality and quantity management, lake management, basin planning, surface water quality, groundwater quality, and sediment quality. He has substantial experience in NPDES and TMDL compliance for municipal stormwater and wastewater discharges.

Clifton Bell, PE

Water Quality Expert

Clifton serves as BC's Technical Leader for Water Quality and Total Maximum Daily Loads (TMDL). He is recognized nationally for his expertise in Clean Water Act compliance, crafting solutions to complex water quality challenges and fostering consensus among public and private stakeholders. A former hydrologist with the U.S. Geological Survey, Clifton has led water quality management, NPDES, and TMDL projects across the country, from Florida to California. He is especially noted for his expertise in nutrient science and standards development. Clifton recently worked on the Water Quality Management of the Cocheco River and Impoundments project in Rochester, New Hampshire. On this project, he performed water quality monitoring and analysis to support NPDES permitting, 303(d) listing, and water quality standards development.

Section 9

Exhibits and Certifications

Fresh Perspective

Customized Solutions

Climate Readiness

Educated Citizens

EXHIBIT C – Certificate of Non-Collusion

Chapter 30B, § 10

"The undersigned certifies under penalties of perjury that this proposal or proposal has been made and submitted in good faith and without collusion or fraud with any other person. As used in this certification, the word "person" shall mean any natural person, business, partnership, corporation, union, committee, club, or other organization, entity, or group of individuals."

Brown and Caldwell

Individual or Corporate Name of Proposer

Debl Mahoney

Signature of Authorized Agent

Deborah Mahoney

Printed Name of Authorized Agent

Client Services Manager

Title

January 4, 2021

Date

Form must be signed by a duly authorized officer(s) eligible to sign contract documents for the firm. Consortiums, joint ventures, or teams submitting proposals will not be considered responsive unless it is established that all contractual responsibility rests solely with one contractor or one legal entity. The Proposal must indicate the responsible entity. Contractors should be aware that joint responsibility and liability will attach to any resulting contract and failure of one party in a joint venture to perform will not relieve the other party or parties of total responsibility for performance.

EXHIBIT D - Certificate of Tax Compliance

Pursuant to Massachusetts General Law Chapter 62C, § 49A, I hereby certify under penalties of perjury that I have, to the best of my knowledge and belief, filed all state tax returns and paid all state taxes required under law.

94-1446346

Social Security or Federal I.D. Number

Signature: Individual or Corporate Officer

Client Services Manager

Title

January 4, 2021

Date

Please Print:

Brown and Caldwell

Corporate Name (as used for tax filing)

201 North Civic Drive

Address

P.O. Box

Walnut Creek, CA 94596

City, State, Zip Code

* Your Social Security Number or Federal Identification Number will be furnished to the Massachusetts Department of Revenue to determine whether you have met tax filing or tax payment obligations. Proposers who fail to correct their nonfiling or delinquency will not have a contract or other agreement issued, renewed or extended. This request is made under the authority of M.G.L. Ch. 62C, § 48A.

Form must be signed by a duly authorized officer(s) eligible to sign contract documents for the firm. Consortiums, joint ventures, or teams submitting proposals will not be considered responsive unless it is established that all contractual responsibility rests solely with one contractor or one legal entity. The Proposal must indicate the responsible entity.

Contractors should be aware that joint responsibility and liability will attach to any resulting contract and failure of one party in a joint venture to perform will not relieve the other party or parties of total responsibility for performance.

EXHIBIT E - Certificate of Authority
Meeting of Board of Directors

At a meeting of the Directors of the Brown and Caldwell duly called and held at
(Corporation)

Walnut Creek, California Headquarters on the 12 day of February, in the 2020 year at

which a quorum was present and acting, it was voted, that Deborah Mahoney the

Client Services Manager of this Corporation is hereby authorized and empowered to make,
(Name) (Title/position)

enter into, sign, seal and deliver, on behalf of this Corporation a Proposal and subsequent Contract

for:

Consulting Services for Lake Boon Municipal Vulnerability Preparedness Project
(brief description)

with the Town of Stow, and any performance and payment bonds (each in the amount of the contract) in

connection with such Contract, if applicable.

I hereby certify that the above is a true and correct copy of the record, that said vote has not been amended or repealed and is in full force and effect as of this date, and that Deborah Mahoney *is a duly elected* Client Services Manager *of this Corporation.*

Clerk or Secretary of the Corporation

BROWN AND CALDWELL INCORPORATED NOV. 7, 1958 CALIFORNIA

If a corporation, attach certificate of vote or apply corporate seal here

EXHIBIT F

EQUAL OPPORTUNITY CERTIFICATION

Pursuant to 28 CFR Part 42.204 (d), I certify that my employment practices comply with Equal Opportunity Requirements and complies with 28 CFR Part 42.202.; that my organization complies with the Americans with Disabilities Act.

Brown and Caldwell

Individual or Corporate Name of Proposer

Debel Mahony

Signature of Authorized Agent

Deborah Mahoney

Printed Name of Authorized Agent

Client Services Manager

Title

January 4, 2021

Date

Form must be signed by a duly authorized officer(s) eligible to sign contract documents for the firm. Consortiums, joint ventures, or teams submitting proposals will not be considered responsive unless it is established that all contractual responsibility rests solely with one contractor or one legal entity. The Proposal must indicate the responsible entity.

Contractor should be aware that joint responsibility and liability will attach to any resulting contract and failure of one party in a joint venture to perform will not relieve the other party or parties of total responsibility for performance.

Appendix A

Resumes

Fresh Perspective

Customized Solutions

Climate Readiness

Educated Citizens

Kirk S. Westphal, PE

Experience Summary

Kirk Westphal has 28 years of professional experience as an engineer and water resource planner, leading clients, technical teams, stakeholders, and regulators through consensus-based decisions processes. He has directed regional water supply plans, Integrated Resource Plans (IRPs), statewide water plans, water quality management plans for lakes and rivers, water system resiliency plans, climate vulnerability studies, and risk-based drought management plans. He frequently employs integrated systems modeling to simplify complex systems and better understand their interconnectivities, and facilitates stakeholder engagement to help explain scientific information and build consensus on decisions. He gives frequent guest lectures at New England universities, and has received two national writing awards for journal papers on progressive water management techniques. His experience in the U.S. spans 28 states as well as U.S. federal agencies.

Assignment

Technical Lead

Education

M.S., Water Resources Engineering, Tufts University, 2001

B.S., Aerospace Engineering, Boston University, 1991

Registration

Professional Engineer No. 45452 Massachusetts, 2003

Experience

28 years

Joined Firm

2019

Relevant Expertise

- *Watershed Hydrology*
- *Integrated Resource Plans*
- *Stakeholder Facilitation*
- *Regional Water Planning*
- *Water Quality*

Merrimack River Watershed Assessment Study, US Army Corps of Engineers and Merrimack River Watershed Community Coalition, New Hampshire and Massachusetts

Technical Lead. Directed water quality monitoring, flow monitoring, hydraulic and water quality modeling, and stakeholder meetings for the US Army Corps of Engineers and five metropolitan communities along the Merrimack River to better understand the relative impacts of stormwater, wastewater, and combined sewer overflows on water quality. Supplemented the assessment with an evaluation of alternative pollution abatement strategies and encouraged regional cooperation throughout the watershed.

Integrated Decision Framework for the Merrimack River, Merrimack Valley Planning Commission

Program Director led a broad group of elected officials and municipal, utility, environmental, and business-owning stakeholders through a visioning process for improving water quality in the Merrimack as a unified, multi-state resource.

Assabet River Sediment and Dam Removal Study, US Army Corps of Engineers, New England District

Technical Advisor. Helped direct a modeling and monitoring study that quantified benefits of removing low-head dams and dredging accumulated sediment throughout the Assabet River in Massachusetts. Focused on improving the understanding of phosphorus exchange between sediment and the water column by developing a steady-state nutrient flux model and calibrating it to laboratory measurements of phosphorus flux from sediment cores. Results completely reprioritized presumed management measures for the basin because of the scientific clarity of the sediment analysis.

Integrated Water Resources Plan, Phase II (Water Quality Evaluation), City of Franklin, Tennessee

Technical Lead. Directed the calibration and application of a dynamic water quality model of the Harpeth River. The model simulated nutrient and sediment loads and DO levels in the river in response to changes in wastewater discharges, drinking water withdrawals, low-head dam removal, and stormwater controls.

Climate Change Vulnerability Study, Metropolitan North Georgia Water Management District, Georgia

Technical Lead. Integrated results from downscaled climate models to help estimate the range of potential impacts of climate change on water supply, water quality, and flood potential, then prioritize responses.

Emergency Reservoir Water Quality Studies, Massachusetts Water Resources Authority

Project Engineer. Determined the trophic status/potential of five emergency supply reservoirs based on watershed hydrology and pollutant loading. Recommended ways to improve water quality by reducing pollutant contributions and prevent deterioration of water quality.

Integrated Resource Plan, Portland, Maine

Program Director led the City of Portland Maine and its stakeholders through the process of reprioritizing investments in stormwater, wastewater, and CSO abatement such that water quality and community benefits are more effectively realized. The work also formulated an adaptive management framework for future water quality improvements, and included climate resilience as one of the key performance factors.

Connecticut State Water Plan, Connecticut Water Planning Council, State of Connecticut

Project Director. Led an interdisciplinary group of stakeholders, an appointed council, and state committees through the process of drafting water policy to guide legislative decisions on balancing consumptive and non-consumptive water uses, climate change adaptation, and matching water quality to intended use. Also led the group through responses to public comments and ultimately to legislative approval and adoption.

South Carolina Surface Water Modeling / Statewide Water Planning, South Carolina Department of Natural Resources and Department of Health and Environmental Control, South Carolina

Technical Director for the development of 8 river basin models as part of the Statewide Water Plan. The models will evaluate reservoir operations, interbasin transfers, instream flow legislation, and future permits. Participated in numerous stakeholder workshops to help focus the tools on a full spectrum of needs.

NPDES Permit Comments and Appeal, Greater Lawrence Sanitary District, Massachusetts

Technical Advisor. Provided technical analysis and drafted scientific rationale for alternative nutrient thresholds as part of the NPDES discharge permitting process related to a reach of the Merrimack River by using scientific data and rationale to demonstrate the current health of the river.

Total Maximum Daily Load (TMDL) Analysis, Rock River Basin, US Environmental Protection Agency and Wisconsin Department of Natural Resources, Wisconsin

Technical Lead. Directed the development and application of an allocation model for total phosphorus (TP) and total suspended solids (TSS) for 81 reaches of the Rock River Basin. Also helped formulate an equitable allocation strategy for discharges and contributed to a precedent for a TMDL flow basis in Wisconsin.

Total Maximum Daily Load (TMDL) Analysis, Milwaukee Metropolitan Sewerage District, Wisconsin

Technical Advisor. Provided technical counsel on the process of establishing allowable loads in three rivers draining to Lake Michigan: The Milwaukee River, the Menomonee River, and the Kinnickinnic River. The TMDLs focused on bacteria loads, total phosphorus, and total suspended solids. The work included collaboration with US EPA and Wisconsin DNR to formulate a plan that was broadly accepted by regulators and stakeholders.

Ipswich River Basin Water Management Planning Grant, Massachusetts Department of Environmental Protection, Massachusetts

Technical Director for a team of planners and engineers developing an integrated model of the Ipswich River Basin to study alternative operating practices. The evaluation was aimed at identifying the availability of water in the basin hydrologically vs. operationally (by permit), evaluate alternative methods of satisfying local shortfalls with regional water, and develop triggers for importing water from outside the basin.

Targeted Integrated Water Resources Plan, Westport, Massachusetts

Technical Director guiding the process for the Town of Westport to systemically reduce nitrogen loading into the Westport River and Buzzards Bay while also mitigating public health risks from contaminated private wells. The town is mostly serviced by private wells and on-site septic systems, and as a "right to farm" community, has a significant agricultural presence.

Merrimack River Support Consultation, Communities of the Merrimack River Watershed, Massachusetts and New Hampshire

Technical Advisor. Offered interpretation of 15 years of water quality monitoring and modeling results in terms of the River's ability to provide drinking water, aquatic habitat, recreation, shell-fishing, and hydropoer.

Andrew S. Goldberg

Experience Summary

Andrew Goldberg is a water resources planner and project manager with five years of experience serving municipal clients in New England. He has managed contributed technically on a wide variety of projects related to water quality, stormwater management, integrated water resource planning, risk and resiliency, and capital improvement plans. He has experience with the Municipal Vulnerability Preparedness program and other Grants a transferable problem-solving philosophy to help clients maximize benefits of operational, financial, and water resources. Mr. Goldberg uses data, a broad set of analytical tools, and effective communication strategies to improve decision-makers' understanding of complex relationships between water resources challenges, regional or community-specific objectives, and constraints like budgets and regulations. Recent project contributions have included geospatial analyses, statistical analyses, integrated models, field data collection, computerized maintenance management systems, and development of databases and dashboards to visualize findings and recommendations. This approach helps communities reach consensus around decisions and provides a clear pathway to achieving optimal outcomes.

Assignment

Project Manager

Education

M.S., Environmental Planning & Management, Johns Hopkins (2018 - anticipated 2021)

B.S., Environmental Science, Lafayette College (2015)

Certifications

HAZWOPER

Experience

5 years

Joined Firm

2020

Relevant Expertise

- *Project Management*
- *Stormwater Management and regulatory compliance*
- *Asset Management*
- *Modeling, Data Analysis, and Visualization*
- *Integrated Water Resource Plans*
- *Stakeholder Facilitation*
- *Water Quality*
- *Water Supply Plans*

MVP Action Grant - Flood Resiliency Master Plan, Town of Canton, MA

Project Manager that and led the field data collection program, development of hydraulic and hydrologic model, and a public education and outreach program. The model was used to assess climate risks to critical infrastructure Town-wide under current and future climate conditions and to evaluate the effectiveness of nature-based solutions on mitigating risks.

MVP Action Grant - Watershed and Water Supply Vulnerability, Risk Assessment and Management Strategy, City of Gloucester, MA

Technical Leader for a resiliency study that provided watershed and water supply management recommendations to reduce risks associated with climate change hazards including diminished water quality and water supply availability, drought, fire, and landslides. Led a public outreach and stakeholder engagement process as well as the development of a geospatial and statistical model that incorporated data on land-based characteristics, watershed management.

MVP Planning Grant, Town of Canton, MA

Project Manager that led the Town through the Community Resilience Building process and identified top climate hazards, community strengths, and priority actions. Secured Action Grant funding for a detailed assessment of flood risks.

MVP Planning Grant, Town of Arlington, MA

Workshop Leader for the Community Resilience Building process responsible for facilitating discussions and building consensus around the community's top climate hazards, community strengths, and priority actions.

Ipswich River Basin Water Management Act Grant, Town of Danvers, MA

Planner Supported multiple phases of a Plan recommended alternative drinking water sources and operating practices for multiple communities in the Ipswich River Basin. Led the stakeholder engagement process in the first phase, which assessed baseline operational practices, demand forecasts, and supply availability. Supported the development of an integrated model of the watershed, in the second phase, to identify opportunities to adjust operations, evaluate alternative methods of satisfying local shortfalls with regional water, and develop triggers for importing water from outside the basin if and when necessary.

Integrated Water Resources Plan, Portland, ME

Project Planner that led the development of an alternatives evaluation for the City of Portland's integrated plan The evaluation used an integrated model and ranking tool that incorporated water quality, risk, and resiliency data in prioritizing investments in stormwater, wastewater, and CSO abatement to achieve community goals and improve water quality.

Targeted Integrated Water Resources Plan, Westport, MA

Technical Leader that developed a model to assess the sources of nitrogen-loading in Town. Incorporated water quality data, watershed studies, and public infrastructure data into the model to prioritize strategies to improve water quality in the Westport River and Buzzards Bay while also mitigating public health risks from contaminated private wells.

Integrated Water Resources Management Plan, Canton, MA

Project Manager responsible for the administration of multiple rounds of state grant funding towards a 5-year program, which incorporated asset management principles into the development of a capital improvement plan for water, wastewater, stormwater, and pavement assets. The Town implemented a work management system and used mobile data collection methods to collect asset inventory and condition data. Through a collaborative stakeholder engagement and process and robust analysis plan, the Town began track and visualize levels of service targets using dashboards, streamline regulatory reporting processes, assess risk, and prioritize investments to optimize return on investment.

Water Quality Study, Wareham Fire District, MA

Environmental Scientist responsible for leading the design and implementation of a hydrology study and investigation on the extent of contamination in several drinking water supply wells. Led the field program and analysis of data collected through a baseline hydraulic evaluation and two surface water to groundwater tracer studies and incorporated information into a groundwater model.

MS4 Permit Support, Cambridge, MA

Project Manager that led the development and implementation of all aspects of the City's Stormwater Management Plan including a regulatory compliance gap analysis, Notice of Intent, Annual Reports, Illicit Discharge Detection and Elimination Program, Good Housekeeping documentation, and guidance and plans to meet Total Maximum Daily Loads (TMDLs) and water quality goals. The work also included a robust education and outreach program for each of the City's target audiences and interactive classroom and field-based training for City staff on inspecting stormwater infrastructure and infrastructure operation and maintenance plans and procedures.

Stormwater Management Program Implementation, Millis, MA

Project Manager that developed the Town's Stormwater Utility and implemented programs funded through this entity. Secured multiple rounds of grant funding to complete a stormwater utility feasibility assessment and a preliminary engagement process; guided the rate setting and policy development process; and maintained the billing, abatement, and credit records for all property owners. After the development of the Utility, secured state funding for a robust asset management program that included a field data collection and condition assessment program for public infrastructure. Stormwater management program responsibilities included strategic planning for phosphorus and bacteria load reduction, system mapping and investigations, training Town staff on water quality sampling and work management software, and regulatory compliance activities.

Stormwater Consulting Services On-Call, Brookline, MA

Planner supporting the development of a wide range of stormwater consulting services to the Town, such as assisting planning, operation and maintenance, and engineering activities to comply with the requirements of the MS4 Permit. Supporting the development of a phosphorus reduction plan to meet a TMDL requirement to reduce phosphorus-loading from the Town's stormwater discharges by 50%.

Experience Summary

Ms. Mahoney has worked in the private and public sectors of the water industry for over 20 years. Her experience covers all aspects of wastewater conveyance including planning, design and construction of gravity sewers, force mains, pump stations and low-pressure sewers. Furthermore, she has experience with comprehensive wastewater management plans, combined sewer overflows and infiltration/inflow mitigation, and CMOM planning and implementation. In addition, Ms. Mahoney has received recognition for her work with low pressure sewers and pipe bursting, a trenchless technology used to replace aging infrastructure.

Assignment

Principal in Charge / Public Engagement

Education

M.B.A., Business Administration, University of Massachusetts, Lowell, 2006

B.S., Civil Engineering, University of Massachusetts, Lowell, 1998

Affiliations

New England Water Works Association

Massachusetts Water Works Association

New England Water Environment Association

2009 Young Professional of the Year Award

Inducted into the NEWEA 5S, 2011

New Hampshire Water Pollution Control Association

Massachusetts Coalition of Water Resources Stewardship

Experience

21 years

Total years with firm

January 2020

Relevant Expertise

Collection system evaluation and design

Pumping facility design

Wastewater master planning

Asset management

CMOM

Westbrook Gorham Windham Regional WWTF, Portland, ME

Project Manager. Led the development of a Facility Plan for the Westbrook WWTF, with specific attention to phosphorus removal facilities for a range of future limits. Developed alternatives for an aeration system replacement and grit removal equipment. Developed and evaluated life cycle costs for the various phosphorus removal facilities and aeration systems.

Town of Hudson, CWMP, Hudson, MA

Project Engineer. Performed future needs assessment for the Hudson wastewater treatment facility, including alternative equipment for phosphorus removal and nitrogen removal to groundwater discharge. Wrote the corresponding section of the CWMP.

Town of Newport, Phosphorus Removal Upgrade Design, Newport, NH

Deputy Project Manager. Led the design to upgrade a 5 mgd lagoon plant to remove phosphorus down to 0.35 mg/l or with chemical addition down to 0.09 mg/l. The design includes a rapid mix tank using submersible pumps, and two cloth media filters.

Assabet Consortium, Comprehensive Wastewater Management Plans, Assabet Communities, MA

Project Engineer. Investigated and evaluated alternative technologies for phosphorus removal and nitrogen removal for review of the Assabet River Communities and the Department of Environmental Protection in preparation of the new NPDES permit limits established by a TMDL study by the state of Massachusetts. Assisted the Program Manager in compiling data from all the Assabet Communities individual CWMPs.

Town of Concord, Phase I Sewer System Expansion, Concord, MA

Project Engineer. Supported the design and construction of more than 22,000 linear feet of 8 and 10-inch gravity sewer, more than 6,000 linear feet of 4-inch and 6-inch force main, more than 9,000 linear feet of water main replacement, more than 500 linear feet of drain line replacement and two pumping stations. Project characteristics included the elimination of failing septic systems, a compressed project schedule, design within watershed area, pump station land takings, environmental protection, extensive underground utilities (electric, cable, telephone, drainage, gas, water, drainage), and funding under the MA DEP's Revolving Loan Program.

Town of Marion, Sewer System Expansion, Marion, MA

Project Engineer. Supported the design and construction of approximately 35,500 linear feet of 1-1/4 inch to 4-inch PVC low-pressure sewer, approximately 8,700 linear feet of 1.25-inch PVC service connections from main line to property line, approximately 33,000 linear feet of 1.25-inch PVC services connections on private property; approximately 5,500 linear feet of 6-inch PVC gravity sewer between low-pressure pumps and homes on private property; approximately 415 prefabricated low pressure sewage pump systems on private property and abandonment of approximately 415 existing on-site sewage disposal system on private property. Special project characteristics consisted of the elimination of failing septic systems, a compressed project schedule during design and construction, design within watershed area, environmental protection, various underground utilities (electric, cable, telephone, drainage, gas, water, drainage), Massachusetts State Highway crossing, easement preparation for private roadways, coordination of private property work and funding under the MA DEP's State Revolving Fund Loan Program, as well as obtaining numerous state and local permits, including Conservation Commission, Massachusetts Highway Department, and Sewer Extension. This is the largest low-pressure sewer project in New England.

Fawcett Street Roadway and Stormwater Management Infrastructure Improvements, Cambridge, MA

Project Engineer. Project involves the design of roadway, stormwater management LIDs and subsurface utility improvements in a heavily commercial/industrial area in the City of Cambridge. The current right- of-way was not clearly defined (i.e., lack of strong curb lines and sidewalks). In addition, there was little vegetation and the road surface was in poor condition, resulting in inadequate drainage and a traffic hazard. Finally, the street was in an environmentally sensitive area (i.e., Alewife Brook catchment), and significant planning had been performed to create a future vision to transform the area into a more modern, mixed-use, pedestrian and biker-friendly area. The scope of the project included the design of new roadway, sidewalk and curbing, electrical lighting, catch basins and water system infrastructure. In addition, a green-street/low-impact development approach was incorporated to infiltrate runoff from the public right-of-way using bioretention and enhanced tree pits. Responsible for the contract documents and coordinating them with Mass DOT specifications.

Town of Northbridge, Union Street Drainage Analysis, Northbridge, MA

Project Manager. Led the evaluation of the peak flow rates and volumes for both present dry conditions and pre-development (pre-1987) conditions of the Union Place subdivision, using HydroCAD stormwater modeling software to develop models for both pre- and post- conditions. Managing review of peak flow rates and volumes and preparation of a technical memorandum to summarize the findings.

CMOM and Stormwater Program, Nashua, NH

Program Manager. Managed the City's CMOM Program and Stormwater Management Plan. The City hired Hazen to develop the City's first CMOM Program including tasks such as O&M Program Manual, SOPs for O&M of the collections system and pump stations, development and implementation of a continuous sewer assessment program, integration of CMOM with GIS and CMMS, and hydraulic model of collection system. In addition, the City requested Hazen to develop a stormwater management plan to meet the requirements of the MS4 permit.

Program Management, Design, and Project Support for Integrated Plan, Lowell, MA

Program Manager. Led the City's $40 million-dollar program to upgrade and manage infrastructure assets as part of a water and wastewater integrated plan. This five-year contract includes development of the City's first Integrated Water Plan, negotiations with MA DEP and EPA Region 1 for NPDES Permit, MS4 Permit, and Integrated Plan, Evaluation and Selection of a CMMS System, and design of various upgrades to the wastewater treatment facility. Additional tasks included upgrades to the City's website as a public engagement tool, a water and wastewater department integration evaluation and support for the development of the City's Clean Stream Initiative which focuses on data gathering, management and interpretation for water quality parameters along the Merrimack River.

CMMS Evaluation, Selection and Implementation and Data Governance, Portland Water District, Portland, ME

Project Manager. Assisting the District evaluate, select and implement a computerized maintenance management system (CMMS) for the Districts water and wastewater assets. Project included establishing requirements for the CMMS such as business, functional and technical. Then selecting CMMS solutions for customized demonstrations for the District followed by facilitating the selection of the preferred vendor. Once selected, Hazen provided support for contract negotiations and implementation of the solution. The District has also asked Hazen to support the District in establishing data governance for the various business units. This includes documenting and organization systems and procedures for data management, data warehousing, data architecture, and business analytics.

William K. Faisst, PhD, PE

Experience Summary

Dr. Faisst has more than 45 years of diverse experience as project director, project manager and project engineer in water resources planning (including multiple lake and reservoir water quality assignments), the planning, design and construction of water and recycled water supply, treatment and distribution facilities; numerous effluent outfalls; and wastewater collection, pumping and treatment facilities.

Assignment

Senior Advisor

Education

Ph.D., Environmental Engineering Science, California Institute of Technology, 1976

M.S., Environmental Engineering Science, California Institute of Technology, 1972

B.S., Civil Engineering, University of California-Davis, 1971

Registration

Professional Engineer, Civil, California, No. 29146, 1978

Professional Engineer, Nevada, No. 7082, 1985

Experience

45 years

Joined Firm

1976

Relevant Expertise

- *Lake and Reservoir Management Planning and Implementation*
- *Water system planning*
- *Water facilities design*
- *Water and wastewater treatment planning and design*
- *Recycled water facilities planning and design*
- *Effluent outfall planning and design*
- *Collection system design*
- *Stormwater facilities planning*
- *Water quality monitoring and assessments*
- *Construction assistance for water and wastewater projects*
- *Expert report preparation and litigation support*

Water Quality Assessment, Lake Hodges Reservoir, City of San Diego Water Department, California

Project Engineer. Bill provided engineering support for a water quality assessment. Lake Hodges Reservoir is listed for mercury in fish, has suffered from algae blooms and fish kills and suffers with hypolimnetic anoxia. BC directed evaluation of numerous alternatives to arrive at a multifaceted, phased management plan--hypolimnetic oxygenation system (HOS), vigorous epilimnetic mixing, algae filtering wetlands, fish harvesting, and floating islands. The City is now implementing improvements incrementally, starting with a Speece cone HOS.

Lake Waughop Water Quality Planning, City of Lakewood, Washington

Senior Technical Advisor. Lake Waughop, a 33-acre kettle lake in Pierce County with minimal catchment, has degraded water quality from over 100 years of storm water agricultural, slaughterhouse and sewage input, with a huge accumulation of nutrients in its sediment. It has suffered from HABs and fish kills. Bill assisted a team that assembled and reviewed water and sediment quality data and developed alternatives for improving water quality. The alternatives included aeration, oxygenation, sediment dredging, vigorous epilimnetic mixing and chemical addition (alum application). BC developed an overall lake management plan. Based on cost effectiveness and assessment of potential impacts and future maintenance requirements, the recommended solution is alum addition, to precipitate and settle phosphorus, to be implemented in spring 2021.

Lake Spanaway Water Quality Planning, Pierce County, Washington

Senior Technical Advisor. Lake Spanaway, a 251-acre natural lake in Pierce County with a 10,800-acre catchment, has degraded water quality from runoff, septage contaminants that carry to the lake in groundwater and internal nutrient cycling. It has suffered from toxic algae/HABs. Bill assisted a team that assembled and reviewed water and sediment quality data and developed alternatives for improving water quality. The alternatives considered included aeration, oxygenation, sediment dredging, vigorous epilimnetic mixing and chemical addition (alum application). BC developed an overall lake management plan with a phased implementation plan. The initial phase includes hypolimnetic oxygenation to reduce nutrient cycling.

HOS Design, Camanche Reservoir, East Bay Municipal Utility District, Contra Costa County, California

Project Manager. Bill directed design preparation for the San Pablo Reservoir hypolimnetic oxygenation system. The assignment included conceptual and detailed design, permitting, bidding assistance, engineering services during construction, specialty inspection and assistance during commission and startup. The system has operated successfully for more than 10 years. It includes a liquid oxygen evaporation system with a capacity of 10,000 pounds per day, a 20-foot-high Speece Cone, a 60-horsepower submersible pump and an innovative diffuser designed to spread oxygenated water thoroughly in the hypolimnion. An intake screen prevents fish aspiration.

HOS Design, San Pablo Reservoir, East Bay Municipal Utility District, Contra Costa County, California

Senior Technical Adviser/Reviewer. Bill is serving as project manager for the design and permitting of a Speece-cone hypolimnetic oxygenation system for San Pablo Reservoir. A top-of-dam oxygen storage facility with vaporize trucked in LOX to supply the HOS. The 10,000 pounds-per-day HOS will discharge its oxygenated water through an innovative diffuser box to spread oxygenated water throughout the hypolimnion. Regulation associated with dam safety required minimal foundation depths for new structures.

Soulajule Reservoir and Sausal Creek Mercury Occurrence and Bioaccumulation Study, Marin Municipal Water District, California

Project Director and Senior Reviewer. The San Francisco RWQCB required MMWD to develop a mercury monitoring plan as part of the Walker Creek Mercury TMDL; studies will lead to a management plan to address BG algae blooms and mercury accumulation within the reservoir's food chain. This work involved helping MMWD respond to Order 13267 and submitting a technical report and monitoring plan on methylmercury production and bioaccumulation in Soulajule Reservoir and downstream in Arroyo Sausal Creek, followed by remediation alternatives development and evaluation. Bill provided technical leadership for water quality management system development.

Indian Creek Hypolimnetic Oxygenation System, South Tahoe Public Utilities District, California

Project Manager. Bill completed the preliminary design and managed design assistance for a HOS at IC Reservoir in Alpine County, California. The project addresses ICR TMDL issues--water transparency, nutrients, and trophic state. The project has added a Speece Cone oxygenator with 1,000 lb/day capacity, pump, and PSA O2 generation. Bill developed an approach compatible with limitation for the existing utility supply.

HOS Design, Camanche Reservoir, East Bay Municipal Utility District, San Joaquin County, California

Project Engineer. Bill prepared design/build procurement documents for the Camanche Reservoir hypolimnetic oxygenation facility. The assignment included conceptual design, bidding assistance, review of contractor's design, specialty inspection and assistance during commission and startup. The system has operated successfully for more than 10 years. It includes a liquid oxygen evaporation system with a capacity of 14,000 pounds per day, a 20-foot-high Speece Cone, a 175-horsepower submersible pump and a 150-foot-long diffuser. An intake screen prevents fish aspiration. Since 1992, facility operation has maintained water quality.

Facilities Planning, Upper San Leandro Reservoir, East Bay Municipal Utility District, California

Project Engineer. Bill evaluated hypolimnetic oxygenation alternatives and prepared the conceptual design for a fine bubble system. He also developed preliminary sizing criteria and layouts and addressed oxygen delivery and limited electrical service issues.

Aeration/Oxygenation System Project, Santa Clara Valley Water District, California

Project Director. The District faces tremendous challenges owing legacy mercury in several reservoirs, their water quality, and potential mercury methylation/ food chain accumulation. Bill directed evaluation of data collection and oxygen needs in Almaden, Guadalupe, and Calero Reservoirs, obtaining and analyzing water quality data necessary for designing, testing, and evaluating potential reservoir oxygenation systems for the three reservoirs. Analyzing the data helped identify design risks and uncertainties associated with varying levels of data collection and data quality and pointed to potential oxygenation needs.

Experience Summary

Jeff Herr has over 34 years of environmental engineering experience in watershed and stormwater management, surface water monitoring and assessment, and stream and lake restoration, from contract preparation through study, design, QA/QC, value engineering, permitting, bidding, construction administration, startup, and operation and maintenance. 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; TMDLs; NPDES; structural and nonstructural stormwater BMP evaluation, design, permitting and construction oversight; regional stormwater retrofit including green infrastructure, wetland, and chemical treatment; development of enhanced land development regulations, stormwater design criteria and O&M procedures. He has successfully completed over 200 stormwater and surface water quality projects including over 50 regional stormwater retrofit projects for public entities. Mr. Herr is a Diplomate, Water Resources Engineer, American Academy of Water Resources Engineers, and is a registered Professional Engineer in multiple states.

Assignment

Senior Advisor

Education

M.S.E., Environmental Engineering, University of Central Florida, 1983

B.S.E., Environmental Engineering, University of Central Florida, 1981

Registration

Professional Engineer #029019, Georgia, 2003

Professional Engineer #36807, Florida, 1986

Professional Engineer #30951, Washington, 1994

Experience

34 years

Joined Firm

2008

Relevant Expertise

- *Watershed planning*
- *Monitoring and assessment*
- *Pollutant loading analyses*
- *TMDLs/NPDES MS4 compliance*
- *Stream and lake assessment and restoration*

Lake hydrologic and pollutant budgets

- *Nutrients*
- *Coagulant stormwater treatment*
- *Structural and nonstructural BMPs*
- *Green Stormwater Infrastructure*
- *Stormwater regulations*

Indian Lake Phosphorus Reduction Plan, City of Worcester, Massachusetts

Technical Lead. This project involved the development of a phosphorus reduction plan for Indian Lake. Indian Lake is a 190-acre, 10-foot average depth eutrophic lake with a 2,100-acre urbanized contributing watershed. Due to phosphorus inputs from stormwater runoff and dry weather baseflow the lake became impaired and a TMDL for total phosphorus was prepared by the state. A field monitoring program was completed including tributary flow measurements, and the collection and analysis of stormwater, baseflow and lake water samples. Lake vertical profile measurements were performed over a 4-month period. A vegetation survey was also prepared for the lake and surrounding areas. An average annual rainfall probability distribution was developed and modeling was completed to determine stormwater runoff peak flow rates and volumes for nineteen different storm events. The modeling results were used to estimate the average annual runoff volume from the watershed. Hydrologic and nutrient budgets (including all sources) were prepared for the lake. A nutrient assimilation model was used to determine the phosphorus reduction needed to meet the TMDL. Various options to reduce phosphorus loads to the lake were evaluated including low impact development infiltration and reuse practices and chemical treatment. Conceptual plans and opinions of cost were developed for the top 8 restoration options. Non-structural BMPs were identified which could be used to reduce pollutant loads in the watershed. A pilot demonstration LID project is planned to begin the restoration effort along with the implementation of non-structural BMPs.

Canterbury Brook Green Infrastructure Retrofit Evaluation and Preliminary Design, Boston, Massachusetts

Technical Lead. BC is helping Boston Water and Sewer Commission achieve cost-effective, long-term phosphorus reduction in the 2-square mile Canterbury Brook Tributary area using green infrastructure (GI). The goal of the project is to improve water quality conditions in the Charles River by reducing the phosphorus load in stormwater runoff. The project includes the evaluation and preliminary design of a range of green infrastructure practices in the right-of-way, public spaces and public-private partnerships. A spatial model and sampling program was used to identify phosphorus loading hot spots and GI priority areas. BC is selected technologies based on their cost, treatment performance, and non-cost prioritization factors.

Spanaway Watershed-Scale Stormwater Management Plan (SMP), Pierce County, Washington

Water quality technical lead. This plan was developed to meet MS4 NPDES permit requirements. Surface water-groundwater interactions are important in this watershed due to permeable soils, “gaining” lakes and creeks, and the presence of approximately 1,000 stormwater infiltration systems, 100 stormwater ponds, and 4,000 septic systems. Project involved monitoring plan development; surface water and groundwater monitoring; HSPF and MODFLOW modeling; simulation of existing, historical, and future watershed conditions; evaluation of future benthic and water quality conditions; and development of regulatory and retrofit strategies to improve lake water quality and comply with state water quality standards.

Waughop Lake Management Plan, City of Lakewood, Washington

Water quality technical lead for a plan to improve water quality in a lake with a long history of toxic blue-green algae problems. The watershed contains numerous septic systems, dry wells, and infiltration basins. The project involves monitoring lake water, stormwater, groundwater, and lake bottom sediment; development of water and nutrient budgets; evaluation and selection of lake management measures; and stakeholder involvement.

Lake Eva and Lake Henry Restoration Feasibility Study, City of Haines City, Florida

Technical Lead. This 1 Water project includes evaluating the concept and projects identified in SWFWMD's Peace Creek Canal Watershed-Lakes Structure Optimization Report, and developing other feasible solutions to connect Lake Henry and Lake Eva through natural systems such as wetlands, private canal systems through Morrison Ranch, and an existing drainage ditch maintained by Haines City Water Control District. This project will focus on how best to meet regional integrated water resource needs. This will include regional water bodies, alleviating flooding, optimizing water retention within the region, and improving lake water quality. BC’s services include data collection, field investigations, ICPR4 modeling, water quality analysis, development of alternatives and evaluation, conceptual design, cost estimating, public/stakeholder involvement, and feasibility report.

Lake Placid Watershed Management Plan, Southwest Florida Water Management District (SWFWMD), Florida

Technical Lead, Engineer of Record. The Lake Placid Watershed Management Plan includes three lakes and approximately 40 square miles of watershed. BC developed a digital terrain model (DTM), from 1-foot resolution LiDAR topography for the entire watershed. Conducted an extensive field inventory of the existing stormwater infrastructure in the watershed. ArcHydro was used to build a detailed watershed geodatabase with 1,100 data points and all field information including photos and survey data. AdICPR was used to model hydrology and hydraulics of the stormwater systems. Developed new detailed 100-year flood maps for these watersheds. Analyzed water quality monitoring results for 3 years; calculated watershed pollutant loads for each sub-basin; identified highest priority sub-basins based on pollutant loadings; and prepared a nutrient assimilation model for three lakes. Evaluated BMPs for flood protection and lake water quality improvement.

Upper Lake Lafayette Nutrient Reduction Facility, City of Tallahassee, Tallahassee, Florida

Project Manager/Engineer of Record. Provided stormwater collection and analysis, laboratory jar testing, pollutant loading calculations, estimation of pollutant load reduction, design, permitting, and bidding and construction assistance for a coagulant stormwater treatment system with 10-acre floc settling pond to retrofit a 10,000-acre watershed. Stormwater flows up to 200 cfs are treated and the predicted total phosphorus load reduction is 4,100 lb/yr. An existing 15-acre wet detention pond was converted to an off-line coagulant treatment system. The project was completed to satisfy a phosphorus TMDL for downstream Lake Lafayette. The project included concrete tanks for sedimentation, rapid mix, and flocculation. An architectural building was designed for housing the stormwater flow metering, coagulant addition equipment and coagulant storage. The project includes remote radio monitoring and controls.

Michael M. Milne

Experience Summary

Mike Milne has 40 years of professional experience in water resources management, including stormwater quality and quantity management, lake management, basin planning, surface water quality, groundwater quality, and sediment quality. He has substantial experience in NPDES and TMDL compliance for municipal stormwater and wastewater discharges.

Assignment

Senior Advisor

Education

M.S., Forestry, emphasis in Watershed Management, Northern Arizona University, 1979

B.S., Forestry, emphasis in Resource Management, Southern Illinois University, 1977

Experience

40years

Joined Firm

2001

Relevant Expertise

- *Lake management*
- *Surface water, groundwater, sediment monitoring*
- *NPDES and TMDL compliance*
- *Basin planning*
- *Project management*

Spanaway Lake Management Plan, Pierce County, Washington

Project Manager of a plan to improve water quality in a heavily used lake with a long history of toxic blue-green algae and bacteria problems. Surface water-groundwater interactions are important in this watershed due to permeable soils, "gaining" lakes and creeks, and the presence of approximately 1,000 stormwater infiltration systems, 100 stormwater ponds, and 4,000 septic systems. Project involved monitoring plan development; monitoring flow, surface water, groundwater, and sediment; HSPF and MODFLOW modeling; simulation of existing, historical, and future watershed conditions; evaluation of future benthic and water quality conditions; and development of regulatory and retrofit strategies to comply with state water quality standards. The project involved; development of water and nutrient budgets; evaluation and selection of watershed and in-lake management measures; and stakeholder involvement. Recommended lake management measures included hypolimnetic oxygenation with alum injection, aquatic plant monitoring, and public education/outreach to reduce phosphorus loads from shoreline landscapes and septic systems and bacteria loads from waterfowl and pets.

Waughop Lake Management Plan, City of Lakewood, Washington

Project Manager of a plan to improve water quality in a lake with a long history of toxic blue-green algae problems. The watershed contains numerous septic systems, dry wells, and infiltration basins. The project involves monitoring lake water, stormwater, groundwater, and lake bottom sediment; development of water and nutrient budgets; evaluation and selection of lake management measures; and stakeholder involvement. Implementation began in 2020.

Lake Whatcom TMDL Reassessment, Whatcom County, Washington

Project Manager for reassessment of DO TMDL for Lake Whatcom, which is the water supply for 100,000 people in and around Bellingham. Project involves watershed (HFAM) and lake response (CE-QUAL-W2) modeling using post-TMDL lake and tributary monitoring results. Model results will be used to recalculate phosphorus wasteload and load allocations. Also using HFAM results to estimate P-load reductions from County retrofits and programmatic measures. Providing technical support for discussions with Ecology.

Lake Whatcom Tributary Monitoring, Whatcom County, Washington

Project Manager for a long-term monitoring program to help Whatcom County and the City of Bellingham address pending TMDLs for phosphorus and fecal coliform bacteria and protect water quality in Lake Whatcom, Bellingham's primary water supply. Phase I involved storm and baseflow sampling and continuous turbidity monitoring. Evaluated continuous turbidity as a potential surrogate for phosphorus. Used Phase I results to evaluate the HSPF and CE-QUAL-W2 model used for phosphorus and TMDL development. In Phases II-III, the monitoring was expanded to include more than 25 tributaries and an assessment of P- sources in watershed. Results were used to update HFAM watershed model for TMDL reassessment.

Nisqually River Basin Plan, Pierce County, Washington

Project Manager of a plan to address existing and future drainage/flooding, water quality, and habitat issues in an approximately 700-square-mile basin with more than 20 lakes.

American Lake Watershed Management Plan, Pierce County and City of Lakewood, Washington

Project Manager for development of a watershed management plan to protect the quality of the largest natural lake in Pierce County. Reviewed existing water quality, hydrogeologic, land use, and other data to assess potential pollution sources and groundwater-surface water interactions. Designed a monitoring program to evaluate groundwater and stormwater inputs to the lake. Evaluated results to identify and prioritize pollution sources. Identified appropriate control measures to address the priority sources.

Clarks Creek TMDL Reassessment Pierce County, Washington

Project Manager for development and execution of plan to meet DO and sediment TMDLs. Performed detailed review of the TMDL models. Used HSPF to predict pollutant load reductions from ponds, filters, infiltration facilities, bioswales, LID measures, and street sweeping. Used HEC-RAS/MFA to estimate sediment load reductions from channel stabilization projects. Prepared modeling needs report and quality assurance project plan (QAPP) for Ecology approval. Designed and conducted comprehensive monitoring program to collect data needed to recalibrate HSPF, HEC-RAS, and QUAL2Kw models. In next phase we will use the models to recalculate the WLAs and Las for the DO and sediment TMDL.

Clarks Creek TMDL Compliance, City of Puyallup, Washington

Project Manager for development and execution of plan to meet DO and sediment TMDLs requirements. Used HSPF to estimate pollutant load reductions for wide range of projects and programs including green infrastructure and permeable pavement. Developed ledger to document TMDL credits as required for City's new NPDES permit. Now developing QAPP for study to refine water quality benefits of street sweeping. Providing technical support for discussions and negotiations with Ecology.

Lake Whatcom TMDL Reassessment, Whatcom County, Washington

Project Manager for reassessment of DO TMDL for Lake Whatcom, which is the water supply for 100,000 people in and around Bellingham. Updating watershed (HFAM) and lake response (CE-QUAL-W2) models and recalculating wasteload and load allocations using the results. Using HFAM model to estimate P-load reductions since the TMDL was established. Providing technical support for discussions and negotiations with Ecology.

Clarks Creek TMDL Retrofit Plan, City of Puyallup, Washington

Project Manager for a comprehensive plan to meet TMDL targets for dissolved oxygen and sediment in a creek that supports five species of salmon and two fish hatcheries. Developed and applied methods to quantify water quality benefits of a wide range of measures including stormwater diversion, floodplain re-connection, media filters, modular wetlands, permeable pavement, and channel stabilization projects. Prepared retrofit plan to document results and meet TMDL requirements.

Steilacoom Lake TMDL Evaluation, City of Lakewood, Washington

Project Manager. Helped the City of Lakewood respond to a draft TMDL for phosphorus.

Study of Phosphorus Sources in the Lake Steilacoom Watershed, City of Lakewood, Washington

Project Manager of a study to identify sources of phosphorus responsible for a severe algae problem in Lake Steilacoom. The project involved surface water, groundwater, and soil sampling; geochemical modeling; and stakeholder involvement.

Monitoring Program Update, Pierce County, Washington

Project Manager for evaluation of County's existing ambient monitoring program. Project involved field evaluations of current BIBI and WQI monitoring protocols and locations; GIS analyses to delineate and catchment areas for each site and determine their salient characteristics identification of redundant or problematic sites; evaluation of alternative monitoring approaches and development of a transition plan.

Clarks Creek Dissolved Oxygen (DO) Study, Puyallup Tribe, Tacoma, Washington

Project Manager for a study to evaluate DO concentrations in Clarks Creek and their relationship to invasive aquatic plants and fine sediment accumulations in the creek. The study indicated that invasive plants appeared to exacerbate low DO concentrations and affect sediment accumulation in the creek.

Adrian D’Orlando, EIT

Experience Summary

Adrian is an environmental engineer with growing experience in integrated planning, sustainability evaluation, stormwater management, asset management, stormwater outfall inspection, water quality monitoring, wastewater treatment plant upgrades, and construction management and administration. Her responsibilities have included preparing studies and reports; coordinating and integrating work between subconsultants; reviewing and preparing shop drawings, RFIs, and change orders; and providing engineering support in various projects relating to stormwater, wastewater, and energy.

Assignment

Project Engineer

Education

BS, Environmental Engineering, University of New Hampshire, 2018

Registration

Engineer-in-Training: Rhode Island, NCEES No. 18-897-77

Experience

2 years

Joined Firm

2018

Relevant Expertise

- *Construction Management and Administration*
- *Water and Wastewater Treatment Facility Upgrades*
- *Asset Management and Capital Improvements*
- *Sustainability Evaluations*
- *Stormwater Management*

Integrated Decision Framework for the Merrimack River, Merrimack Valley Planning Commission, Massachusetts and New Hampshire

Project Engineer. Helped coordinate regional participation for workshops and outreach. Effort supported a steering committee of 35 stakeholders (mayors, city administrators, utility directors, business owners, non-profit groups, and recreational groups), a technical advisory group, and legislative delegations for relevant regions in MA and NH to re-prioritize near-term funding needs for the Merrimack River. The group is working to engage a federally authorized coordinator for future interstate issues.

Lake Quinsigamond Water Quality Study, City of Worcester, Massachusetts

Project Engineer. This study investigated the water quality conditions in Lake Quinsigamond and Flint Pond in order to support the City of Worcester’s ongoing efforts to manage water quality conditions in the Lake and its principal tributaries. The goal of this project was to improve water quality conditions and meet water quality standards by reducing the nutrient loads to the Lake and resulting algal blooms, eutrophication, and nonnative vegetation growth, especially during the summer-time when algae blooms can be an issue. Adrian’s responsibilities included leading field work to coordinate and conduct water quality sampling and flow measurements at 18 Lake inlets and outlets, organizing and evaluating the collected field data, and developing a technical memorandum to summarize and interpret the data for the City.

Ararat Brook Water Quality Study, City of Worcester, Massachusetts

Project Engineer. This study investigated the water quality conditions in Ararat Brook, the largest tributary to Indian Lake, in order to support the City of Worcester’s ongoing efforts to manage and improve water quality conditions in the Lake. This project follows up on the findings of a 2013 BC project by seeking out the sources of phosphorus in the Ararat Brook watershed in order to support the overall nutrient control strategy for Indian Lake. Adrian’s responsibilities included leading field work to coordinate and conduct water quality sampling and flow measurements at 14 sites as well as organizing the field data.

Stormwater Detention Investigation Project, Boston Water and Sewer Commission, Boston, Massachusetts

Project Engineer. Project includes identification, rating, and evaluation of sites in the City that have the potential to store stormwater during severe storm events and slowly release the stormwater back into the storm drain collection system to prevent surcharging in the system and flooding of downstream developed areas of the City that are susceptible to flooding. Conceptual designs and costs estimates were prepared for selected sites that were identified as suitable and optimal for stormwater detention. Adrian provided support in the prospective site assessments and preparation of site information packets and conceptual design costing.

Braintree Stormwater On-Call Task Order One, Town of Braintree, Massachusetts

Project Engineer. This project is the first task order under the Braintree Stormwater Master Services Agreement. Under this Task Order, BC assisted the Town with updating their stormwater regulations, establishing a stormwater fee, and delineating stormwater outfall subcatchments. Adrian developed GIS layers delineating the Town's outfall subcatchments based on identified flow paths and town infrastructure.

Pump Station Evaluation, City of Newton, Massachusetts

Project Engineer. Project includes evaluation of 15 sanitary, stormwater, and potable water pumping stations ranging from 45 GPM to 4.7 MGD in the City of Newton, MA. Based on a combination of historical operational data review, field vibration and drawdown testing, flow monitoring, and detailed condition assessment for mechanical, electrical, instrumentations, HVAC, and structural components, the project will produce a prioritization list of improvements, including recommended costs for the City's Capital Improvement Program. This detailed condition assessment will provide confidence to the City that the future expenditures are cost effective, addressing their highest priorities to increase the reliability, performance, and safety of the stations.

Asset Management and CMMS Support, City of Oswego, New York

Project Engineer. Project included an evaluation of the City of Oswego's Westside Wastewater Treatment Plant and Excess Flow Management Facility to develop and validate an asset registry and asset hierarchy of over 600 critical assets. A high-level condition assessment and prioritization of those critical assets was conducted to help the City develop a 10-year Capital Improvement Plan. BC also provided support for implementation of a new Computerized Maintenance Management System (CMMS). Adrian conducted condition assessments of the critical mechanical, electrical, instrumentations, and HVAC assets at the facility via visual evaluation and discussion with facility operators.

Gowanus CSO Facilities, New York City Department of Environmental Protection, Brooklyn, New York

Project Engineer. Developing sustainability memoranda incorporating DEP sustainability goals at 60%, 90%, and 100% Design for the Gowanus CSO Storage Facility. The purpose of this project is to build an 8 mg storage tank to alleviate sewage discharge into the Gowanus Canal, a Superfund site. Adrian performs calculations to estimate the amount of recycled, regionally sourced, and sustainably procured new materials that can be incorporated into the construction of the storage facility and estimates the amount of waste materials generated by demolition and construction activities. The sustainability memoranda aim to provide achievable goals to ensure the facility minimizes waste and utilizes sustainable materials as much as possible.

Experience Summary

Clifton serves as BC's Technical Leader for Water Quality and Total Maximum Daily Loads (TMDL). He is recognized nationally for his expertise in Clean Water Act compliance, crafting solutions to complex water quality challenges and fostering consensus among public and private stakeholders. A former hydrologist with the U.S. Geological Survey, Clifton has led water quality management, NPDES, and TMDL projects across the country, from Florida to California. He is especially noted for his expertise in nutrient science and standards development. Related experience includes major contribution to the Chesapeake Bay Restoration efforts, co-authoring national guidance on nutrient modeling, service on state science panels for nutrient criteria development, and development of restoration plans for lakes and reservoirs.

Role

Water Quality Expert

Education

M.S., Environmental Engineering, Virginia Polytechnic Institute and State University, Blacksburg, VA, 1995

B.S., Geology, College of William and Mary, Williamsburg, VA, 1990

Registration

Professional Engineer: VA

Professional Geologist: VA

Experience

28 years

Relevant Expertise

- *Water quality management*
- *Water quality modeling*
- *NPDES permitting*
- *TMDL compliance*
- *Watershed management*

Guidance for Modeling to Develop Water Body-Specific Nutrient Goals (LINK1T11), Water Environment Research Foundation

Co-Principal Investigator. Lead the development of nationwide guidance for site-specific, predictive approaches for developing nutrient-related criteria and standards. This project involved a comprehensive review of states' nutrient-related endpoints, the creation of a process for developing site-specific nutrient criteria, and a model selection decision tool. The project advisory group includes both municipal and regulatory agency (including USEPA) representatives, to help ensure the utility of the final guidance.

Water Quality Management of the Cocheco River and Impoundments, City of Rochester, New Hampshire

Technical Lead. Performing water quality monitoring and analysis to support NPDES permitting, 303(d) listing, and water quality standards development. This project has included evaluation of nutrient controls on macrophytes and macroalgae in a non-tidal river and impoundments. It also involves extensive interaction with EPA and state regulators to advocate scientifically defensible regulatory actions.

Lake Zumbro Nutrient TMDL, City of Rochester, Minnesota

Technical Lead. Performing scientific and water quality modeling analysis to support development of NPDES permit limits and a nutrient TMDL for the Lake Zumbro and the Zumbro River, MN. Developed the technical rationale for site-specific phosphorus standards and a comprehensive strategy for setting phosphorus limits.

Lake James Monitoring and Management Strategy, City of Virginia Beach, VA

Project Manager. Developed and implemented a comprehensive water quality monitoring plan in a residential lake. Identified the major drivers of water quality impairments and algal blooms. Identified management options and facilitated meetings between City staff and the homeowners association.

Nutrient Criteria Development for Lakes and Reservoirs, North Carolina Water Quality Association

Project Manager. Serving on NC's Science Advisory Council for development of nutrient criteria. Performing independent technical analysis to support criteria and research proposals. Developed nutrient criteria for High Rock Lake as a pilot water body, and also developed statewide framework for site-specific criteria development. Tracking state & national developments and providing regular updates to NCWQA membership.

Nutrient Standards Development – Statewide Lakes and Reservoirs, Arizona Department of Environmental Quality, Phoenix, Arizona

Project Manager / Lead Scientist. Led the development of nutrient criteria for freshwater lakes and reservoirs. Performed statistical and modeling analysis of lakes and reservoirs data to support implementation of nutrient standards. Derived lake classification system, water quality targets, and writing implementation procedures for lake assessments. Facilitated public participation in nutrient standard refinement process.

Stoneman Lake Nutrient TMDL, Arizona Department of Environmental Quality, Stoneman Lake, Arizona

Project Manager. Developed TMDL for one of Arizona's only natural lakes. Performed watershed/water quality modeling to evaluate the benefits of various implementation scenarios. Modeled response of submerged grasses to changes in lake depth and water quality. Evaluated cost and feasibility of alternatives and helped watershed stakeholders achieve consensus. This project won engineering excellence awards from the Arizona Consulting Engineers Association and the American Academy of Environmental Engineers.

Chesapeake Bay TMDL Integration, Virginia and Maryland Associations of Municipal Wastewater Agencies, Virginia and Maryland

Lead Scientist. Leading the development of new water quality goals and load allocations for the Chesapeake Bay. Worked with EPA Bay Program teams to derive new use designations and nutrient-related water quality criteria for the Bay and tidal tributaries. Assisted formulation of implementation scenarios and proper application of Chesapeake Bay Water Quality Model to make loading allocations.

Freshwater Nutrient Criteria Derivation, Virginia and Maryland Associations of Municipal Wastewater Agencies, Virginia and Maryland

Lead Scientist. Ongoing, multi-year project to represent municipal stakeholder group in the state-led development of nitrogen and phosphorus standards for lakes, reservoirs, and free-flowing streams. Performed numerous technical analyses to support and advocate sound science in the standards development process. Developed innovative approach for using screening-level model for nutrient permitting.

Modeling to Support Water-Specific Nutrient Goals in Boulder Creek, CO (LINK2T14), Water Environment Research Foundation

Principal Investigator. Applied WERF's Nutrient Model Toolbox to develop and calibrate a nutrient response model for a freshwater stream system in Colorado. Applied the model to develop a water body-specific nutrient management strategy.

Reservoir Protection Planning, Birmingham Water Works and Sewer Board, Birmingham, Alabama

Quality Assurance Manager. Project evaluated vulnerability of two large municipal water supply reservoirs to future watershed build-out. Developed method for modeling pollutant loading and reservoir water quality response. Evaluated various scenarios, including use of stormwater BMPs and riparian buffers.

Savannah Harbor TMDL Facilitation, Multi-Discharger Coalition, Savannah, Georgia

Project Manager. Worked with a diverse group of dischargers to negotiate distribution of wasteload allocations and achieve TMDL for Savannah Harbor. Modeled various wasteload allocation distribution scenarios and facilitated discussion of equality, fairness, and cost-effectiveness. Represented discharger groups in regulatory negotiation with federal and state regulators.

Rueter-Hess Reservoir Watershed Management Plan, Parker Water and Sanitation District, CO

Lead Scientist. Developed a comprehensive watershed protection plan for a new water supply reservoir. Identified monitoring requirements, pollutant sources, and protection measures for the reservoir. Developed a process and schedule for implementing the plan and engaging key stakeholders.

River Input Monitoring Project, U.S. Geological Survey, Chesapeake Bay Basin, Virginia

Project Chief. Managed wet-weather monitoring program of five major tributaries to the Chesapeake Bay. Performed statistical modeling of water quality and trend analysis. Interpreted effects of point and non-point sources on water quality. Published scientific-interpretive reports of effects of point and non-point sources on water quality to be used by environmental managers.

Matthew H. Davis, PE

Experience Summary

Matt Davis has been performing water quality studies in New England and nationally for 25 years. He has developed water quality and hydraulic models, developed water quality sampling plans, performed water quality sampling, analyzed water quality data, evaluated the impacts of septic systems on water quality, performed field investigations in watersheds to identify sources of excess nutrient loads, designed green infrastructure projects and led illicit discharge detection and elimination investigations. Matt is a Professional Engineer (PE) in Massachusetts and the former Chair of the CSO and Wet Weather Issues Committee.

Assignment

QA/QC

Education

M.S., Civil and Environmental Engineering, Cornell University, 1995

B.S., Civil and Environmental Engineering, Cornell University, 1993

Registration

Professional Engineer:

Massachusetts, No. 50418

Washington, No. 36665

Experience

25 years

Joined Firm

1996

Relevant Expertise

- *Hydraulic and water quality modeling*
- *Water quality monitoring*
- *Green infrastructure design*
- *Phosphorus reduction plans*
- *IDDE investigations*
- *MS4 Permit compliance*
- *Project management*
- *Hydraulic evaluation of sewer and storm drain systems*

Indian Lake Phosphorus Reduction Plan, City of Worcester, MA

Project Manager. Indian Lake is a 190-acre pond located in the City of Worcester, MA. It has dense vegetation and a history of algal blooms. A TMDL was issued for the lake in 2002. This project is part of the City's efforts to manage nutrient input to the lake and meet the TMDL requirements. This project measured the sediment depths in the lake, measured the available phosphorus in the sediments and investigated the watershed of a tributary brook to identify sources of excess phosphorus. Matt oversaw all aspects of the project, served as technical expert, analyzed the data and authored the report. The project found that sediments do not contribute significantly to the available phosphorus in the lake (about 9 percent). Additionally, the investigations in the brook identified areas with elevated phosphorus loads where site controls may effectively reduce phosphorus loads to the lake. The findings of this project have played an important role in helping the City to formulate a well-targeted and effective plan to manage nutrient levels in the lake.

Fort Point Channel Water Quality Assessment, Boston Water and Sewer Commission

Project Manager. The Fort Point Channel is a mile-long channel separating South Boston from downtown Boston. The area surrounding the Fort Point Channel has been a major focus of redevelopment in the City since the late 90's. This study measured the water quality of the channel and developed a coupled, three-dimensional hydraulic and water quality model to evaluate the effectiveness of different water quality mitigation measures. The stormwater outfalls were surveyed and inspected, nearby CSO regulators were inspected, a wide range of water quality parameters were measured at the stormwater outfalls and within the channel during both dry and wet weather events, the flow rates at the major inputs to the channel were continuously monitored, the tributary areas were delineated and a physical trash survey was performed. Matt managed the project, served as technical expert for several tasks, performed much of the task work and authored the report. The study identified significant sources of pollution that have been subsequently removed, resulting in improved water quality conditions.

Coes Reservoir Study, City of Worcester, MA

Project Manager. Coes Reservoir is a recreational pond in the City of Worcester. This study surveyed the streams and stormwater outfalls tributary to the reservoir, delineated the tributary areas and measured the bathymetry of the reservoir. Matt oversaw all aspects of the project, performed task work and authored the report. The information developed by this study will be used to help manage the reservoir in the future.

Budd Inlet Scientific Study, LOTT Wastewater Partnership, Olympia, Washington

Project Engineer. Matt oversaw the development of a comprehensive water quality study of Budd Inlet, the southernmost inlet in Puget Sound. The project included water quality sampling of the inlet, measuring flows and the water quality of discharges to the inlet, and the development of a coupled three-dimensional hydrodynamic water quality model of the inlet. Matt coordinated the activities of various teams involved with the project and performed water quality and flow measurements, developed a computerized hydraulic model to simulate discharges over a dam during low tides from an adjoining lake, developed a hydrologic model to simulate flow inputs to the inlet, and served as a liaison to environmental regulators.

Stormwater Consulting Services On-Call, Brookline, Massachusetts

Project Manager. Matt is the project manager for a stormwater on-call contract with the Town of Brookline. One of the key challenges facing the Town is meeting the phosphorus reduction target of 59% for stormwater discharged to the Charles River. The cost of compliance may range from $100-$200 million. Matt is developing a strategy to meet the phosphorus reduction requirements. The strategy includes green infrastructure, phosphorus sampling, removing illicit sources from storm drains and tracking best management practices implemented by redevelopment in the Town.

Stormwater Services, Town of Braintree, MA

Project Manager. Matt has managed multiple stormwater-related projects for the Town of Braintree, MA. As part of these projects, he has performed a comprehensive review of the Town's stormwater program and determined its readiness to meet the requirements of the upcoming Municipal Separated Storm Sewer (MS4) Permit. The assessment included a review of the Town's stormwater bylaws and regulations. He developed a list of activities and the level of effort that will be required for future compliance with the Permit. He also oversaw the investigation and testing of the Town's stormwater outfalls and the delineation of the stormwater tributary areas. His team performed follow-up upstream illicit source tracking for stormwater outfalls suspected of contamination.

IDDE Program, City of Springfield, MA

Project Manager. Matt managed an IDDE investigations program for the City of Springfield, MA. The project was being driven by an Administrative Order from the United States Environmental Protection Agency (EPA) which required the City to complete a series of investigations according to a strict timeline. The City of Springfield is a highly urbanized area with old stormwater infrastructure. The City has approximately 330 stormwater outfalls. The project performed dry weather investigations at the stormwater outfalls. For outfalls that were observed to have water present during dry weather conditions, water quality samples were collected according to EPA requirements. This includes collecting water samples for E. Coli, ammonia, surfactants and numerous other water quality constituents which can indicate the presence of sewage. For outfalls identified as potentially having sewage contamination, upstream investigations were performed to locate the source. The upstream investigations include additional visual observations, sampling, dye testing and CCTV. Matt oversaw all of the activities for this project and authored the report that was submitted to EPA ahead of schedule.

Canterbury Brook Green Infrastructure Planning Study, Boston Water and Sewer Commission, Boston, Massachusetts

Project Manager. Matt was the project manager and one of the lead investigators for a Green Infrastructure/Low Impact Development Study of a 1,116-acre area that falls within the Boston neighborhoods of Jamaica Plain, Mattapan and Roslindale. The purpose of the Study was to identify GI/LID features in the study area that could reduce the stormwater phosphorus load to the Charles River by 62 percent. Matt has overseen all aspects of the Study including the identification and conceptual design of over 120 GI/LID features in the study area, an evaluation of surface and subsurface conflicts, development and implementation of a phosphorus sampling program and the development of a geotechnical investigation program which includes soil classification, infiltration testing and groundwater monitoring. The Study was completed in October of 2018.

Colin O’Brien, EIT

Experience Summary

Colin is an environmental engineer with experience developing conceptual design plans for green infrastructure, performing stormwater outfall inspections and water quality monitoring of lakes and bays. He is the stormwater/water resources field operations leader of the Boston office. He also has experience with wastewater treatment plant designs.

Colin has been a valuable team member on a number of projects including the design of wastewater treatment plant upgrades, pump station evaluations, energy evaluations, and collection system modeling. Most recently, he served as a key member of a team responsible for the preliminary design of improvements at the Oneida County (NY) Water Pollution Control Plant.

Assignment

Field Coordinator

Education

BS, Environmental Engineering, Clarkson University, 2015

Experience

6 years

Joined Firm

2015

Relevant Expertise

- *Stormwater Green Infrastructure Planning*
- *Stormwater Illicit Discharge Detection and Elimination (IDDE)*
- *Wastewater treatment plant design*
- *Energy Evaluations and Projects*
- *Pump Station Design and Evaluation*
- *Groundwater Contamination*
- *Collection System evaluations*

Canterbury Brook Green Infrastructure Planning Study, Boston Water and Sewer Commission, Boston, Massachusetts

Project Engineer. Colin is a project engineer for a Green Infrastructure/Low Impact Development Study of a 1,116-acre area that falls within the Boston neighborhoods of Jamaica Plain, Mattapan and Roslindale. The purpose of the Study is to identify GI/LID features in the study area that can reduce the stormwater phosphorus load to the Charles River by 62 percent. Colin has assisted with coordinating sub-contractor’s effort for a geotechnical investigation including soil classification, infiltration characteristics, stormwater sampling program, has been involved with the planning level design of over 120 GI/LID features in the study area and an evaluation of surface and subsurface conflicts.

Implementation of Indian Lake Phosphorus Reduction Plan, City of Worcester, MA

Project Engineer. Colin is assisting with the implementation of a phosphorus reduction plan for Indian Lake in Worcester, MA. The goal of the project is to reduce nutrient loads to the Lake and improve water quality conditions, especially during the summer-time when algae blooms can be an issue. Colin is assisting the design of a green infrastructure project to reduce phosphorus loads to the Lake. He also led the field work effort to collect sediment and water quality samples in the Lake.

Stormwater Services, Town of Braintree, MA

Project Engineer. Colin has been involved with multiple stormwater-related projects for the Town of Braintree, MA. Colin has performed stormwater outfall inspections and water quality sampling to identify outfalls suspected of having sewage contamination. Colin performed additional investigations and testing in storm drains upstream of contaminated outfalls in order to locate the sources of sewage contamination. Colin was responsible for planning and coordinating all of the field activities. He also analyzed the field and laboratory data using a GIS system and prepared maps to document the results.

GenCorp, Lawrence, Massachusetts

Project Engineer. Performed groundwater sampling, surface water sampling and NAPL thickness measurement at a former industrial site impacted by polychlorinated biphenyls (PCBs), polychlorinated dibenzofurans, chlorinated dibenzodioxins, and industrial chlorinated solvents, such as TCE.

Field testing for CEPT and HRD, Oneida County, New York

Project Engineer. Colin was part of the efforts to conduct bench testing to evaluate CEPT and HRD for the planned wet weather improvements to the

Oneida County treatment facility. The work includes various testing protocols to minimize future facilities and improve solids settling efficiency as well as disinfection of wet weather flows.

Wet Weather Treatment Facilities, Metropolitan District Commission (MDC), Hartford, Connecticut

Project Engineer. Design team engineer for 210 mgd wet weather expansion including Chemical Storage Facility (ferric chloride and emulsion polymer), dual use primary clarifiers chemical injection facilities, and high rate wet weather disinfection (with hypochlorite storage and feed). The design allows the 90 mgd secondary treatment plant to receive and treat wet weather flows up to 210 mgd with primary treatment and high rate disinfection. Design included extensive pilot and physical model studies to validate design criteria, allowing the design to minimize facility footprint, saving capital and operations costs. Chemical storage facility includes coagulant storage and pumping, polymer storage and blending units, disinfectant storage and pumping, as well as mechanical, electrical and communication rooms. The wet weather disinfection tank includes chemical diffusers, chemical mixers, and channel flushing gates. Work includes coordination with a multi-consultant design team and construction administration services.

Capacity Assurance Planning Environment (CAPE), Western Lake Superior Sanitary District, Duluth (WLSSD), Minnesota

Project Engineer. Utilized CAPE to evaluate infiltration and interception of WLSSD collection system based on varying environmental conditions. Colin compiled long term flow meter and weather conditions to identify areas of concern to later be used in fabricating a master plan. CAPE is an integrated framework of software tools for waster capacity planning and has been used by more than a dozen wastewater utilities across the country. It includes tools for managing/analyzing flow meter and rainfall data, developing wastewater flow and forecasts, and planning capital improvements. CAPE allows utilities to update data and evaluate changing conditions dynamically.

Deer Island On-Call Services, Massachusetts Water Resources Authority, Boston, Massachusetts

Project Engineer. As part of the on-call engineering services contract, BC will conduct various studies and design work as deemed necessary by the authority at the Deer Island Treatment Plant. Colin will be involved in several of these Task Orders from the evaluation phase through final design and production of bid documents.

Barriers to Energy Efficiency and Resource Recovery, Water Environment Research Foundation

Project Engineer. Colin collaborated with over 160 wastewater utilities throughout New York and U.S., including the Wisconsin cities of Stevens Point and Sheboygan, who have demonstrated conclusively that energy efficiency combined with co-digestion and energy production can achieve net-zero wastewater treatment in both small and large facilities and other partners like Metropolitan Council Environmental Services (MCES), NEW Water of Green Bay, WI, and the County of Albany, NY, who are aggressively working toward established energy goals and initiatives. This project:

- Identified the hurdles to energy efficiency and resource recovery at WRRFs and solutions to address barriers
- Developed online surveys to be taken by industry personnel to assist in evaluating energy barriers throughout the industry.
- Assessed the effect of state legislation, public utility commissions, and power companies on energy efficiency and energy recovery
- Showcased facilities with well-developed energy programs
- Evaluated energy trends over the last 10 years at New York State wastewater facilities

Jamie R. Lefkowitz, PE

Experience Summary

Jamie has over 14 years of experience as a civil engineer, managing water resources projects for a diverse set of clients and partners throughout the US. Her experience includes remote sensing, advanced analytics, internet-of-things application, watershed planning, integrated water resource management, numerical modeling and analysis, surface water quality, and stormwater management. Jamie has combined traditional engineering methods with innovative analysis and implementation strategies to plan, design, and deliver surface water management solutions in an evolving regulatory environment. She is practiced and knowledgeable in permitting requirements and inter-agency coordination for project implementation.

Assignment

Dashboard Advisor

Education

B.S., Civil Engineering – Villanova University, Villanova, PA

M.S., Water Resources and Environmental Engineering – Villanova University, Villanova, PA

Registration

Registered Professional Civil Engineer, Massachusetts, No. 49863

Experience

14 years

Joined Firm

2020

Relevant Expertise

- *Water resources planning and management*
- *Internet of Things applications in water resources*
- *Sensor integration and environmental data collection*
- *Water quality analysis and numerical modeling*
- *Integrated systems modeling*
- *Decision support systems*
- *MS Office and Google for Business*
- *ArcGIS*
- *Seeq*
- *STELLA*
- *Numerical models (SWMM, WASP, HSPF, HydroCAD)*

Early Alert System for Bacteria Pollution in the Merrimack River, Newburyport, MA

Digital Solution Lead. An early alert system was developed to notify river users of the risk of elevated bacteria (*E.coli*) concentrations in a downstream estuary. The alert is based on real time stream flow and precipitation data and upstream combined sewer overflow status. The platform automatically ingests this information and runs an advanced analytical solution to predict the risk of contamination at the estuary in upcoming days using previously studied time of travel and bacterial decay rates. A dashboard shows the result of the calculations and alert status to project stakeholders in real time. At project completion, the alert status will be displayed on a public website for commercial and recreational river users to see to plan their water contact.

Butano State Park Streamflow Enhancement, San Mateo Resource Conservation District, Pescadero, CA

Project Manager. Project aims to restore flows to the Little Butano Creek by introducing alternative supply options for the Butano State Park facility and campground. Includes alternatives analysis to assess the existing water system and evaluate water supply and storage options; full design of chosen alternative; assisting with grant funding applications; leading permit negotiations with State Division of Drinking Water.

Smart Integrated Stormwater Management Systems Study, National Fish and Wildlife Foundation Anacostia River Watershed, Metro Washington, D.C.

Project Manager. Deployed forecast-integrated outlet controls and extensive continuous water quality monitoring at two ponds and one bioretention cell in the Anacostia River Watershed. The purpose of the project is to compare the performance of each management practice with and without the forecast-integrated controls. Jamie was responsible for:

- Design, procurement, installation, and software deployment of the three retrofits
- Overall research study design and analysis
- Management of project subcontractors and the relationships with study partners, including the Metropolitan Washington Council of Governments and the local facility owners.

Green Infrastructure Performance Monitoring, NYCDEP Office of Green Infrastructure Research and Development, New York, NY

Project Manager. Worked with a team of researchers and consultants for NYCDEP to deploy continuous monitoring at over 20 green infrastructure sites in New York City. The purpose of the study is to evaluate the performance of NYCDEP's significant investment in green infrastructure. Jamie was responsible for:

- Managing the data storage and collection provided by the Opti products and platform
- Working closely with external project team members and the client to establish the study scope
- Management of an internal team consisting of operations and software development staff

Merrimack River Watershed Study, USACE, NH and MA

Project Manager. USACE study focusing on management strategies for current water quality issues: bacteria, nutrient enrichment, and dissolved oxygen. Study supports making CSO abatement, TMDL, and NPDES permit decisions based on sound science. Led a team of more than 30 staff and 3 subcontractors through a multi-phase, 7-year study that included:

- Conducting multi-year water quality monitoring program spanning 100+ river miles
- Data management and analysis
- Developing simulation models to explore impacts of CSOs, discharges, nonpoint sources, climate change, etc.
- Extensive stakeholder collaboration – local WWTPs and municipal stormwater managers, water providers, planning groups, NHDES, MassDEP, and US EPA

Stormwater Drain System Monitoring and Modeling Study, Boston Water and Sewer Commission, Boston, MA

Task Leader. The purpose of the study was to quantify the pollutant loading from over 200 of the City of Boston's stormwater outfalls and estimate the potential pollutant reduction attainable using LID and green infrastructure technologies. Jamie served as the task lead for the low impact development and green infrastructure analysis as part of the storm drain modeling study. She developed a scope of work to complete the analysis and led the modeling team to represent various levels of LID implementation throughout the City. This work was completed to satisfy the Boston Water and Sewer Commission's municipal separate storm sewer system (MS4) permit requirements and satisfied an associated consent decree. The scope included narrowing down LID options using available GIS coverages, for example, the square footage of possible green roofs. Then, the potential for LID solutions in specific areas were matched with the subbasins with the highest measured and modeled pollutant loading.

Stormwater Management Incentives Program Pond Retrofit, Philadelphia Water Department, Philadelphia, PA

Project Manager. Philadelphia Water Department (PWD) is a national leader in using LID and green infrastructure to meet their combined sewer overflow mitigation goals. A private, industrial property in West Philadelphia was redeveloped in 2007. Due to operations and maintenance challenges, the site was deemed non-compliant and unable to qualify for stormwater credits against the Stormwater Management Service Charge. Through a PWD grant, the property owner aimed to improve the performance of the basin and create a long-term operations and maintenance plan for the property. The retrofit added capacity to the existing basin, requiring a short construction period, limited earth disturbance, and significant cost savings to PWD as compared to traditional stormwater retrofits. Additionally, this retrofit exceeds PWD's current regulations of detention and slow release, ultimately decreasing the site's impact on combined sewer overflows. Jamie managed the planning and execution of the project, working closely with PWD, the landowner, and several subcontractors to complete the retrofit under budget within 6 months of the project award.

Watershed Study and Basin Management Plan for Urban Stream Restoration, Stamford, CT

Project Engineer. Project Engineer for the development of a Basin Management Plan, based on the results of the monitoring and modeling. The plan identified strategies for watershed restoration, including the expected benefits to water quality and associated costs to the city. The plan included action items for multiple stakeholders and coordination between the City and the regional drinking water provider, who maintains storage reservoirs in the Rippowam River watershed.

Experience Summary

Glenn brings 40 years of environmental expertise and regulatory experience to his role at Brown and Caldwell. Throughout his career he has acted as director of state-wide environmental improvement projects, served as representative on several national committees and drafted regulatory regulations. Prior to joining Brown and Caldwell, Glenn served as the Massachusetts Department of Environmental Protection's Director of Watershed Management where he provided overall management of the Commonwealth's programs to protect environmental resources. His contributions to the State included projects such as the $3 billion Boston Harbor cleanup that revitalized a once unusable body of water, turning it into a destination and local asset. Glenn brings tremendous value to creating, negotiating, and executing a regulatory strategy and has a history of assuring recommendations made to our clients are in concert with developments in upcoming compliance requirements.

Assignment

Regulatory Advisor

Education

B.S., Civil Engineering, Northeastern University, 1973

M.S., Environmental Engineering, Northeastern University, 1982

Experience

40 Years

Joined Firm

2010

Relevant Expertise

- *Regulatory*
- *Water*
- *Wastewater*
- *Storm Water/CSO*
- *Wetlands*

Stormwater Consulting Services On-Call, Brookline, Massachusetts

Project Manager. Oversight for a wide range of stormwater consulting services to the Town. One of the key responsibilities will be developing phosphorus reduction plans that will meet a TMDL requirement to reduce the phosphorus in the Town's stormwater discharges by 50%. Current assignments under the contract include evaluating options for funding the Town's stormwater program, assessing the Town's current stormwater program and capabilities, and providing other compliance assistance.

Fort Point Channel Hydraulic Evaluation and Water Quality Assessment, Boston Water and Sewer Commission, Boston, Massachusetts

Technical Expert. Providing technical expertise on project concerning an effort by Boston to ensure adequate support for a future neighborhood positioned for great economic development. Duties include: compiling historic and existing data to provide a baseline for assessment; performing a sanitary survey to confirm existing infrastructure; identifying measures to minimize the impacts of perpetual discharges from combined sewer overflows (CSOs); verifying that the CSO discharges comply with the Control Plan; and improving the quality of stormwater discharge.

Permitting and Compliance Assistance, NewStream, LLC, Attleboro, Massachusetts

Technical and Regulatory Advisor. This project involves assisting in the negotiation of the settlement of an enforcement action take by the MassDEP and the Attorney Generals office for violation by NewStream of their sewer connection permit and operation of their industrial wastewater treatment facility and assisting in the negotiation with MassDEP of new permit conditions for their permit renewal.

Phosphorus Reduction Study, City of Worcester, Massachusetts

Technical Advisor. The project is to develop a phosphorus reduction plan for Indian Lake. The first phase of the project will be to review and assess historic water quality data for the lake since 1980 and then perform water quality testing. The water will be tested for a number of parameters ranging from alkalinity to total phosphorus. The effort will also include extensive hydrologic modeling and the development of a water quality model for the lake. BC will perform an evaluation of phosphorus reduction options based on the major sources of nutrients in the watershed, including stormwater runoff reduction, and develop a list of "Best Management Procedures" (BMPs) to reduce phosphorous concentrations to the lake.

Bureau of Resource Protection, MassDEP Division of Watershed Management, Massachusetts

Director. Responsibilities included overall management of the Commonwealth's programs to protect environmental resources: the Drinking Water Program, the Wastewater Permitting Program, the Wetlands and Waterways Program, and the Watershed Planning Program. As the Director of Watershed Management, integrated these programs with other agency initiatives and coordinated policy development and setting of priorities for all permitting and enforcement activities. Duties also included developing, interpreting and revising all associated policies and regulations which, in addition to permitting and enforcement, involved the State's water quality standards and TMDL program. Also responsible for developing future priorities, including stormwater management, and addressing nutrients.

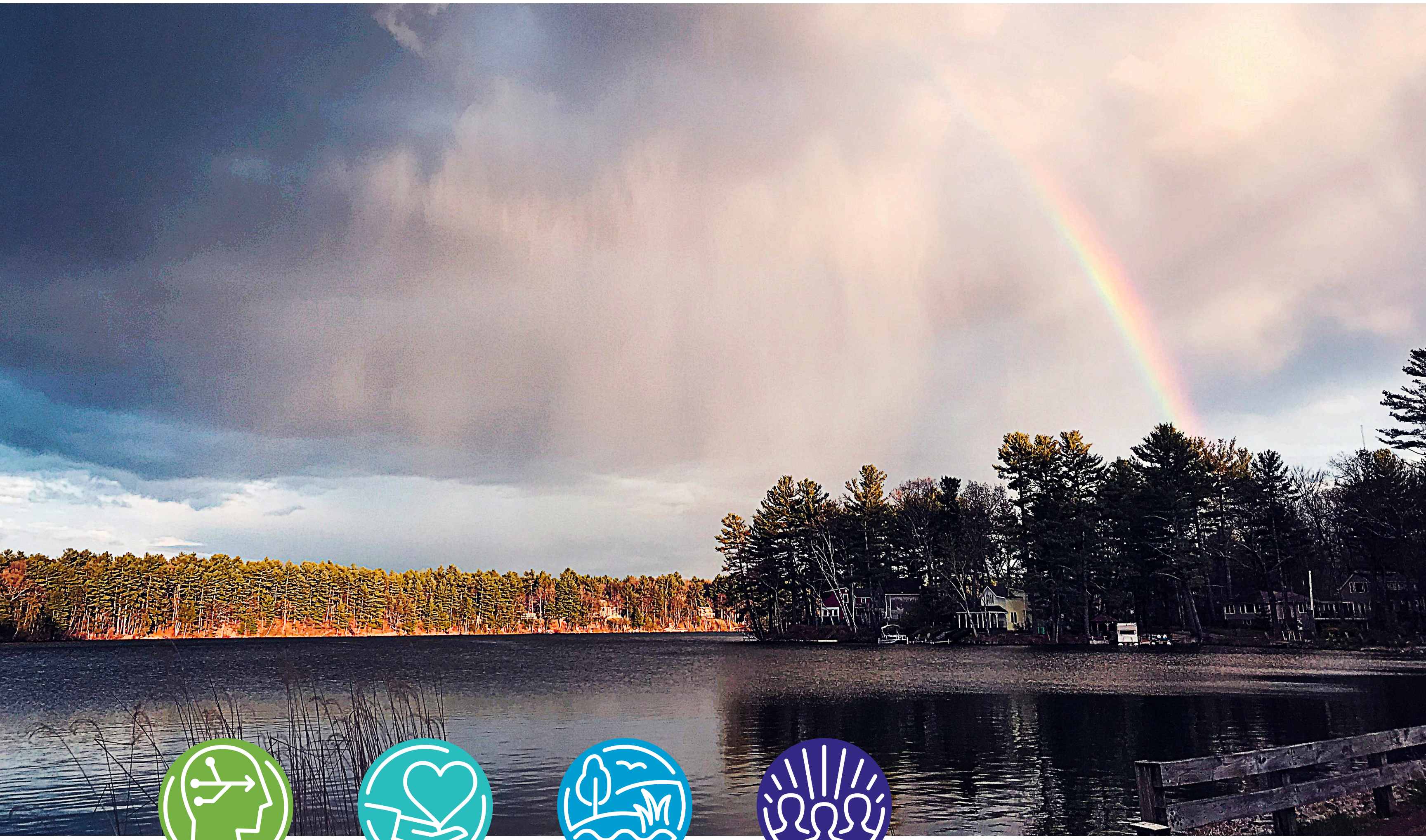
Assistant Commissioner. Had the additional duties of overseeing the management of two other divisions within the Bureau, the Wastewater and Drinking Water State Revolving Loan Fund, and the Bureau's information technology strategies. Managed approximately $7 million in federal operating grant funds.

Bureau of Resource Protection, MassDEP Division of Watershed Management, Massachusetts

Deputy Assistant Commissioner. Responsibilities included management of the diverse technical activities for all municipal assistance programs, such as the State Revolving Loan Fund. These activities include wastewater and water planning alternatives, facility plan reviews, MEPA reviews, and plan/specification reviews. All program initiatives in water pollution control and water supply are coordinated through the position of Deputy Assistant Commissioner for integrated program management and consistency in technical review standards, technical policies, and project management procedures. This position served a key role and is responsible for coordination of municipal assistance activities with the regulatory and enforcement requirements as determined by the Assistant Commissioner of Resource Protection.

Long-Term Control Plan (LTCP) Review, Springfield Water and Sewer Commission, Massachusetts

Technical Advisor. Aided water quality and regulatory issues related to the development of the City of Springfield's CSO LTCP. Work includes reviewing and commenting on the LTCP and projected water quality improvements.



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