CHINA LAKE

CHINA & VASSALBORO, MAINE

WATERSHED-BASED MANAGEMENT PLAN

(2022-2032)

MARCH 2022

CHINA REGION LAKES ALLIANCE CRLA Est. 1995

CHINA LAKE ASSOCIATION China's Pride Keep it Alive Est. 1987

KWD Kennebec Water District

CHINA LAKE
WATERSHED-BASED MANAGEMENT PLAN

Prepared for:

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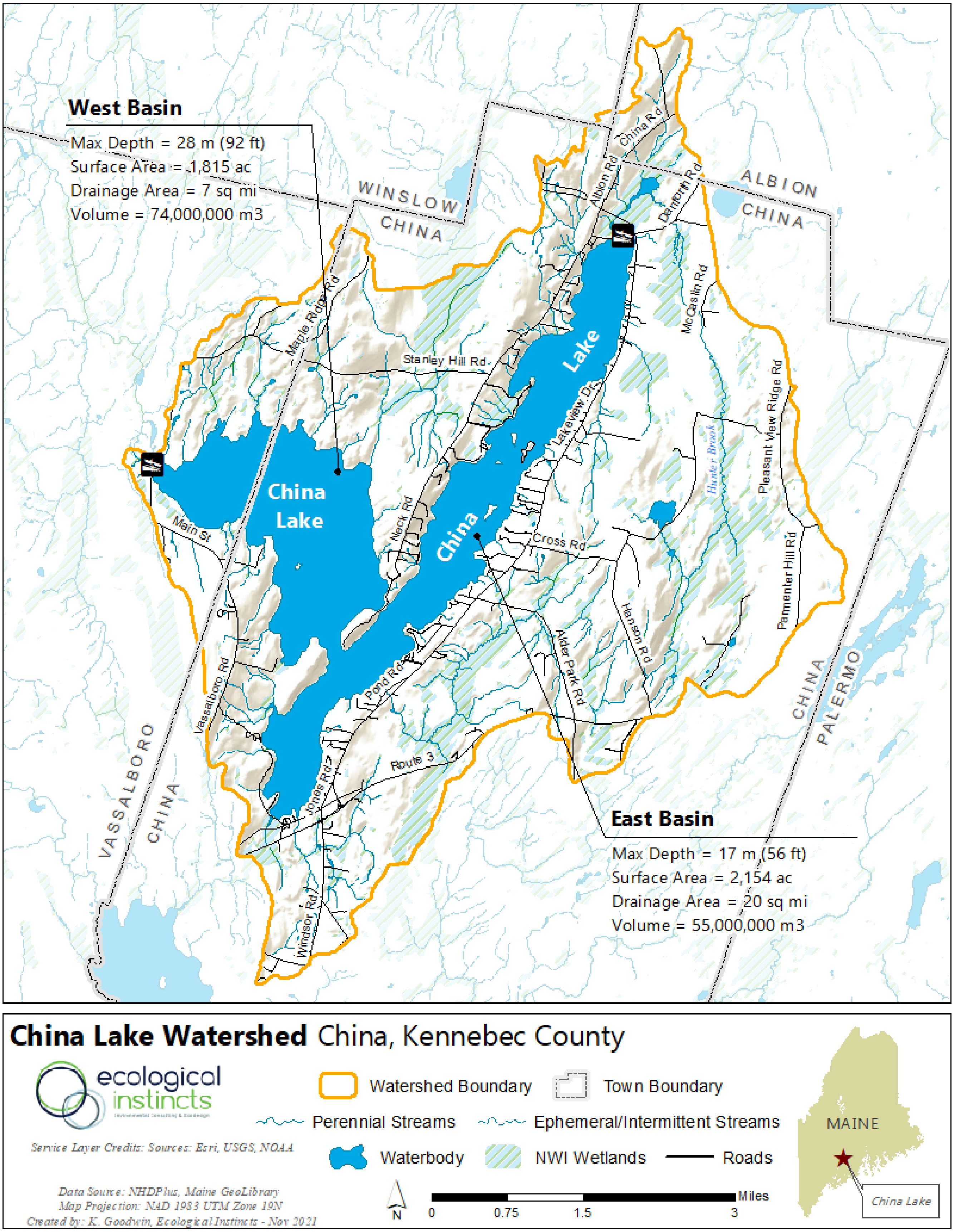
Cover Photo: *Foggy morning on China Lake*
Photo Credit: *China Lake Association*


West Basin
Max Depth = 28 m (92 ft)
Surface Area = 1,815 ac
Drainage Area = 7 sq mi
Volume = 74,000,000 m3
East Basin
Max Depth = 17 m (56 ft)
Surface Area = 2,154 ac
Drainage Area = 20 sq mi
Volume = 55,000,000 m3
China Lake
China Lake
WINSLOW
CHINA
ALBION
CHINA
VASSALBORO
CHINA
CHINA
PALERMO
China Rd
Albion Rd
Danforth Rd
McCaslin Rd
Maple Ridge Rd
Stanley Hill Rd
Lakeview Dr
Pleasant View Ridge Rd
Hunter Brook
Main St
Neck Rd
Cross Rd
Parmenter Hill Rd
Hanson Rd
Alder Park Rd
Vassalboro Rd
Pond Rd
Route 3
Jones Rd
Windsor Rd
China Lake Watershed China, Kennebec County
ecological instincts
Watershed Boundary
Town Boundary
Perennial Streams
Ephemeral/Intermittent Streams
Waterbody
NWI Wetlands
Roads
Service Layer Credits: Sources: Esri, USGS, NOAA
Data Source: NHDPlus, Maine GeoLibrary
Map Projection: NAD 1983 UTM Zone 19N
Created by: K. Goodwin, Ecological Instincts - Nov 2021
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Miles
MAINE
China Lake

Acknowledgments

The following people and organizations were instrumental in helping with the 2022 China Lake Watershed-Based Management Plan:

China Lake Steering Committee

Linda Bacon	Maine Department of Environmental Protection
Robbie Bickford	Kennebec Water District
Eugene Field	Town of Vassalboro
Dale Finseth	Kennebec County SWCD
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Watershed Modeling Review and Internal Loading Analysis: Dr. Ken Wagner, WRS, Inc.

Commonly Used Acronyms

The following are used throughout this document:

CLA	China Lake Association
CRLA	China Region Lakes Alliance
KWD	Kennebec Water District
BMP	Best Management Practice
Chl-a	Chlorophyll-a
DO	Dissolved Oxygen
LLRM	Lake Loading Response Model
Maine DEP	Maine Department of Environmental Protection
NPS	Nonpoint Source (pollution)
NRCS	Natural Resources Conservation Service
ppb	Parts Per Billion
ppm	Parts Per Million
SDT	Secchi Disk Transparency
TAC	Technical Advisory Committee
TP / P	Total Phosphorus / Phosphorus
US EPA	United States Environmental Protection Agency
WBMP	Watershed-Based Management Plan

CHINA LAKE WATERSHED-BASED MANAGEMENT PLAN (2022-2032)

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Executive Summary

PURPOSE

The China Lake Watershed-Based Management Plan (WBMP) describes the water quality conditions, watershed characteristics, and steps that can be taken to restore water quality in China Lake over the next 10 years. The plan is estimated to cost $3.16 million to complete through state, federal and local resources over this time period. The plan outlines management strategies and a planning schedule (2022 – 2032), establishes water quality goals and objectives, and describes actions needed to achieve these goals. This includes strategies to:

1. Increase efforts to **reduce the external phosphorus load** by addressing existing nonpoint source (NPS) pollution throughout the watershed and limit new sources of phosphorus from future development and effects of climate change;
2. Significantly **reduce the internal phosphorus load** through inactivation of phosphorus in bottom sediments;
3. **Prevent new sources** of nonpoint source pollution from getting into the lake through municipal planning and enforcement, land conservation, and climate change adaptation;
4. **Raise public awareness** about lake restoration strategies to increase participation in planning efforts among watershed residents;
5. **Build local capacity** through partnership building and fundraising activities;
6. **Monitor and assess improvements** in China Lake's water quality over time. This includes annual baseline monitoring in the lake, stream monitoring, plankton monitoring, and monitoring of harmful algal blooms.

THE GOAL

A team of scientists and local stakeholders worked collaboratively over a two-year period to set a revised water quality goal for China Lake that would help restore water quality and prevent the future occurrence of nuisance algal blooms. Findings of this analysis show that reducing P from the watershed load alone will not achieve desired water quality conditions due to the dominant influence of P loading from the lake's sediments.

What P load reductions are needed to meet the goal?

Reducing the P load by 712 kg/yr in the east basin, and by 270 kg/yr in the west basin is expected to reduce the average in-lake total P concentration by 8 ppb in the east basin (goal of 10 ppb), and by 2 ppb in the west basin (goal 13 ppb). Additional water quality benefits include an increase in summer water clarity readings by 1.4 m in the east basin, and 0.4 m in the west basin, and a reduction in the probability of recurring annual algal blooms from approximately 27% to 1% in the east basin, and from 13% to 5% in the west basin.

WATER QUALITY RESTORATION GOAL

China Lake has a stable or improving water quality trend and is free of nuisance algal blooms.

In-Lake Phosphorus (East Basin) = 10 ppb

In-Lake Phosphorus (West Basin) = 13 ppb

"P" REDUCTIONS NEEDED

East Basin- 712 kg/yr
656 kg/yr internal load
56 kg/yr external load

West Basin- 270 kg/yr
249 kg/yr east basin reductions;
21 kg/yr external load

Timeframe: 2022- 2032

Projects: Erosion Control BMPs LakeSmart, Alum treatment (East Basin only)

An in-lake P concentration of 10 ppb in the east basin, and 13 ppb in the west basin is a desirable target to restore water quality and is achievable by addressing both the external (watershed) load by addressing runoff from developed properties (56 kg/yr east basin and 21 kg/yr west basin, plus an additional 20 kg/yr reduction in the west basin as a result of addressing the external load in the east basin), and addressing the internal load through P inactivation (712 kg/yr east basin plus 229 kg/yr reduction in the west basin as a direct result of addressing the internal load in the east basin).

The influence of the P load from the east basin on the water quality of the west basin revealed from the watershed modeling is an important consideration for the 10-year watershed plan. Ultimately, anything that is done to reduce P inputs from reaching the east basin will help improve water quality in the west basin. By managing land in the watershed to minimize runoff and improve its quality, we can reduce NPS inputs that are causing algal blooms and contributing the most to the sediment reserves in the lake that ultimately provide the seasonal internal load.

The influence of the P load from the east basin on the water quality of the west basin is an important outcome of the watershed plan; **any actions taken to reduce P inputs in the east basin will ultimately help improve water quality in the west basin.**

What actions are needed to achieve the goal?

The China Lake WBMP provides 113 individual actions within six core planning categories to achieve the water quality goal. This includes a renewed effort to address NPS pollution in the watershed and to inactivate P in the sediments of the east basin to reduce the internal P load. The internal loading analysis for China Lake weighed the pros and cons of different management options for reducing in-lake P concentrations (e.g., dredging, oxygenation, drawdown, and P inactivation). These recommendations are outlined in the plan which was developed with input from both the Technical Advisory Committee (TAC) and the Watershed Plan Steering Committee.

The action plan provides current, science-based solutions for restoring water quality in China Lake while simultaneously promoting communication between residents, watershed towns, and watershed groups including CLA, CRLA, and KWD. The action plan outlines pollution reduction targets, responsible parties, potential funding sources, approximate costs, and an implementation schedule for each task within each of the five categories.

How will the plan be funded?

A sustainable funding strategy is needed within the first year that includes diverse sources of funding to carry out planned implementation activities. A large portion of the estimated cost of implementing this plan will be needed in the first 4 - 5 years for the aluminum treatment. The combined resources of state, federal, and local grants, and contributions from watershed towns, private landowners, and lake association members expect to be leveraged to support watershed implementation projects that address both the external load (watershed) and internal (sediment) phosphorus load in the lake. The funding strategy should be revisited on an annual basis by an engaged steering committee.

The action plan (Sections 7 & 8) is divided into six major objectives. The estimated load reductions and estimated costs to complete the work are presented below:

Planning Objective	Planning Action (2022-2032)	P Load Reduction Target	Cost
1	**Reduce the External (Watershed) P Load** (NPS sites, LakeSmart, agriculture)	56 kg/yr east basin 270 kg/yr west basin[1]	$1,175,000
2	**Reduce the Internal (Sediment) P Load** (Aluminum treatment, east basin only)	656 kg/yr east basin	$1,441,500

[1] Estimated reductions in the west basin of China Lake equal 270 kg/yr. Only 21 kg/yr is expected from the direct watershed, whereas a 229 kg/yr reduction is expected as a direct result of reducing the internal load in the east basin, as well as an additional 20 kg/yr by addressing the external load in the east basin.

Planning Objective	Planning Action (2022-2032)	P Load Reduction Target	Cost
3	**Prevent New Sources of NPS Pollution** (Road maintenance, land conservation, municipal planning & enforcement, climate change adaptation)	n/a	$55,500
4	**Education & Outreach** (Outreach plan, welcome packets, signage, aluminum treatment education, buffer campaign, agricultural outreach, workshops)	n/a	$62,350
5	**Build Local Capacity** (Funding plan, steering committee, grant writing, relationship building & partnerships)	n/a	$169,000
6	**Long-Term Monitoring & Assessment** (Baseline monitoring, sediment sampling & analysis, aluminum treatment monitoring plan, alewife monitoring, stream monitoring, plankton monitoring, NPS and septic systems, invasive plants & Harmful Algal Blooms)	n/a	$258,400
	TOTAL	**982 kg/yr**	**$3,161,750**

How will success be measured?

Environmental, social, and programmatic milestones were developed to reflect how well implementation activities are working and provide a means by which to track progress toward the established goals (Section 9). The steering committee will review the milestones on an annual basis, at minimum, to determine if progress is being made, and then determine if the watershed plan needs to be revised if the targets are not being met.

THE LAKE & WATERSHED

China Lake (MIDAS 5448)[2] is a 3,939-acre[3] lake (Class GPA)[4] located in China and Vassalboro, Maine. The surface area of the east basin is 339 acres larger than the west basin. The lake is a naturally formed dual-basin waterbody with an east and west basin that was enlarged in 1969 by raising the height of the dam at Outlet Stream. China Lake serves as the drinking water supply for the municipalities of Waterville, Winslow, Fairfield, Benton, and Vassalboro.

[2] The unique 4-digit code assigned to a lake.

[3] Based on 2021 bathymetric map update.

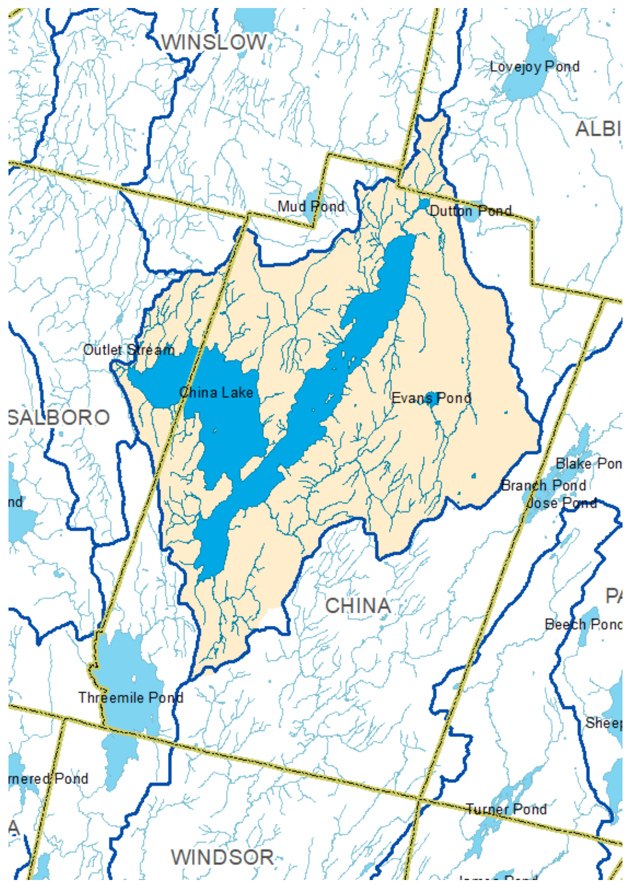
[4] Defined by MRSA Title 38 §465-A, Maine Standards for Classification of Lakes and Ponds: Class GPA is the sole classification of Great Ponds (>10 acres) and natural lakes and ponds <10 acres in size.

The watershed is located within the towns of China (89%), Vassalboro (9%), Albion (2%), and Winslow (0.1%) in Kennebec County, Maine and drains approximately 27 square miles of the surrounding landscape. It has a maximum depth of 28 m (92 ft), with the deepest location in the west basin, and an average depth of 8 m (25 ft). The west basin has a flushing rate of 0.64 times per year, and the east basin has a flushing rate of 0.68 times per year. The elevation of the lake is 194 ft above sea level, with the highest elevation in the watershed on Barmeter Hill in the northern section of the watershed, at 646 ft.

The narrows between China Lake's east and west basins. (Photo Credit: CLA)

The watershed is drained by multiple perennial tributaries including Ward Brook, Jones Brook, Starkey Brook, Hunter Brook, and Muldoon Stream. In addition to these perennial streams, numerous intermittent streams and the direct shoreline drainage areas contribute to the flow of water from the watershed into the lake.

Water flows north to south through the east basin into the west basin. Water exits the lake through the west basin via the dam on Outlet Stream on the west shore of the west basin. The outlet dam, managed by the Town of Vassalboro, controls the lake's water level. Each fall, the lake is drawn down by 2.5 ft to allow for surface water containing high concentrations of phosphorus to leave the lake. Outlet Stream flows into the Sebasticook River, which empties into the Kennebec River and eventually into the Atlantic Ocean.



Map of the China Lake watershed (yellow), adjacent waterbodies, and surrounding towns.

What is the current status of development in the watershed?

Development is limited on the shoreline of the west basin as a result of an approximately 200 ft wide shoreline buffer owned and managed by the Kennebec Water District (KWD) for source water protection. However, the shores of the east basin are highly developed. According to available records in the Town of China, there are 529 shoreline lots, 452 of which are developed. Of the developed lots, 61% are seasonal and 39% are used year-round.[5]

A recent land cover analysis for China Lake indicates that forestland makes up the majority of the watershed (56%). Developed land (e.g., residential, commercial, roads) accounts for approximately 13% of the land area in the watershed, followed by agriculture at 12%. Wetlands account for the remaining 19% of the watershed area. The largest shift in land cover in the watershed over the past 15 – 20 years is an increase in low- and mid-density residential and commercial development throughout the watershed.

Roads encompass 84 acres of land in the watershed, the majority (61%) of which are unpaved gravel roads that service high-density residential development along the shoreline of the east basin. The remaining 39% of roads are paved, including Lakeview Drive (Rt. 202) that runs along the eastern shore of the east basin, Vassalboro Road (Rt. 32), running through the southwest corner of the watershed, and Neck Road that runs parallel to the west shore of the east basin. Commercial development is concentrated near the southern tip of the watershed near the intersection of Route 3 and Route 202, and near China Village at the northern tip of the watershed.

THE PROBLEM

China Lake has a history of water quality problems including excess P loading from the watershed, lack of dissolved oxygen at the bottom of the lake (anoxia), internal recycling of P from bottom sediments, and recurring annual algal blooms dating back to 1983, when the lake experienced a sudden decline in water quality and its first algal bloom, and correspondingly low Secchi disk transparency (SDT) readings less than 2 m. This change in water quality is the result of a complex set of conditions that is not fully understood but is related to changes in land use in the watershed, referred to as the "China Lake Syndrome". Specifically, these changes are related to decades of runoff from agricultural land in the watershed that contributed to the build-up of phosphorus in the sediment, a dramatic increase in new development in the 1970s that delivered an increased load of stormwater runoff to the lake, and a release of phosphorus from the sediment

An algal bloom on China Lake.
(Photo credit: Maine DEP)

[5] Personal communication, Janet Preston, Town of China Selectman. Email communication June 2, 2021

that progressed into an annual cycle of increased oxygen demand during the summer and the recurrent release of phosphorus from the sediments that triggered the algal blooms.

Subsequently, China Lake was listed as impaired due to non-attainment of the state's GPA water quality standards for primary contact recreation and occasional nuisance algal blooms by the Maine Department of Environmental Protection (DEP) in 1998. In addition to being impaired, China Lake is also on the list of lakes most at risk from new development. Lakes on this list include, but are not limited to, public water supplies, lakes not meeting state water quality standards, lakes with potential for internal phosphorus recycling, and where new, incompletely mitigated development may prevent successful restoration of the lake in situations where lakes have a history of severe algal blooms. Water quality is an especial concern in China Lake since it serves as a drinking water source for several municipalities.

Maine GPA Statutory Water Quality Standard: All Maine lakes are free of culturally induced algal blooms and have a stable or decreasing trophic state, which translates into stable or improving water & habitat quality.

Water quality data have been collected at China Lake at three stations beginning in 1970, spanning 51 years, in cooperation with Maine DEP, KWD, and Lake Stewards of Maine. This long-term data set, along with recent, more intensive monitoring and assessment of water quality in 2020, was used to examine both long- and short-term water quality trends. The trend analysis included SDT, total phosphorus (TP), chlorophyll-a (Chl-a), dissolved oxygen, temperature, conductivity, alkalinity, color, pH, and minimum anoxic depth (MAD).

What are the trends?

Long-term water quality trends in China Lake show a decline in water clarity in both the east and west basin, an increase in Chl-a in the east basin, and an increase in MAD in both the east and west basin. Water clarity declined slowly from 1970 through 2000 with a loss of 3 m of clarity over the 30-year period, then leveled off to around 3 m for the last 20 years. Minimum SDT has fallen to less than 2 m in 32 of the last 38 years.

Even more concerning is that the area and volume of the lake experiencing anoxia is increasing, with anoxia at depths as shallow as 6 - 7 m in the east basin. Roughly 33% of the lake area and 55% of the lake volume is in water deeper than 7 m.

CHINA LAKE
WATER QUALITY TRENDS

LONG-TERM (1970-2020)

→ Decline in water clarity in the east and west basins

→ Increase in Chlorophyll-a in the southeast basin

→ Increase Minimum Anoxic Depth in the west and southeast basins

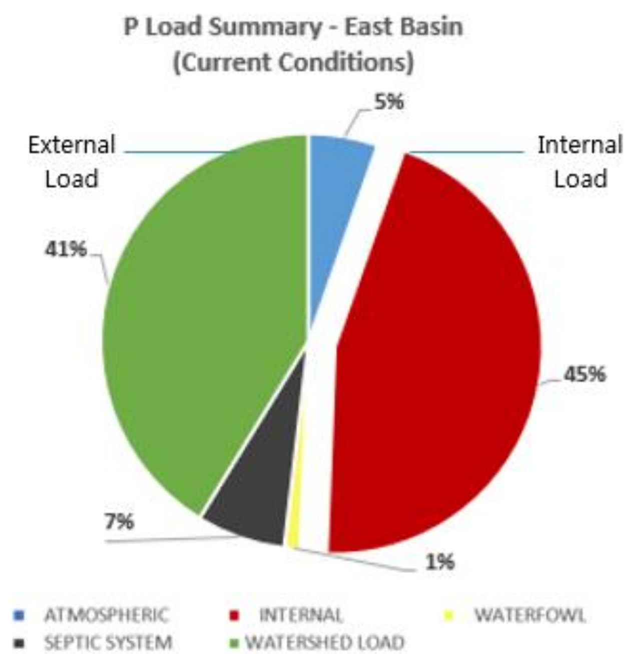
SHORT-TERM (2011-2020)

→ Decrease in total phosphorus in the west basin

→ Decrease in Chlorophyll-a in the west basin

The increased exposure of sediments to low oxygen and corresponding release of phosphorus (P) from the sediment is a major driver for recurring annual algal blooms. However, short-term trends (last 10 years) indicate a decrease in P and Chl-a in the west basin compared to historical concentrations which may indicate response to watershed improvements over the past decade.

Where are the primary sources of P?



Watershed modeling was used to determine the sources and relative contribution of P loading to China Lake. The model estimates a total P load of 1,612 kg/yr to the east basin of China Lake annually, and 1,611 kg/yr to the west basin. Internal loading is the largest contributor of P to the east basin of China Lake (46%), followed by the watershed load (41%). Septic systems make up 7% of the load with atmospheric deposition and waterfowl accounting for an estimated 5% and 1% of the remaining load, respectively. In the west basin, internal loading is also the largest contributor of P (40%), followed by the P load from the east basin (35%), and the direct watershed load from the land draining to the west basin (19%). P loading from septic systems is minimal due to limited development (<1%), while atmospheric deposition and waterfowl account for the remaining 5% and 1% of the P load to the west basin, respectively.

Nonpoint Source (NPS) Pollution: Nonpoint source pollution includes diffuse sources of pollution carried in overland flow to lakes, streams, and other waterbodies via stormwater runoff. NPS may include sediment from erosion sites, fertilizers, pet waste, and road salt among other pollutants.

Why do we need to address NPS pollution?

Reducing nonpoint source pollution (NPS), stemming from development in the watershed, is essential for minimizing current known P inputs and maximizing benefits of reducing the internal sediment load. Developed land (residential and commercial development, roads, and agriculture) accounts for approximately 25% of the watershed area but contributes 70% of the P load from the watershed.

Developed land (buildings, driveways, roads, and agriculture) **accounts for just 25% of the watershed area yet makes up 70% of the total P load** from the watershed.

The density of development, and proximity of the developed land to the lake and tributary streams are significant factors in the amount of P being exported on an annual basis. A recent watershed survey identified 161 sites in the watershed that are contributing P in stormwater runoff (the majority on residential properties on the shoreline).

The action plan includes addressing 79 high- and medium-impact NPS sites, reducing the P load from agricultural land by 25%, and taking steps to assess and mitigate impacts of 318 septic systems located on sensitive soils within 150 ft. of China Lake or a tributary stream that could result in short-circuiting of the leach field and be contributing excess P to the lake via groundwater.

A gravel road contributing NPS pollution to China Lake. (Photo credit: CLA)

Site-specific actions to infiltrate and treat stormwater runoff throughout the watershed will reduce P loading from developed areas. A well-buffered shoreline that mimics natural conditions and consists of a mix of trees, shrubs, groundcovers, and duff to filter and absorb runoff from development may result in less P reaching the lake compared to a highly-impacted non-shoreline property connected to the lake via the vast network of streams and ditches in the watershed. Therefore, it is important that every property owner do their part to prevent runoff.

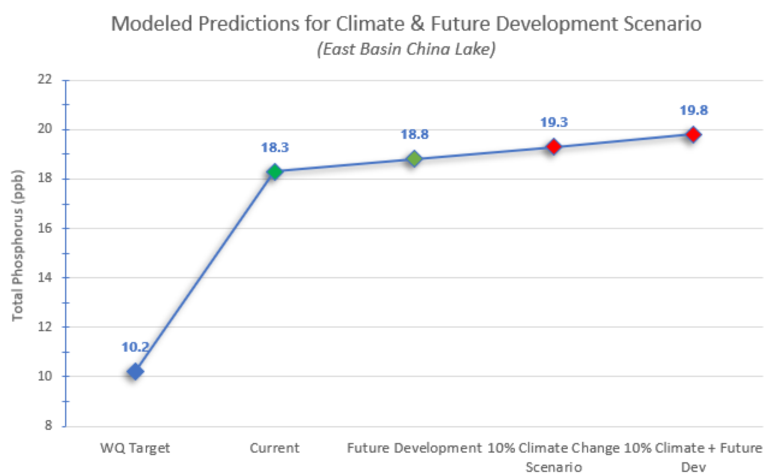
Why do we need to address the internal load?

Sediment testing results from 30 samples collected throughout the lake indicate that conditions in China Lake favor internal loading that contributes to the water quality impairment and recurrent nuisance algal blooms. Because the total P load to China Lake is dominated by internal P loading, addressing the watershed load alone is not enough to restore water quality in China Lake. The trend of increasing area of anoxia, and climate change will only result in an increase in internal loading if the problem is not addressed. While the 10-year plan focuses on addressing the internal P load in the east basin, long-term management of the P load in the sediment of the west basin will also need to be considered in order to minimize effects of bottom-dwelling cyanobacteria.

Addressing the watershed load alone is not adequate for restoring water quality in China Lake but can prevent new sources of P from getting into the lake and prolong the effectiveness of management actions to inactivate P in the sediments.

What about future development & climate change?

In addition to new development on the shoreline, population growth (and an increase in the developed land area in watershed) is likely to result in the conversion of small seasonal camps to larger year-round homes on the shoreline.



New development on the remaining developable shorefront lots, as well as new residential and commercial development and roads within the watershed all lead to new sources of P to China Lake if not factored into planning and development standards for new construction. Conservatively, future development in the watershed could result in an additional 50 kg/yr increase in P in the east basin, and 68 kg/yr in the west basin (18 kg/yr as a result of increased development in the east basin).

The primary climate change impacts to lakes include variation in both precipitation and temperature. Higher (air and water) temperatures lead to increased algal growth, greater oxygen demand due to increased decomposition rates, lower oxygen near the lake bottom, and increased P release from surficial sediments where iron is the major P binder (internal loading). Warmer water temperatures and increased P also favor invasive species, cyanobacteria, and harmful algal blooms (HABs) that produce toxins harmful to humans and wildlife. Movement toward bigger and more frequent storms not only exacerbates the internal loading problem but presents a big challenge for watershed management efforts as more intense rainfall will increase the amount of nutrient transport to the lake from the watershed via stormwater runoff. Climate change is estimated to increase the P load to China Lake by an additional 71 and 65 kg/yr in the east and west basins, respectively. **When climate change impacts are combined with impacts from future development, in-lake TP concentrations may increase by 1.5 and 1.7 ppb in the east and west basins, respectively.** Taking steps to proactively offset the potential impacts to water quality from both new development and climate change and addressing current sources of P loading will be needed to restore China Lake.

ADMINISTERING THE PLAN

The China Lake WBMP provides a framework for restoring the water quality in China Lake so that it no longer supports nuisance algal blooms and so that it meets state water quality standards. The plan will be led by the China Lake Association with guidance and support from a watershed steering committee, China Region Lakes Alliance, Kennebec Water District, the towns of China and Vassalboro, Kennebec County Soil & Water Conservation District, local businesses, and landowners. The formation of subcommittees that focus on the six main watershed action categories will result in more efficient implementation of the plan. The steering committee will need to communicate regularly, especially during the first 1-3 years to get the plan off on solid footing.

INCORPORATING US EPA'S 9 ELEMENTS

The US EPA has identified nine key elements that are critical for achieving improvements in water quality. An approved nine-element plan is a prerequisite for future federally funded work in impaired watersheds. The nine elements are designed to provide a robust framework by which to restore waters impaired by NPS pollution through characterization of the watershed, partnership building, development of an implementation plan (actions, schedule, costs), goal setting, and monitoring. The nine elements can be found in the following locations within the China Lake WBMP.

Planning Element	WBMP Section	Description
a) Identify Causes & Sources	Section 1	Highlights current programs and research that have helped frame the water quality problem.
	Section 2	Describes the characteristics of the lake and watershed that contribute to the changes in water quality.
	Section 3	Provides an analysis of water quality data to describe changes in water quality.
	Section 4	Provides an estimate of watershed loading.
	Section 7 & Appendix I	Summarizes NPS sites in the China Lake watershed.
b) Estimated P Load Reductions expected from Planned Management Measures	Sections 4 & 6	Provides an overview of water quality and phosphorus (P) reduction targets to reduce annual P loading to China Lake from both internal and external sources over the next ten years and methods used to estimate P reductions. These reductions apply to both in-lake P inactivation (aluminum treatment) and watershed loading - applying best management practices (BMPs) to documented NPS sites in the watershed.

Planning Element	WBMP Section	Description
c) Description of Management Measures	Sections 6, 7 and 8	Identifies ways to achieve the estimated P load reduction and reach water quality targets described in (g) below. The action plan covers six major topic areas that focus on NPS pollution, including: mitigating the external P load, addressing the internal load in the east basin, preventing new sources of P, education and outreach, building local capacity, and conducting long-term monitoring and assessment.
d) Estimate of Technical and Financial Assistance	Sections 7 - 10	Provides a description of the associated costs, sources of funding, and organizations responsible for plan implementation. The estimated cost to address NPS pollution and reduce P loading to China Lake is estimated at $3,151,750 over the next ten years.
e) Information & Education & Outreach	Section 7	Describes how the education and outreach component of the plan should be implemented to enhance public understanding of the project. This includes leadership from watershed partners to promote lake/watershed stewardship.
f) Schedule for Addressing the NPS Management Measures	Section 7 & 8	Provides a list of strategies and a set schedule that defines the timeline for each action. The schedule should be reviewed and adjusted by the steering committee on an annual basis.
g) Description of Interim Measurable Milestones	Section 9 (Tables 17 & 18)	Lists milestones that measure implementation success that will be tracked annually. Using milestones and benchmarks to measure progress makes the plan relevant and helps promote implementation of action items. The milestones are broken down into two different categories: programmatic and social.
h) Set of criteria	Section 9 (Tables 15 & 16)	Provides a list of criteria and benchmarks for determining whether load reductions are being achieved over time, and if substantial progress is being made towards water quality objectives. Environmental milestones are a direct measure of environmental conditions, such as improvement in water clarity. These benchmarks will help determine whether this plan needs to be revised.
i) Monitoring Component	Section 8	Provides a description of planned monitoring activities for China Lake, the results of which can be used to evaluate the effectiveness of implementation efforts over time as measured against the criteria in (h) above.

1. Background

China Lake, located in China and Vassalboro, Maine (Figure 1), has a history of water quality problems including excess P loading from the watershed, lack of dissolved oxygen at the bottom of the lake (anoxia), internal recycling of P from bottom sediments, and recurring annual algal blooms dating back to 1983, when the lake experienced a sudden decline in water quality and the onset of yearly algal blooms (Kleinschmidt, 2012), and correspondingly low Secchi disk transparency (SDT) readings less than 2 m. This change in water quality was shown to be caused by nonpoint source (NPS) pollution from development in the watershed. Water quality is an especial concern in China Lake since it serves as a drinking water source for the municipalities of Waterville, Winslow, Fairfield, Benton, and Vassalboro. Since the first algal bloom on China Lake in 1983, numerous remediation efforts focused on reducing NPS pollution have been conducted on the lake by local organizations and with the support of state and federal funding. The lake has also been extensively monitored over this time period by the Maine Department of Environmental Protecton (DEP) and Kennebec Water District (KWD).

Despite remediation efforts and some evidence of recent improvements in a few water quality parameters, the pattern of summertime anoxia in the deepest areas of the lake, release of P from sediments into the water column, and the resulting increase in algal productivity is still occuring 40 years later. In fact, a recent water qualty trends analysis indicates that water quality has generally worsened since the onset of algal blooms. This includes a long-term worsening of the primary trophic state criteria including water clarity and Chlorophyll-a.

Even more concerning is that the area and volume of the lake experiencing anoxia is growing. The increased exposure of sediments to low oxygen and corresponding release of P from the sediment is a major driver for recurring annual algal blooms.

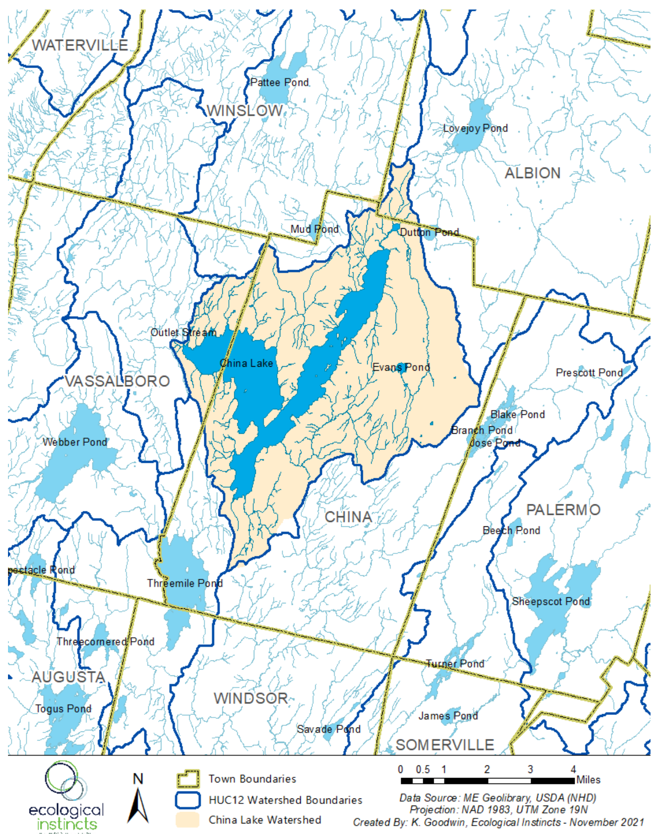


Figure 1. Map of the China Lake direct watershed (yellow) and adjacent watersheds.

China Lake was listed as impaired due to non-attainment of the state's GPA water quality standards for primary contact recreation and occasional nuisance algal blooms by the Maine Department of Environmental Protection (DEP) in 1998. A Total Maximum Daily Load (TMDL) was developed in 2001 which set an in-lake TP target of 15 ppb. This was followed by a Watershed-Based Management Plan (WBMP) developed by Kennebec County Soil & Water Conservation District (KCSWCD), KWD, and China Lake Association (CLA) in 2008. This 2022 WBMP provides updated recommendations and develops a solid foundation for lake and watershed restoration at China Lake over the next 10 years.

Development of the China Lake WBMP included a water quality analysis, an internal loading analysis, sediment analysis, land cover update, watershed nutrient modeling, soil vulnerability analysis, development of watershed maps, future development and climate scenarios, and a public webinar.

Since P is the nutrient driving declining water quality trends in China Lake, it was used as the primary parameter for setting the water quality goal for the next 10-year planning period.

PURPOSE

The China Lake Watershed-Based Management Plan (WBMP) describes the water quality conditions, watershed characteristics, and steps that can be taken to restore water quality in China Lake over the next 10 years. The plan is estimated to cost $3.16 million to complete through state, federal and local contributions over this time period. The plan outlines management strategies and a planning schedule (2022 – 2032), establishes water quality goals and objectives, and describes actions needed to achieve these goals. This includes strategies to:

1. Increase efforts to **reduce the external phosphorus load** by addressing existing nonpoint source (NPS) pollution throughout the watershed and limit new sources of phosphorus from future development and effects of climate change;
2. Significantly **reduce the internal phosphorus load** through inactivation of phosphorus in bottom sediments;
3. **Prevent new sources** of nonpoint source pollution from getting into the lake through municipal planning and enforcement, land conservation, and climate change adaptation;
4. **Raise public awareness** about lake restoration strategies to increase participation in planning efforts among watershed residents;
5. **Build local capacity** through partnership building and fundraising activities;
6. **Monitor and assess improvements** in China Lake's water quality over time. This includes annual baseline monitoring in the lake, stream monitoring, plankton monitoring, and monitoring of harmful algal blooms.

This plan was developed to satisfy the Nonpoint Source Program and Grants Guidelines for States and Territories (USEPA, 2013), which requires nine-element plans be completed prior to implementing impaired watershed projects funded with Clean Water Act section 319 watershed project funds. Multiple state, local and federal resources are expected to be leveraged to implement this plan. Information on available financial resources, such as specific grant requirements and project eligibility, will be explored and determined in the future.

STATEMENT OF GOAL

The goal of this plan is to restore the water quality of China Lake so that it meets state water quality standards and no longer supports recurring nuisance algal blooms. Planning recommendations include reducing the internal P load by 90% in the east basin (656 kg/yr) and the watershed P load by 6% (56 kg/yr) in the east basin, and by 4% (41 kg/yr) in the west basin. An additional load reduction of 229 kg/yr is expected in the west basin following the reduction of the internal load in the east basin. This would result in a decrease in the P load in China Lake by 30% or 982 kg/yr[6] thereby reducing the average annual in-lake P concentration in the east basin by 8.1 ppb, reducing the probability of summertime algal blooms from approximately 27% to 1%,[7] and improving average annual water clarity by 1.4 m over the next 10 years. In the west basin, P reductions would reduce the in-lake P concentration by 2.5 ppb, reduce the probability of summertime algal blooms from approximately 13% to 5%, and improve average annual water clarity by 1.6 m.

PLANNING GOALS

(2022-2032)

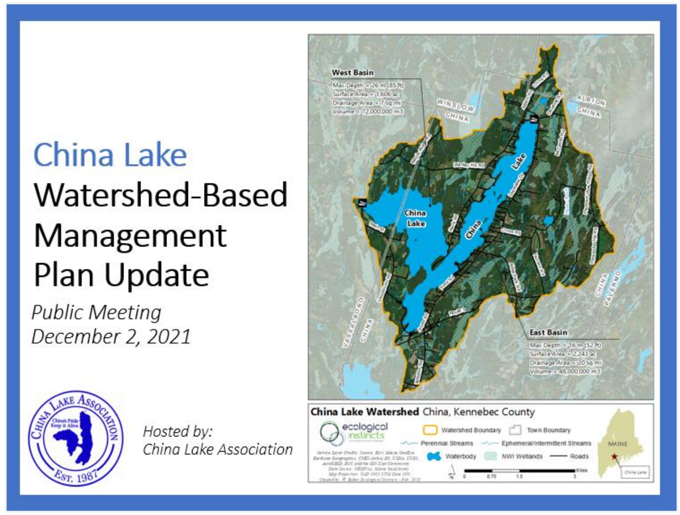
1. **REDUCE P IN RUNOFF FROM THE WATERSHED**
   56 KG/YR E. BASIN
   41 KG/YR W. BASIN (DIRECT)
   229 KG/YR W. BASIN (INDIRECT E. BASIN)
2. **REDUCE INTERNAL P RECYCLING FROM BOTTOM SEDIMENTS**
   656 KG/YR E. BASIN
3. **MONITOR & ASSESS WATER QUALITY**

[6] Loading estimates and estimated P reductions are based on a combination of methods including Region 5, and the DEP Relational Method, and LLRM estimates based on anoxia at depths > 7m and P inactivation for all depths greater than 8 m in the east basin. This represents a conservative approach to treatment as it addresses the highest expected loading.

[7] 1% is based on predictions from the LLRM based on the percent of time chlorophyll-a concentrations are predicted to be >8 ppb when TP concentrations are at 10 ppb.

PLAN DEVELOPMENT & COMMUNITY PARTICIPATION

This plan was developed with input from a diverse group of local stakeholders and scientists over a two-year period. Recommendations are the result of multiple Technical Advisory Committee (TAC), Steering Committee, and subcommittee meetings, as well as conference calls between professional consultants, KCSWCD, KWD, CLA, CRLA, the towns of China and Vassalboro, Colby College, Department of Marine Resources (DMR), and Maine DEP. This included three Steering Committee meetings and three TAC meetings held between May 27, 2020, and November 15, 2021.



An interactive public webinar was attended by 46 stakeholders in December 2021 to provide information about the watershed plan update.

An interactive online public meeting/webinar was held on December 2, 2021, to present the China Lake WBMP.[8] The meeting, attended by 46 stakeholders via Zoom webinar, provided a summary of the two-year planning process and outlined actions needed over the next 10 years for preventing recurrent annual algal blooms in China Lake. A link to the recording from the public meeting and a write-up of the Zoom Question & Answer Session is included in Appendix A.

WATERSHED PROJECTS, PROGRAMS & RESEARCH

China Lake has been the center of ongoing scientific research and remediation as a result of many years of private/public partnerships involving numerous watershed partners effectively working together to improve water quality in China Lake. The list of projects below represents watershed activities that have taken place since the development of the China Lake Total Maximum Daily Load in 2001.

(2001) China Lake Total Maximum Daily Load (TMDL). A report was prepared by the Maine DEP in 2001, which set a target in-lake P concentration of 15 ppb and called for a reduction of **1,075 kg** P/yr (27% reduction) to improve water quality. The report estimated internal recycling of P as 48% of

[8] The meeting was held remotely due to the ongoing COVID-19 pandemic and to increase participation from seasonal residents.

the total load as a result of anoxia during the summer, and external loading from watershed sources as 52% of the total load.

(2005) A Watershed Analysis of China Lake. In 2005 a watershed analysis of China Lake was completed by the Colby College Environmental Assessment Team. The analysis included an assessment of water quality in the lake, a review of land cover and land use patterns in the watershed, modeling the effects of future land use changes on phosphorus loading, and presents possible techniques for remediation. The report recommends managing external phosphorus loading from development including residential areas, roads, and agricultural land. It also recommends considering an aluminum treatment and water drawdown to reduce the internal phosphorus load.

(2006 – 2010) Clean Water Act (CWA) Section 319 funds. Between 2006 and 2010 the CRLA and KCSWCD oversaw two phases of US EPA Clean Water Act Section 319 grant funded implementation projects to help reduce P runoff from the watershed. The major focus was to address high-priority/ high-impact residential sites and gravel roads along the shoreline, as well as high-priority agricultural sites and active forestry. Over $457,000 was invested in the watershed incuding $163,495 in grant funding and $294,317 in local matching funds. The work resulted in a significant decrease in sediment and P loading to the lake.

Before (top) and after (bottom) gravel road improvement project completed in the China Lake watershed with 319 grant funding.

(2008) China Lake Watershed-Based Plan. This 10-year remediation strategy was prepared by the KCSWCD and China Region Lakes Alliance (CRLA) based on recommendations from the 2005 TMDL as well as the Colby Watershed Analysis Report. The plan set an interim in lake TP goal of 17.8 ppb to be reached over the 10-year period by addressing 15% of the external load and removing 20 kg/yr of P through optimizing the fall drawdown, for a total P reduction of 328 kg/yr.

(2009-Present) LakeSmart Program and YCC. In 2016, the CLA/CRLA established a LakeSmart Program for China Lake. Since the program's inception, there have been over 250 site visits completed by trained LakeSmart inspectors. Thirty-five certifications have been awarded to properties on the lakeshore. CRLA also established a Youth Conservation Corps (YCC) program that employs high school and college students to engage in watershed stewardship by implementing lakeshore conservation and erosion control projects. Through the YCC, CRLA is able to implement approximately 20 site improvements a year in the China Lake Watershed.

(2014-2021) Alewife Stocking & Downstream Dam Removal Efforts. The Maine Department of Marine Resources (MDMR) began active alewife (river herring) restoration of China Lake in 2014. Alewife were trucked from the Lockwood hydroelectric facility fish lift in Waterville and stocked at the north end of the east basin boat launch on China Lake. The Inland Fisheries and Wildlife stocking permit allows for 25,000 fish per year to be stocked. In 2021, following removal of downstream barriers, an estimated 180,000 alewife returned to Outlet Stream and were hand netted over the dam into China Lake for several days. In 2022 a fishway will allow fish to freely swim over the Outlet Dam and into China Lake.

(2016 - 2021) China Lake Watershed Road Survey & Road Rehabilitation Program. In 2016, a survey of roads in the China Lake watershed was conducted by Maine Environmental Solutions to provide CLA with an overview of the condition of camp roads along the shoreline. This survey resulted in improvement projects being completed on several camp roads in the watershed between 2018 - 2021.

(2020 - 2021) China Lake Watershed-Based Management Plan Update. The Kennebec SWCD received a Clean Water Act Section 604(b) planning grant from USEPA to develop an updated WBMP for China Lake. The plan included several important monitoring/assessment tasks including:

China Lake Watershed Survey (2020). A comprehensive watershed survey was completed in 2020 with help from 12 volunteers and 10 technical leaders in partnership with Maine DEP to assess the condition of roads and developed properties in the watershed. A total of 161 sites were documented across 11 different land-use types, with 67% of sites located on residential properties. Twenty properties were ranked high impact, 59 medium impact, and 82 sites were ranked low impact.

Sediment Sampling & Analysis (2020-2021). In 2020, Maine DEP with assistance from the KWD, collected 30 sediment samples in China Lake across 10 geographic areas and water depths in the east and west basins. Samples were analyzed by Colby College to document the physical and chemical characteristics of the sediments and to test phosphorus release under reducing conditions at different levels of aluminum treatment. P release at each station was greatly reduced by adding aluminum to the samples. Recommendations from this work include collecting additional sediment samples and conducting an aluminum treatment to reduce the internal P load in the east basin by 90%.

Septic Inventory and Sensitive Soils Analysis (2021). Ecological Instincts conducted a sensitive soils analysis for septic systems in the China Lake watershed. The analysis includes a review of the Maine Soil Catena to identify soils and drainage classes that may result in short-circuiting of septic leachate (e.g., shallow to bedrock soils and coarse sandy soils). The analysis identified 533 parcels located on sensitive soils within 150 feet of a waterbody, at least 318 of which are developed lots. The Town of China's septic system database was also updated in 2021 which indicates 45% of the 452 developed properties in the shoreland zone have been updated since 1998.

(2020 - 2021) Bathymetric Map Update (2020 - 2021). Bathymetric data collected in 2002 by Dan Buckley (University of Maine, Farmington) was re-evaluated in 2020 to produce 1 m contours. The resulting data provided information necessary to more accurately calculate lake surface area, lake volume, and area and volume by depth intervals in the lake from top to bottom in order to estimate the extent of anoxia (loss of oxygen) and internal P loading. Sediment chemistry is discussed in Section 2.

In-Lake Monitoring Initiative (2020). Long-term water quality data has been collected by Maine DEP, Lake Stewards of Maine, and KWD since 1970. In-lake water quality is collected by KWD bi-weekly between April and October. This includes water clarity, dissolved oxygen and temperature profiles, and total phosphorus and chlorophyll-a readings within the water column. In 2020, additional phosphorus sampling was added to the KWD sampling program including two additional samples at Station 1 (10.5 m and 17.5 m), and one additional sample (10.5 m) at Stations 1 and 2 in the east basin. The results clearly documented a significant release of P from bottom sediments in 2020, especially in July – September when dissolved oxygen levels are less than 2 ppm in water below 7 m (23 ft). Water quality will be discussed in Section 3.

Public Outreach. There are three primary entities responsible for public outreach in the China Lake Watershed: KWD, CLA, and CRLA. KWD was formed in 1899, using China Lake as its drinking water supply starting in 1905. KWD conducts source water protection education to its 22,000 users and to residents of the watershed. CLA was formed in 1987 in response to combatting algal blooms that started on China Lake in 1983. Its mission is to preserve China Lake for future generations through environmental stewardship and community action. CLA publishes regular newsletters, hosts an annual meeting, provides updates on its website and works in partnership with KWD and CRLA to implement watershed restoration projects. CRLA was formed in 1995 as a regional watershed alliance to preserve and protect the water quality of China Lake, Threemile Pond, and Webber Pond. CRLA administers the Youth Conservation Corps (YCC), LakeSmart, and the Courtesy Boat Inspection (CBI) program.

2. Lake & Watershed Characteristics

Photo Credit: Elaine Philbrook, CLA

LAKE & WATERSHED FACTS

Towns:	**China, Vassalboro, Albion & Winslow**
Watershed Area:	**27 sq. mi.**
Surface Area:	**3,939 acres (6.2 sq. mi.)**
Max Depth:	**92 ft (28 m)**
Mean Depth:	**25 ft (8m)**
Flushing Rate:	**0.64 flushes/yr (W. basin)** **0.68 flushes/yr (E. basin)**
Lake Elevation:	**194 ft**
Peak Elevation:	**646 ft**
Avg. Clarity:	**12 ft (3.7 m)**
Invasive Plants:	**None recorded**

China Lake (MIDAS 5448)[9] is a 3,939-acre[10] lake (Class GPA)[11] located in China and Vassalboro, Maine. It is a naturally formed dual-basin waterbody with an east and west basin that was enlarged in 1969 by raising the height of the dam at Outlet Stream. China Lake serves as the drinking water supply for the municipalities of Waterville, Winslow, Fairfield, Benton, and Vassalboro.

The watershed is located within the towns of China, Vassalboro, Albion, and Winslow in Kennebec County, Maine and drains approximately 27 square miles of the surrounding landscape (Figure 2).[12] It has a maximum depth of 28 meters (92 feet),[13] and an average depth of 8 meters (25 feet). The west basin has a flushing rate of 0.64 times per year, and the east basin has a flushing rate of 0.68 times per

[9] The unique 4-digit code assigned to a lake.
[10] Based on 2021 bathymetric map update.
[11] Defined by MRSA Title 38 §465-A, Maine Standards for Classification of Lakes and Ponds: Class GPA is the sole classification of Great Ponds (>10 acres) and natural lakes and ponds <10 acres in size.
[12] The watershed of the east basin is 20 sq. mi.; the watershed of the west basin is 7 sq. mi.
[13] The deepest location in the lake is at Station 1 in the west basin at 92 ft; the deepest point in the east basin is 56 ft. at Station 3 at the north end of the east basin.

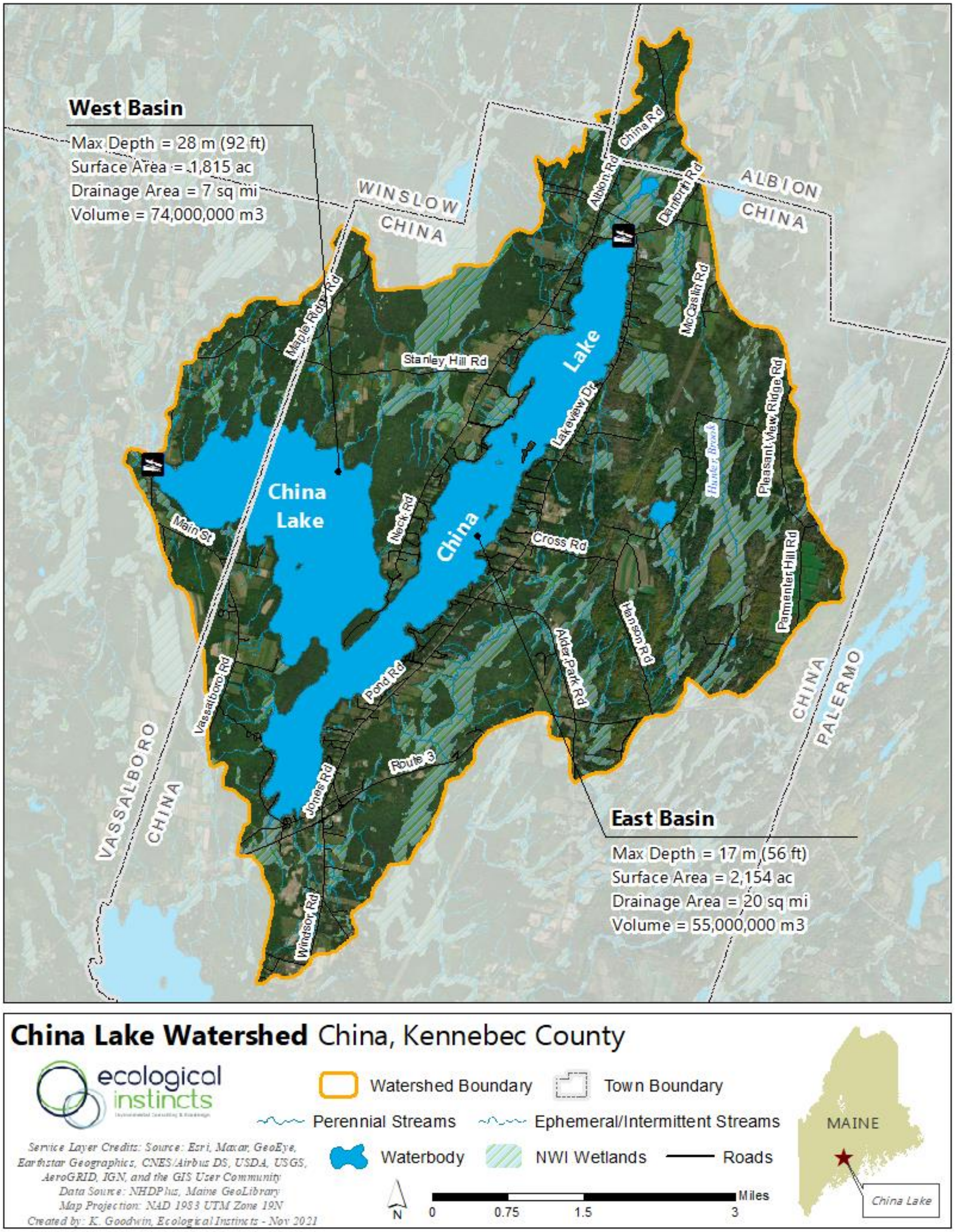


***Figure 2**. Base map of the China Lake watershed.*

year, significantly lower than the average for lakes in the state of Maine of 1-1.5 flushes per year.[14] The elevation of the lake is 194 ft above sea level, with the highest elevation in the watershed being Barmeter Hill in the northern section of the watershed, at 646 ft.

The watershed is drained by several perennial tributaries including Ward Brook that flows into the northeast corner of the west basin, Jones Brook and Starkey Brook which drain into the east basin on the southeast side of the watershed, Hunter Brook which flows into the north end of the east basin, and Muldoon Stream which also flows in at the north end of the east basin, to the southwest of the Hunter Brook outlet. In addition to these perennial streams, numerous intermittent streams, and the direct shoreline drainage areas contribute to the flow of water from the watershed into the lake.

Water flows north to south through the east basin, and east to west through the west basin where it leaves the lake through the Outlet Stream on the lake's western end. Water level is controlled by a dam at the outlet. From Outlet Stream, water flows into the Sebasticook River, which empties into the Kennebec River and eventually the Gulf of Maine.

While the west basin shoreline is largely protected from development, the shores of the east basin are highly developed. According to a recent survey of town records, there are 529 shoreline lots, 452 of which are developed. Of the developed lots, 61% are seasonal and 39% are used year-round.[15] The lake and watershed are also used heavily for recreation, including boating, fishing, swimming, snowmobiling, ice-fishing, and cross-country skiing. Prior to the sudden decline in water quality beginning in the 1980's, the lake supported a coldwater fishery, which is no longer sustainable. Despite this, the lake continues to support a warm-water fishery. There are two public boat launches on the

View of the north end of China Lake, the public boat launch, and Muldoon wetlands (right) from Causeway Road. (Source: Google Maps)

[14] A revised flushing rate was calculated in 2021 as part of the watershed modeling for the plan.
[15] Personal communication, Janet Preston, Town of China Selectman. Email communication June 2, 2021

lake, one on the west basin near the outlet in Vassalboro, and one on the north end of the lake in the Town of China.

Roads encompass 84 acres (34 ha) of land in the watershed, the majority (61%) of which are unpaved gravel roads that service high-density residential development along the shoreline. The remaining 39% of roads are paved, including Lakeview Drive (Rt. 202) that runs along the eastern shore of the east basin, Vassalboro Road (Rt. 32), running through the southwest corner of the watershed, and Neck Road that runs parallel to the west shore of the east basin. Commercial development is concentrated near the southern tip of the watershed near the intersection of Route 3 and Route 202, and near China Village at the northern tip of the watershed.

POPULATION, GROWTH, & MUNICIPAL ORDINANCES

POPULATION

Most of the watershed of China Lake is located in the Town of China, which is largely forested but also includes areas of commercial and residential development, both along the shoreline and in the upper watershed. A portion of the shoreline of the west basin is located in the Town of Vassalboro, but most of this shoreline is protected by the KWD. While most residences in the upper watershed are likely year-round, approximately 61% of the shoreline residences are seasonal, providing an influx of residents in the summer that results in numerous benefits to the local economy. China Lake is valued highly for the many recreational opportunities it provides for residents of both the watershed and the surrounding area.

Spectators watching a parade on the northern shore of China Lake. (Photo Credit: Elaine Philbrook, CLA)

The ability of China Lake to attract new seasonal and year-round residents will likely be related to lake water quality. Landowners, businesses, and the Town of China will likely see a monetary benefit from improved water quality over time as seasonal and year-round residents are attracted to the lake. Factors such as increased property values will also improve the tax base. A study on 36 Maine lakes found that lakes with one-meter greater clarities have higher property values on the order of 2.6% - 6.5%. Similarly, lakes with a one-meter decrease in minimum transparencies cause property values to decrease anywhere from 3.1% to 8.5% (Boyle and Bouchard, 2003). Any improvement in the water clarity of China Lake will be highly desirable to current and potential future residents.

Between 2008 and 2018, the Town of China experienced a slight dip in population while the Town of Vassalboro experienced slight growth (Table 1). The Maine State Economist predicted that growth would continue in Vassalboro, while decreasing trends will reverse in the Town of China by 2023 (Maine State Economist, 2018). According to the Town of China however, the town's population was 4,339 at the time of the 2020 census, greater than the Maine State Economist's prediction for 2023. Along with the larger than predicted increase in the population of the Town of China in 2020, there is evidence to suggest that declining population trends have been reversed and growing trends increased throughout the State of Maine since the last census. The population of the nearby City of Augusta, Kennebec County, and the State of Maine were all higher than estimated in 2019 (O'Hara, 2020). This growth was likely increased even further by the COVID-19 pandemic in 2020. As more people begin to work from home and move out of densely populated areas, Maine has become one of the biggest destination states for movers, according to surveys completed in June 2020 (O'Hara, 2020).

Table 1. *Population statistics for the towns of China and Vassalboro, Kennebec County, and the State of Maine from 2008 to 2020, and projected populations for 2023. (Source: Maine State Economist)*

	Total Population 2008	Total Population 2013	Total Population 2018	% Change 2008-2013	***Projected Population 2023***
China	4,320	4,278	4,276	-0.01%	*4,308*
Vassalboro	4,318	4,326	4,363	0.1%	*4,448*
Kennebec County	-	121,139	122,301	-	*123,805*
State of Maine	-	1,328,009	1,341,160	-	*1,355,924*

Changes in development can influence the character and environment of the community, and the health of the watershed. With population growth continuing in watershed towns and the surrounding area, it is likely that the watershed will continue to be developed further in the future.

Although most residences on the shoreline of China Lake are used seasonally (approximately 61%), it is likely that some of the seasonal homes in the watershed may be converted to year-round use as a result of people working from home during the COVID-19 pandemic. Researchers from Colby College (2005) estimated that there were 30.2 houses per shoreline mile on the east basin, meaning that the shoreline is already highly developed. Along with development of the remaining 70 undeveloped shoreline lots, conversion of seasonal or second homes to year-round homes is the most likely shift in usage along the shoreline. The greatest threat in terms of shoreline land use is likely to be additions to existing homes and heavier use of shoreline property, potentially reducing the amount of natural vegetation near the lake and reducing the natural capacity of the landscape to intercept and infiltrate stormwater and added stress to septic systems.

MUNICIPAL ORDINANCES

China Lake. (Photo Credit: Elaine Philbrook, CLA.)

There is an immediate need to reduce the amount of P getting into China Lake. While current development is contributor, future development is a water quality concern given the extent of developable land in the watershed and the popularity of the area for prospective buyers, especially since 2020 when more people began working from home as a result of COVID-19. Maine saw an immediate jump in out-of-state real estate transactions in 2020 as people fled from urban settings to rural settings. As the watershed continues to develop over time, erosion from disturbed areas and stormwater runoff from these developed areas will also continue to deliver new, and previously unaccounted for P into China Lake, thereby affecting the success of planned management strategies to improve water quality.

The Town of China has several ordinances that regulate P input, runoff, and development in the shoreland zone. The Town's Land Use Ordinance (Chapter 2) establishes land-use districts, including the Resource Protection District that covers China Lake and its shoreline, as well as any other wetlands and waterbodies in the watershed. The Shoreland District protects all land within 250 feet of lakes, ponds, and rivers, and the Stream Protection District protects all land within 75 feet of a stream. These districts all include measures to prevent P loading from new development. Each of these districts has its own land-use restrictions and permitting requirements to protect water quality. Minimum lot sizes of 40,000 square feet for residential development and 60,000 feet for commercial development are established in each of these three districts, as well as setback requirements of 100 feet from GPA lakes and their tributaries, and 75 feet for all other waterbodies. Structures in these districts may not take up more than 15% of their total lot size.

Septic systems are also regulated under this ordinance. All new septic systems must comply with the State of Maine Subsurface Wastewater Disposal Rules and local requirements. Systems must be no closer than 100 ft from the high-water line of a waterbody and must be located in suitable soils where there have been at least five observation holes dug. Clearing of woody vegetation for septic installation must not extend closer than 100 feet from the shoreline of any waterbody or wetland. The use of holding tanks is also prohibited for new residential developments.

Along with the Land Use Ordinance, the Town has a Phosphorus Control Ordinance (Chapter 4), which sets phosphorus export limits for all new developments (except additions to existing residential structures) along the shoreline. Under this ordinance, permit applicants for new development must provide a plan for how they will comply with these standards. The plan must either include a buffer strip at least 50 feet and up to 150 feet wide, depending on the location, slope, and lot size, or must use the DEP's Phosphorus Control Methodology to offset the lack of a buffer.

Many of the older structures on the shoreline of China Lake (built before 1971) do not meet current shoreland zoning standards.

Although the town has many ordinances in place now to protect the water quality of China Lake, many older structures do not meet the current standards, including setback requirements if they were built before the 1971 Mandatory Shoreland Zoning Act. **Since ordinances only regulate new developments, their ability to improve water quality on China Lake is limited. P control measures will need to focus on improving shoreline buffers and stabilizing erosion on existing shoreline development.**

LAND COVER UPDATE

Land cover is the essential element in determining the extent of nutrients and sediments entering the lake from its watershed. More intensive development such as highly impervious commercial development typically contributes more runoff than a low density residential property with natural landscaping. In addition, changes in land cover occur over time in a watershed as forests are cleared for lumber, agricultural land is left fallow or developed, and infill development occurs along the shoreline and existing roads. In order to complete the watershed modeling, a land cover update was needed. Maine Land cover Dataset 2004 [MELCD] was used as a baseline for the updated land cover layer. ESRI World Imagery aerials[16] were uploaded and compared to Google Earth satellite images, and 2018 NAIP imagery for Kennebec County, Maine[17] to determine major land cover changes. If discrepancies between the aerials and the MELCD file were found, changes were made by manually editing polygons. The State road layer (NG911 roads), stream layer, and an NWI wetlands layer were overlaid on the updated land cover layer and relabeled appropriately.

[16] https://www.arcgis.com/home/item.html?id=10df2279f9684e4a9f6a7f08febac2a9
[17] https://datagateway.nrcs.usda.gov/GDGHome_DirectDownLoad.aspx

The resulting updated land cover file provides a more accurate representation of current land cover within the China Lake watershed (Figure 3 & Table 2).

The most significant changes to land cover were the addition of low- and mid-density residential and commercial development throughout the watershed. These data are foundational in the watershed model used to estimate P loading in China Lake (Section 4).

In the model, a P export coefficient is assigned to each land cover type to represent typical concentrations of P in runoff from those land cover types. Unmanaged forested land, for example, tends to deliver very little P downstream when it rains, while row crops and high-density urban land export significantly more P due to fertilizer use, soil erosion, car and factory exhaust, pet waste, and many other sources. Smaller amounts of P are also exported to lakes and streams during dry weather under base flow conditions. A breakdown of land cover types by area and contributing P loads to the lake is presented in Section 4.

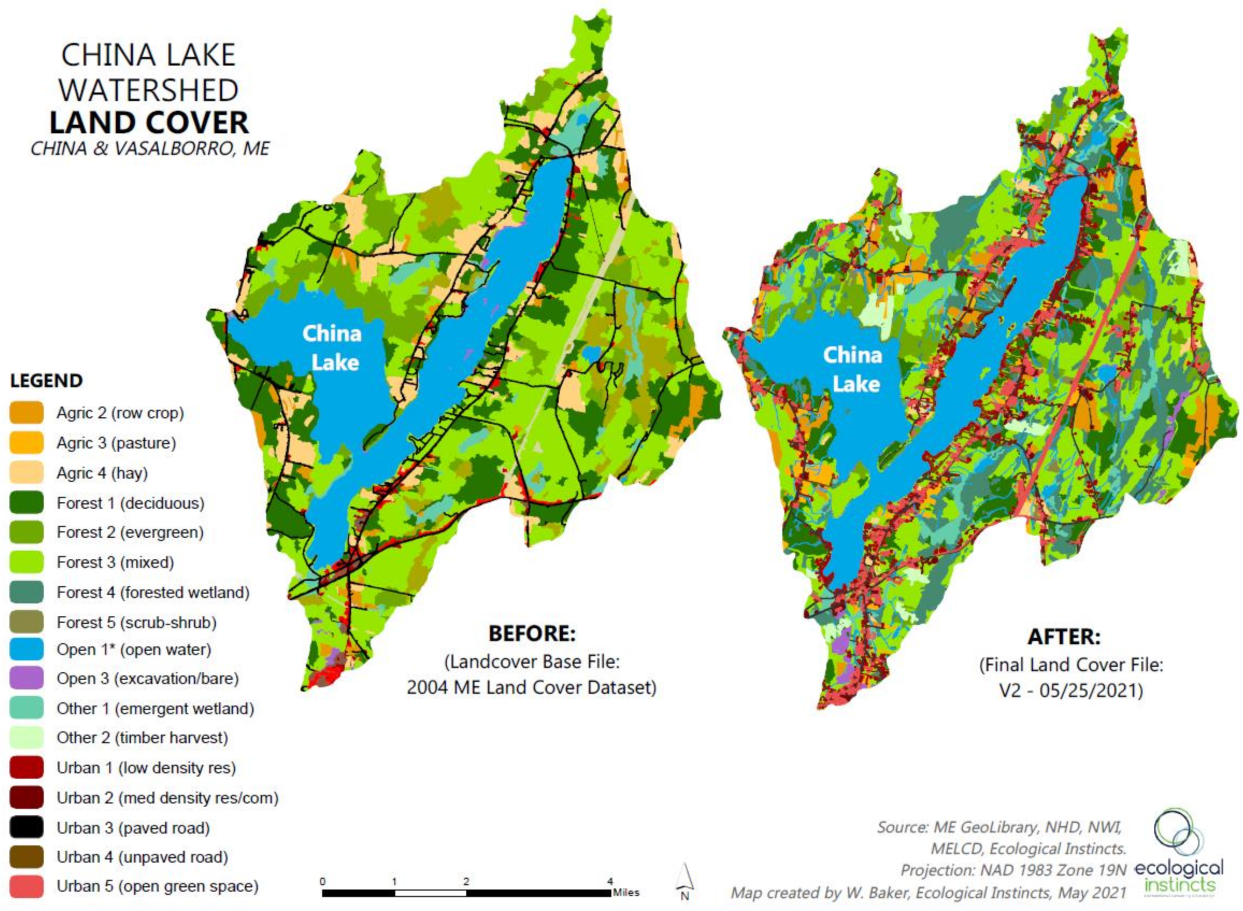


Figure 3. *Before and after 2021 land cover update map for the China Lake watershed.*

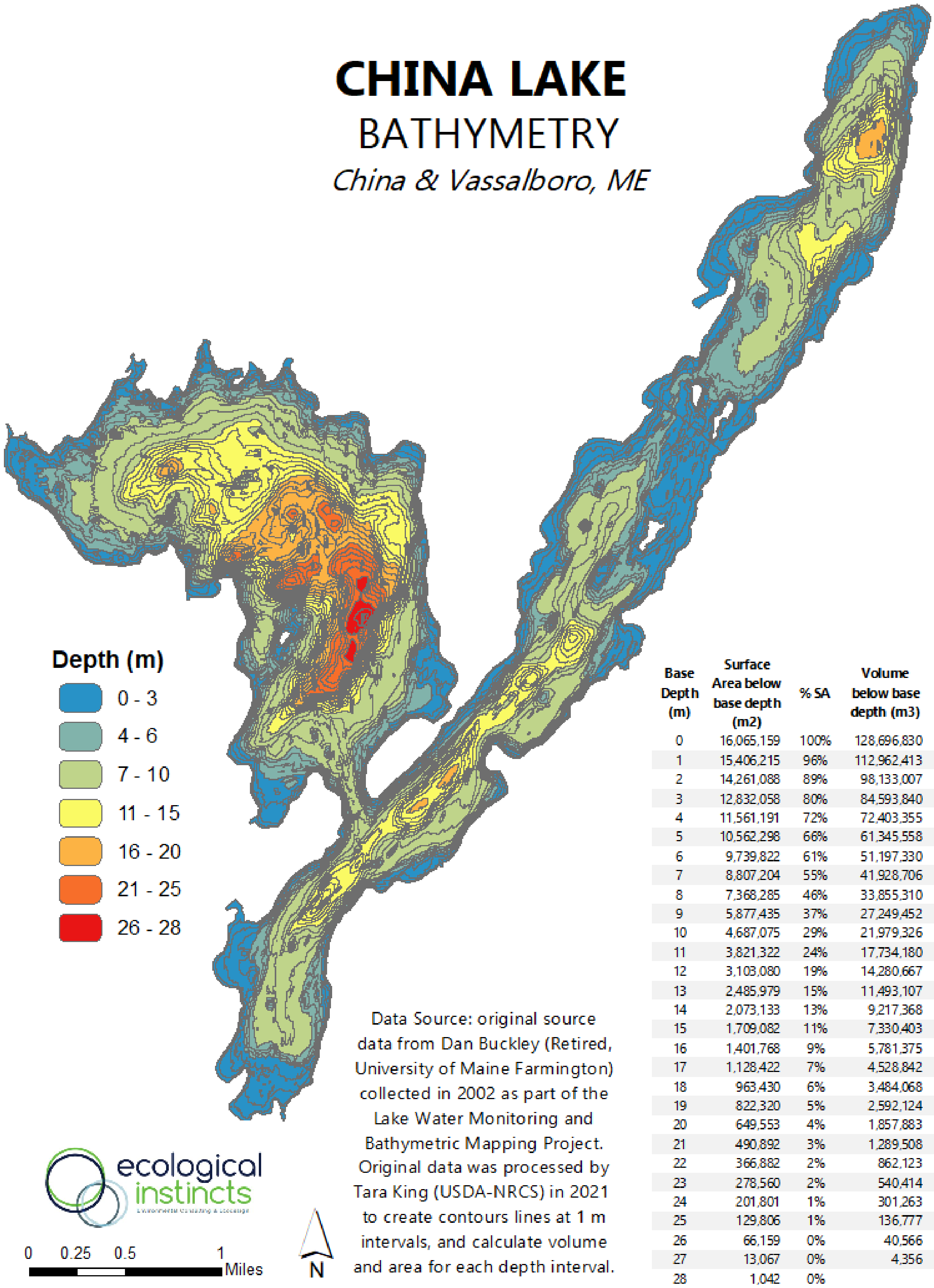
Table 2. *China Lake watershed land cover types.*

LAND COVER TYPE	Area (ha)	%
Forest 1 - 3 (Upland)	534.3	60%
Other 2 (Timber Harvesting)	149.1	17%
Urban 1 (LDR/Residential)	51.3	6%
Forest 4 (Forested wetland)	42.0	5%
Urban 4 (Unpaved road)	20.7	2%
Open 1 (Open water)	18.4	2%
Urban 2 (MDR/Commercial/Industrial)	18.2	2%
Urban 5 (P/I/R/C)	14.7	2%
Other 1 (Freshwater emergent wetland)	13.9	2%
Urban 3 (Paved road)	13.2	1%
Agric 3 & 4 (Hay/Pasture)	9.3	1%
Forest 5 (Scrub-shrub)	6.4	1%
Open 3 (Excavation/bare soil)	0.7	0%
Agric 2 (Row Crop)	0.4	0%
TOTAL	**892.5**	**100%**

BATHYMETRY

A bathymetric map was developed for China Lake using high-resolution bathymetric data collected in 2002 by the University of Maine at Farmington which was then processed by Tara King (USDA-NRCS) to create 1 m contours (Figure 4). The resulting map shows that the deepest water in the lake is associated with a fairly small area of the west basin, with two shallower deep holes located in the north and south ends of the east basin.

Based on the updated map, 83% of the lake area is in water shallower than 10 m (33 ft). This is important to understanding the internal P load, because monitoring data indicates that the zone of anoxia (levels of dissolved oxygen less than 2 ppm) in China Lake varies from a depth of 9 m to as shallow as 7 m in the west basin and the southeast basin, and as shallow as 6 m in the northeast basin in recent years. Roughly 21% of the lake area and 37% of the lake volume is in water deeper than 9 m, compared to 33% of the lake area and 55% of the lake volume in water deeper than 7 m. If the area of the lake bottom exposed to low DO increases to 5 m throughout the lake (66% of the lake area, and 48% of the lake volume) in the future, the area of the lake with potential to contribute to internal loading could increase drastically.



Base Depth (m)	Surface Area below base depth (m2)	% SA	Volume below base depth (m3)	% V
0	16,065,159	100%	128,696,830	100%
1	15,406,215	96%	112,962,413	88%
2	14,261,088	89%	98,133,007	76%
3	12,832,058	80%	84,593,840	66%
4	11,561,191	72%	72,403,355	56%
5	10,562,298	66%	61,345,558	48%
6	9,739,822	61%	51,197,330	40%
7	8,807,204	55%	41,928,706	33%
8	7,368,285	46%	33,855,310	26%
9	5,877,435	37%	27,249,452	21%
10	4,687,075	29%	21,979,326	17%
11	3,821,322	24%	17,734,180	14%
12	3,103,080	19%	14,280,667	11%
13	2,485,979	15%	11,493,107	9%
14	2,073,133	13%	9,217,368	7%
15	1,709,082	11%	7,330,403	6%
16	1,401,768	9%	5,781,375	4%
17	1,128,422	7%	4,528,842	4%
18	963,430	6%	3,484,068	3%
19	822,320	5%	2,592,124	2%
20	649,553	4%	1,857,883	1%
21	490,892	3%	1,289,508	1%
22	366,882	2%	862,123	1%
23	278,560	2%	540,414	0%
24	201,801	1%	301,263	0%
25	129,806	1%	136,777	0%
26	66,159	0%	40,566	0%
27	13,067	0%	4,356	0%
28	1,042	0%		

Figure 4. *Bathymetric map for China Lake.*

SEDIMENT CHEMISTRY

Sediments were collected from the bottom of China Lake (10 cm cores) at 30 locations in 2020, which were then composited into 10 core samples based to represent different lake depths throughout the lake (Figure 5).

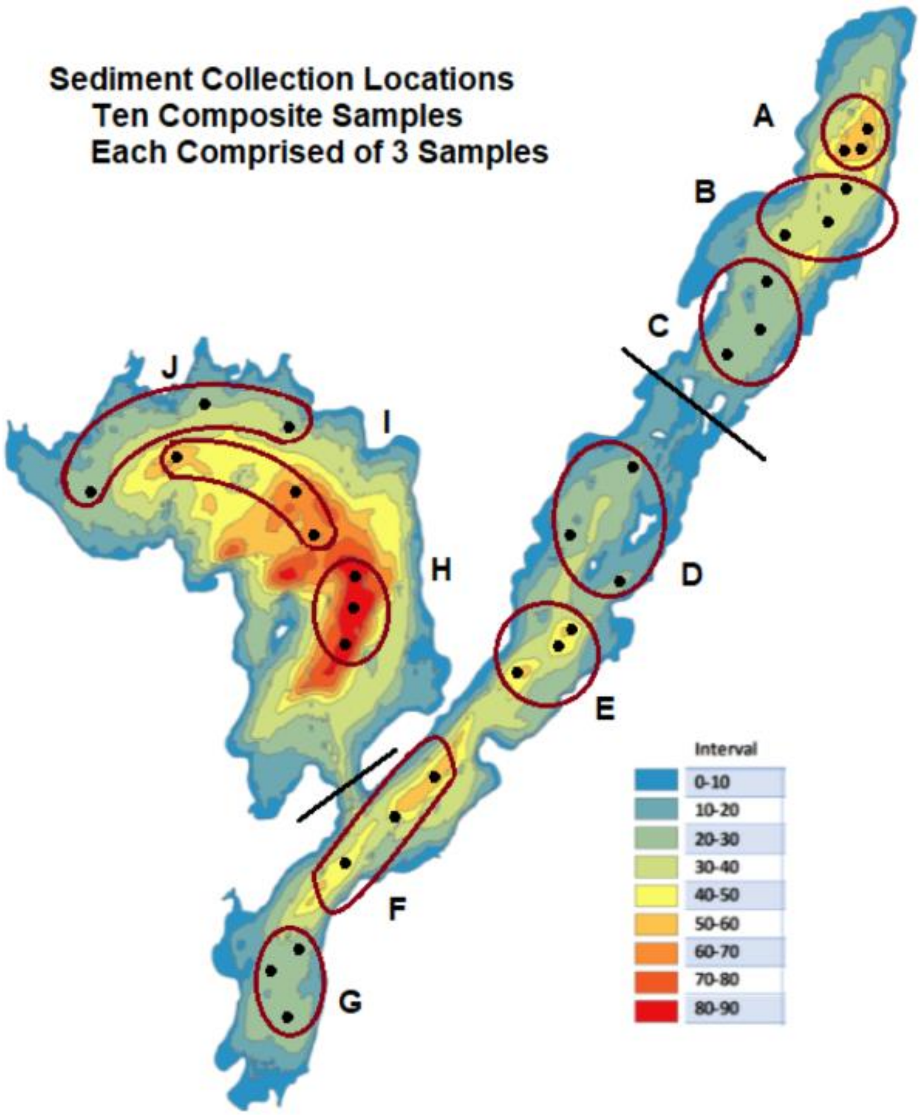


Figure 5. *2020 China Lake sediment sampling locations.*

The upper 10 cm of the sediment cores were analyzed by Colby College to quantify % organic carbon and concentrations of iron, aluminum and P in lake bottom sediments in order to gain a better understanding of the capacity of the sediments to hold onto P under anoxic conditions, the potential for internal P recycling in China Lake, and the amount of aluminum that would be needed to inactivate P in the sediment using sequential sediment extractions with intentionally added aluminum to quantify reductive phosphorus release as a function of added aluminum concentration.

Previous studies have shown that internal P loading is negligible during hypolimnetic anoxia when aluminum to iron ratios (Al:Fe) are less than 3, and lakes below this threshold are good candidates for aluminum additions (Sykes, 2021).

Results of the analysis tell us a few things about the sediments in China Lake:

- Sediments in the northeast basin contained greater amounts of organic carbon which cause greater oxygen demand which leads to lower oxygen and contributes to a higher rate of P release. This is likely a result of organic materials deposited into the lake via the large wetland complex on the north end of the lake.
- There is a clear decrease in mass lost on ignition (burning off of organic carbon) from the northern most sample in the east basin (A) to sample G on the south end of the east basin. This provides additional evidence that the proximity to the deposition of organic matter from the wetlands on the north end of the lake are likely contributing to this pool of carbon.
- The northern most samples (samples A and B) have the lowest Al:Fe ratios and the highest iron concentrations (high iron levels translate to high P release under reducing conditions) (Table 3). As a result, ambient Al:Fe in the north end of China Lake is very low and cannot mitigate reductive phosphorus release as well as other areas of the lake with higher Al:Fe ratios.

Table 3. *Average Al:Fe at each sediment sampling location in China Lake (Source: Sykes, 2021)*

Sample	Average [Al], g/m2	Average [Fe], g/m2	Average Al:Fe
A	28.35	107.37	**0.264**
B	4.00	96.66	**0.041**
C	9.17	1.29	**7.138**
D	60.61	60.89	**0.995**
E	40.33	6.82	**5.911**
G	43.84	61.10	**0.718**

- Sediment extractions indicate that the highest release of P was documented in the north end of the east basin Samples A & B), and the deepest location in the west basin (Sample H). P release at each of these stations was greatly reduced by adding aluminum to the samples.
- P release was greatly reduced by adding aluminum to the samples with the majority of samples plateauing between 35 – 45 g/m2 aluminum.
- Not all the P is being released from the sediments as some P is bound to aluminum that is already present in the sediments.

Sediment testing results indicate conditions in China Lake favor internal P loading that contributes to the current water quality impairment and recurrent nuisance algal blooms. Should the area of sediment exposed to anoxia continue to increase in size, the additional P released into the system is likely to fuel chronic internal loading and recurring nuisance algal blooms annually in China Lake. Sediment assays indicate a significant reduction in P release under anoxic conditions when treated with aluminum. The project's technical advisory committee (TAC) recommended an aluminum treatment in the east basin at depths > 7 m to significantly reduce the internal P load and improve water quality positive in the west basin. However, additional sediment sampling in the east basin is needed to refine preliminary aluminum treatment recommendations and to develop an aluminum treatment plan.

SOILS

Almost 80% of soils in the China Lake watershed are formed from glacial till parent material containing mica schist with granite, gneiss, and phyllite (Figure 6). These soils are primarily shallow and somewhat excessively drained soils (Lyman-Tunbridge), coarse-loamy and moderately well drained soils (Woodbridge), and coarse-loamy, well drained soils (Paxton-Charlton). Other significant portions of these glacial till soils consist of the Ridgebury series, which is a coarse-loamy, poorly drained soil.

Approximately 17% of the watershed's soils are formed from glaciomarine or glaciolacustrine parent materials (Biddeford, Lamoine, Buxton, Hartland, Scantic, Scio and Suffield), most of which are located near the shores of the east basin. A smaller percentage of soils in the watershed are formed from glaciofluvial, alluvial, or organic parent materials.

Organic soils associated with wetlands in the watershed consist of Rifle, Togus, and Vassalboro soils. These soils all consist of very deep, very poorly drained organic soils. Soils in the Rifle series are formed in organic deposits more than 51 inches thick in bogs and depressional areas within outwash plains and lake plains. Soils in the Togus series are formed in the mantle of slightly decomposed organic soil over sandy mineral material and can be found in watershed bogs and along the shoreline of China Lake. Soils in the Vassalboro series are formed in a mixture of herbaceous, woody and sphagnum material in bogs and kettle holes. [18]

Understanding dominant soil types that surround China Lake and their location within the watershed is important for managing the watershed. Factors such as topography, soil quality, erosion potential, and degree of alteration on various soil types will dictate the magnitude of erosion that occurs, and

[18] https://soilseries.sc.egov.usda.gov/

the resulting impact to water quality. Soil types will also dictate the suitability of certain infrastructure, specifically for septic systems not designed or installed properly.

The composition of each soil type dictates the amount of P, iron, and aluminum exported to the lake from the watershed soils. Watershed soils define the sediment composition within China Lake as the P, iron, and aluminum that enters the lake is accumulated within the sediment at the lake bottom. A breakdown of each soil series within the China Lake watershed, associated areas, hydrologic soil grouping, and parent material is provided in Appendix B, along with a soil series map (Appendix C).

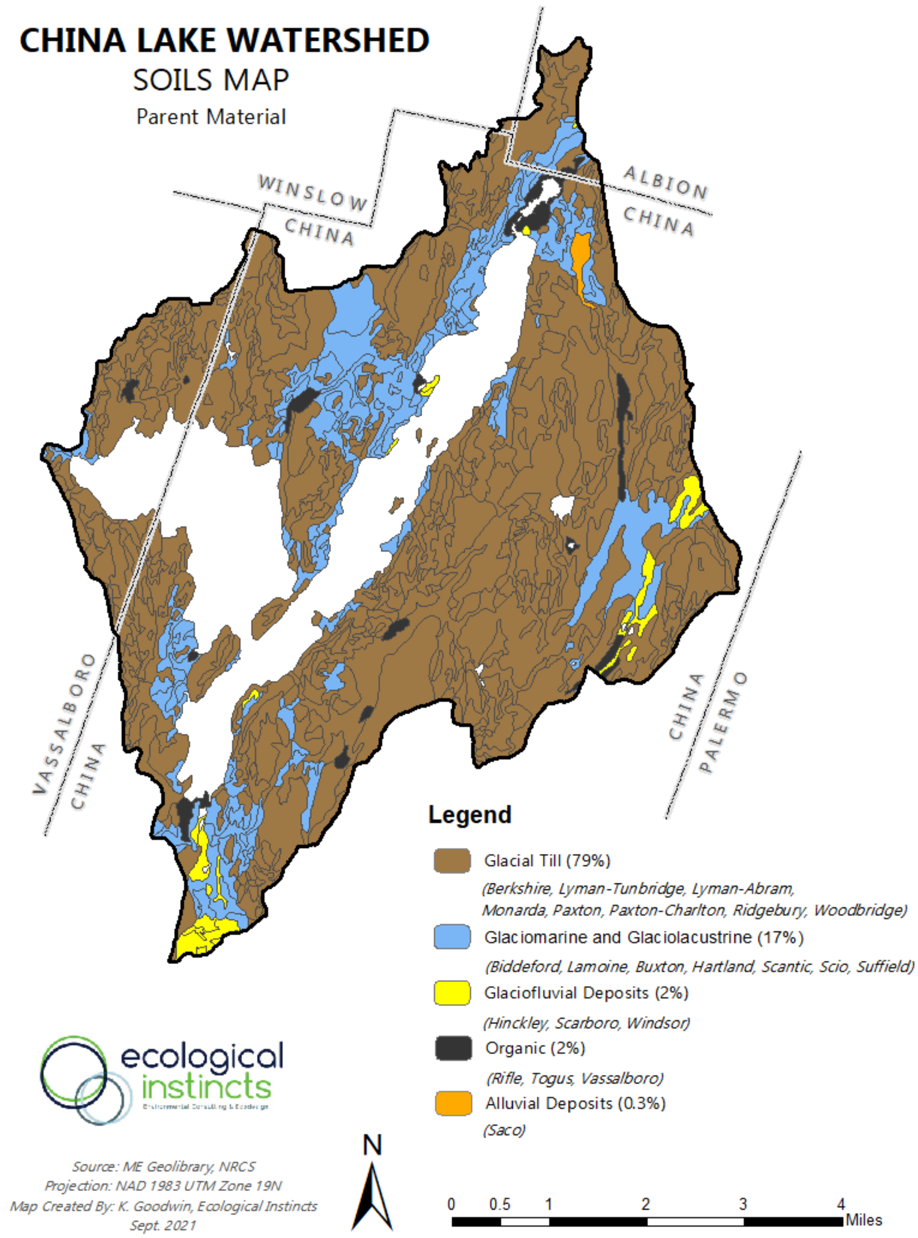


Figure 6. *NRCS soil series displayed by parent material in the China Lake watershed.*

AT-RISK SOILS AND SUBSURFACE WASTEWATER SYSTEMS

Developed properties with septic systems located on sensitive soils are susceptible to short-circuiting of subsurface wastewater disposal system effluent. A short circuit occurs when effluent from the leach field freely drains into a coarse textured soil horizon or bedrock fractures without being partially treated first.[19] If the bottom of the leach field is in coarse sand or gravel or rests on fractured bedrock, particles and microbes may not be able to accumulate to the degree that a bio-mat (a microbial mat that forms under the leach field that slows and treats effluent) is formed. If that happens, the wastewater, along with most of the phosphorus, can travel down to the groundwater table and then move to a nearby lake, pond, or stream. Recent steps taken to assess the condition of septic systems in the watershed include:

1) **A Septic Vulnerability Analysis** was completed by Ecological Instincts in 2021 which included a review of the Maine Soil Catena to identify soils and drainage classes that may result in short-circuiting of septic leachate (e.g., shallow to bedrock soils and coarse sensitive soils). The analysis identified 533 parcels within 150 ft of the lake or tributary streams that are located on sensitive soils, 318 of which are developed lots, 140 of which are undeveloped, and 75 of which are unknown (Figure 7 and Table 4).
2) **A Septic Inventory** was completed by the Town of China in 2021 to identify properties with septic systems built before 1975. The results of this inventory can be used to further improve the prioritization process when compared with the results of the septic vulnerability analysis. The inventory identified 77 undeveloped parcels and 452 developed parcels in the shoreland zone (SLZ), 275 of which are seasonal and 177 of which are used year-round. 198 of the 452 properties have been upgraded since 1998.
3) The soil factors used in this analysis are based on available NRCS soils data for Kennebec County, and the analysis is intended to support municipal prioritization of septic investigations in the shoreland zone (SLZ). Septic systems built on sensitive soils before 1974 within close proximity of a lake, pond, or stream would be of highest priority, followed by systems built between 1974-1995.
4) Factors affecting a soil's suitability for leach fields include soil texture and depth to bedrock. In order to determine the potential for septic short-circuiting, sensitive soils in the China Lake watershed were divided into three categories: 1) Shallow to bedrock soils with a high potential

[19] Dave Rocque. *Soils Series Potential for Having a Short Circuiting Septic System Based on Soil Properties*. December 30, 2020.

for short-circuiting, 2) Coarse soils with a high potential for short-circuiting, and 3) Coarse soils with a very high potential for short-circuiting.

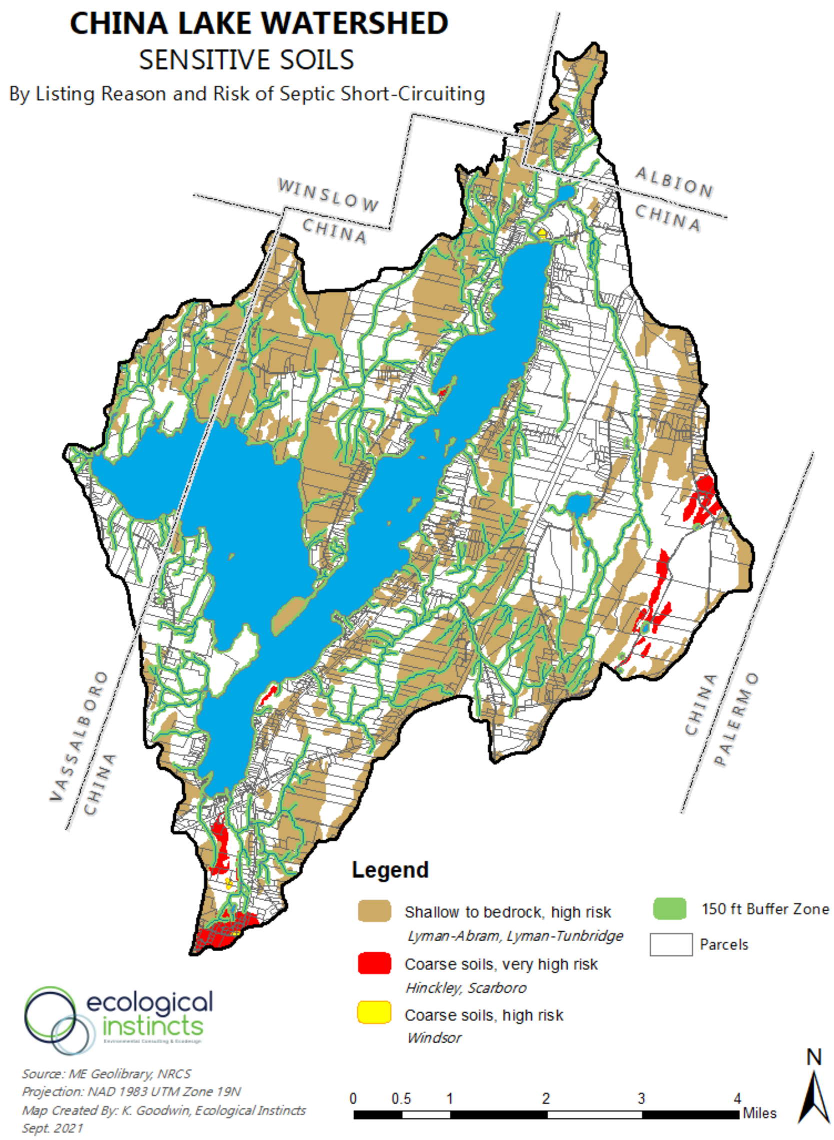


Figure 7. *Septic vulnerability analysis for soils in the China Lake watershed.*

***Table 4**. Summary of the number of lots on sensitive soils within 150 ft of China Lake or tributary streams.*

Lots on Sensitive Soils in the China Lake Watershed				
	Developed	*Undeveloped*	*Unknown*	*Total*
China	318	137	0	455
Vassalboro		3	55	58
Albion			20	20
Total	**318**	**140**	**75**	**533**

The majority of sensitive soils in the China Lake watershed belong to either the Lyman-Abram or Lyman-Tunbridge unit groupings, both of which are shallow to bedrock soils with a high risk of short-circuiting (Appendix B). This includes 471 of the 533 parcels (88%) on sensitive soils within 150 feet of the lake, stream, or pond. Properties with a high risk of short-circuiting due to shallow to bedrock soils on the shoreline of China Lake are mostly associated with properties on Fire Roads 3, 13, 15, 16, 29, 44, 45 and 61.

A total of 67 parcels are located on coarse soils with a very high risk of short-circuiting (Hinckley or Scarboro soils), while only one parcel is located on Windsor soils- another coarse soil with a high risk of short-circuiting. Areas on the shoreline of China Lake located on these course soils include parcels located on Fire Roads 9, 11, and 12.

For some parcels, sensitive soils make up only a small part of the parcel area, while other parcels include areas with multiple soil types and risk factors. Soil conditions can vary greatly within each mapped unit or complex, therefore areas will exist within individual units where a septic system and leach field can be sited and installed if designed properly. Soil conditions should always be validated through on-site inspection and confirmed on a site-by-site basis by a licensed site evaluator or soil scientist.

Priority of Septic System Evaluations in the China Lake Watershed

1. Pre-1974 systems installed in gravelly fill along the shoreline;
2. High and medium-risk systems (pre-1974) located on parcels with at-risk soils;
3. High and medium-risk systems (pre-1995) located on parcels with at-risk soils located within 250 feet of lake; and
4. High and medium impact systems (pre-1995) located on at-risk soils within 75 feet of any tributary stream and/or wetland draining to China Lake.

WATER RESOURCES AND SOURCE WATER PROTECTION

Wildlife habitat is not limited to China Lake and its shoreline. Fish and wildlife require suitable habitat beyond the lakeshore, with healthy riparian buffers, wetlands, and large undeveloped habitat blocks strategically linked to allow for movement of wildlife.

A habitat assessment was completed for the China Lake watershed using Beginning with Habitat (BwH) Program data. BwH was created in 2000 and is maintained by staff at Maine Department of Inland Fisheries & Wildlife with the purpose of helping landowners and communities in Maine incorporate habitat conservation into their long-term planning efforts. Results of the assessment highlight the wealth of water resources in the watershed, including 85 miles of streams, 4,732 acres of riparian habitat,[20] and 3,014 acres of freshwater wetlands (Figure 8).

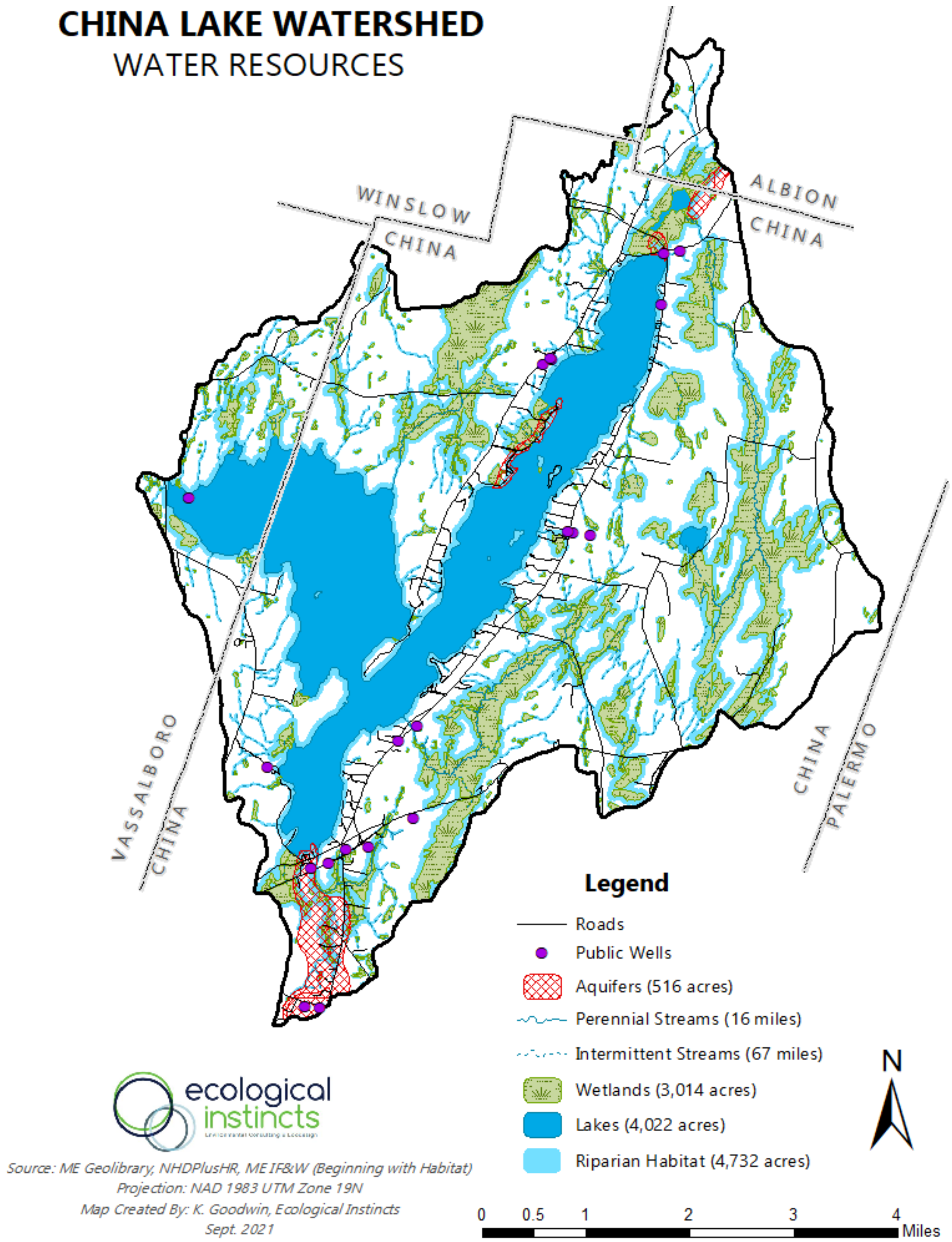


Figure 8. Water resources in the China Lake watershed.

[20] *Riparian habitat consists of a 75-ft buffer on all watershed streams, 250-ft buffer around China Lake, 250-ft buffer around wetlands >10 acres, and a 75-ft buffer on all remaining wetland areas <10 acres.*

Healthy riparian zones are not only important for water quality but are also essential for more than 60 species of Maine wildlife, as more animals live in riparian zones than in any other habitat type in Maine (Maine Audubon, 2006).

Riparian habitat is the transitional area between aquatic habitats and dry, upland areas.

In the China Lake watershed, much of the riparian area along the east basin of the lake is already developed with camps and roads. As development continues, this valuable habitat will diminish - underlining the need for strong protection of the shoreland zone and conservation of undeveloped land within watershed.

SOURCE WATER PROTECTION

To help preserve China Lake as the sole source of supply for over 22,000 customers, KWD has helped implement many programs and protections within the lake and watershed over its more than 100-year use of the lake. These programs and protections fucus on reduction of risks associated with contamination of drinking water and greater controls as proximity to the intake to the treatment process increases. Therefore, a muti tiered approach to protection of the drinking water supply with many layers has been implemented and adjusted over time.

KWD partners with and supports many local community groups such as CLA, CRLA, and Lake Stewards of Maine to implement water quality focused projects and provide education focused conservation techniques to property owners, recreationalists, and users of China Lake. KWD also provides financial and administrative support to water quality focused projects led by these community partners such as the Courtesy Boat Inspection program and Gravel Road Rehabilitation Program, and LakeSmart Program led by CRLA. A full description of current KWD activities and goals for source water protection is provided in Appendix D.

The KWD is in the process of developing a Source Water Protection Plan for China Lake with plans to publish it in 2022. The KWD has taken on many source water protection actions to protect the drinking water supply. These include:

1. Work with and support local community groups (CLA/CRLA) to complete water quality projects such as CBI, Gravel Road Rehabilitation, LakeSmart, etc.
2. Manage KWD lands in the watershed to promote water quality. This consists of 344 acres (~ 200' buffer around 98% of the west basin). This also includes no trespass on KWD land per a state law from 1969.
3. Help educate the public about the "No Bodily Contact" state law in the west basin.
4. Maintain a "Closed Area" around the intake structure (About 200' diameter) to protect the structure and limit contamination of the source water

5. Educate property owners and users of the lake regarding conservation methods and techniques to protect water quality.
6. Monitor the lake with Lake Stewards of Maine. Three locations (Basins) are sampled during summer months for TP, CHL-a, Secchi, & DO. Dam TP samples are collected monthly.

WILDLIFE HABITAT

A symbol of summertime on Maine lakes, loons are regularly observed on China Lake, with 25 adult loons and three chicks counted on the lake in 2020 (Maine Audubon, 2020). Since counts began in 1983, between 3 and 65 loons were observed each year on the lake, with 48 adult birds being counted in 2019.

A bald eagle eats a fish on the frozen waters of China Lake. (Photo Credit: Elaine Philbrook, CLA)

Conserved lands in the China Lake watershed include 344 acres of land owned by KWD that surrounds the shoreline of the lake's west basin (~ 200 ft. wide buffer). This property was acquired by KWD for the purpose of protecting the shoreline from development and erosion in order to protect the water quality of the west basin as a drinking water source. A 119-acre portion of the southeastern watershed is protected as part of the Alonso H. Garcelon Wildlife Management Area, a collection of properties in Augusta and Windsor that were conserved to protect wetland and riparian habitats. This wildlife management area provides diverse wetland habitat for waterfowl, wading birds, and shorebirds including bald eagles and great blue herons (Latti, 2003). Another 22 acres of land in the northern end of the watershed is conserved as farmland under an agricultural easement through the Maine Farmland Trust. Protecting the land and water in the China Lake watershed is vital for maintaining the remaining areas of high-value wildlife habitat. This includes the large areas of forestland and undeveloped habitat blocks in the watershed serving as wildlife connectors, and the small first and second order streams that feed clean, cool water to the lake (see map in Appendix C).

China Lake is home to 23 fish species, including 19 native species, and four introduced non-native species (Maine DIF&W, 2006) (Table 5).

Table 5. *Native and non-native fish species in China Lake.*

Fish Species *Native*	**Scientific Name**	**Fish Species** *Non-Native/Introduced*	**Scientific Name**
Yellow perch	*Perca flavescens*	Brown trout*	*Salmo trutta*
Rainbow smelt*	*Osmerus mordax*	Smallmouth bass	*Micropterus dolomieu*
Golden shiner	*Notemigonus crysoleucas*	Largemouth bass	*Micropterus salmoides*
Common shiner	*Luxilus cornutus*	Northern Pike	*Esox Lucius*
American eel	*Anguilla rostrata*		
White sucker	*Catostomus commersoni*		
Chain pickerel	*Esox niger*		
White Perch	*Morone americana*		
Brown Bullhead	*Ameiurus nebulosus*		
Pumpkinseed sunfish	*Lepomis gibbosus*		
Readbreast sunfish	*Lepomis auritus*		
Banded killifish	*Fundulus diaphanous*		
Brook Trout*	*Salvelinus fontinalis*		
Alewife	*Alosa Pseudoharengus*		
Fourspine stickleback	*Apeltes quadracus*		
Threespine stickleback	*Gasterosteus aculeatus*		
Ninespine stickleback	*Pungitius pungitius*		
Blacknose Dace	*Rhinicthys atratulus*		
Creek Chub	*Semotilus atromaculatus*		

*Coldwater game fish

Due to the pattern of annual anoxia in colder and deeper water throughout the lake, habitat for coldwater game fish such as brown trout and brook trout is limited in China Lake. Landlocked salmon and lake trout were stocked prior to the 1980s, when declining water quality caused the loss of the well-oxygenated water in deeper areas of the lake where young lake trout reside. Brown trout continue to be stocked yearly in the fall with the expectation that they will not survive the summer due to poor water quality. The lake also supports a robust warm water fishery including largemouth and smallmouth bass (IF&W, 2006).

Ice fishing is popular at China Lake. (Photo Credit: Elaine Philbrook, CLA)

ALEWIVES/RIVER HERRING

Alewives (aka river herring) are anadromous fish, meaning they normally spend the majority of their life at sea, but return to freshwater to spawn. Each spring, adult alewives migrate upstream from the ocean to rivers and lakes. After spawning, adults return to the sea while surviving fry remain to feed and grow into juveniles. Surviving juveniles will later migrate downstream to the ocean where they will grow to adulthood (Maine DMR, 2004). China Lake was historically used by spawning alewives moving up through the Sebasticook River and the Outlet Stream.

The Maine Department of Marine Resources (MDMR) began active alewife restoration of China Lake in 2014. Alewife were trucked from the Lockwood hydroelectric facility fish lift in Waterville and stocked at the north end of the east basin boat launch on China Lake. The Inland Fisheries and Wildlife stocking permit allows for 25,000 fish per year to be stocked.

The outlet dam on Outlet Stream. (Photo Credit: Elaine Philbrook, CLA)

In 2021, an estimated 180,000 river herring returned to Outlet Stream. The first of the alewives were detected on April 11 at the Box Mill fishway in North Vassalboro. The alewives were able to ascend Outlet stream through two Denil type fish passages and two dam removal sites before arriving at the outlet dam. At this point the alewife were hand netted over the dam into China Lake for several days. As a result of the fish ladder at the outlet dam in 2021, alewife will be allowed to move freely in and out of the lake beginning in the spring of 2022. In addition to alewife, other fish species such as American eel (*Anuguilla rostrata*) and white sucker (*Catostomus commersonii*) are expected to enter the lake in large numbers from downstream.[21]

Alewife restorations can have a variety of positive effects on lake, river, and ocean ecosystems by improving habitat and providing a food source for species that prey upon sea-run fish. However, there are also concerns that alewife re-introductions could negatively affect water quality in certain cases. Juvenile alewives feed primarily on zooplankton (tiny aquatic animals that feed on algae). A large population of alewife in a lake can reduce the mean size and biomass of zooplankton during the summer when conditions favor excess algal growth. Lakes with robust alewife populations could have

[21] *Personal Communication, Nate Gray, Maine DMR. China Lake Watershed Plan Steering Committee meeting, November 15, 2021.*

larger stocks of algae because there is reduced grazing pressure from zooplankton and compete with other plankton-eating fish for what becomes a scarce zooplankton resource.

In China Lake, reintroduction of alewife is not expected to result in a major net loss of P from the system. In any given year there could be more or less P in the water after the alewife run. A 2012 evaluation of the potential effects of alewife restoration in China Lake concluded that alewife introduction should not negatively affect water quality in China Lake as long as there is an outlet through which fish can emigrate from the lake freely. The evaluation suggests controlling access into the lake (escapement) to minimize nutrient levels at high escapement levels (Kleinschmidt, 2015).

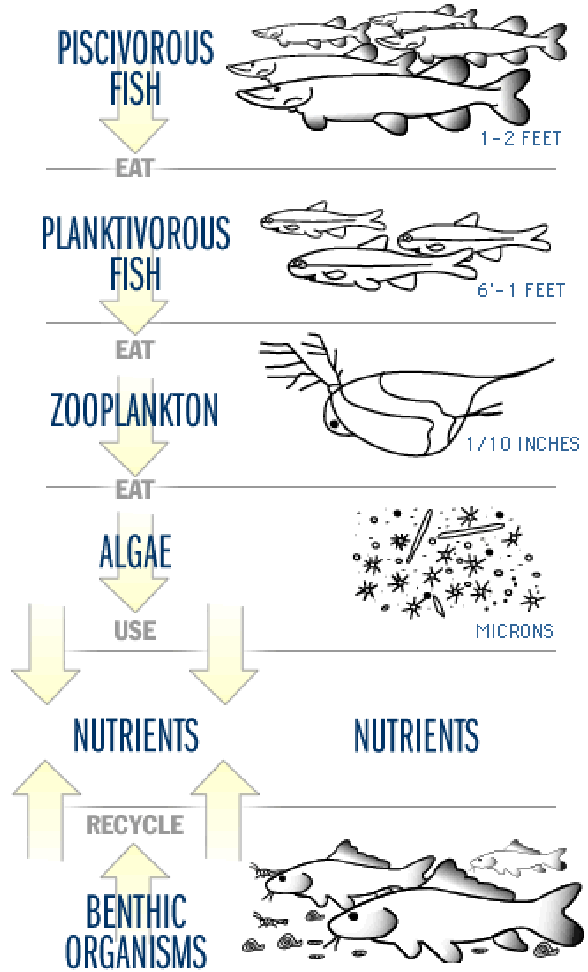
This plan recommends monitoring of the alewife population coming in and out of China Lake as well as baseline monitoring for zooplankton and phytoplankton to better understand this complex dynamic. According to MDMR, the alewife run into China Lake will be monitored for several years through a combination of electronic fish counters, bio-sampling of adult river herring, PIT tagging and antenna arrays as well as visual counts to document the population run strength. MDMR anticipates the establishment of a commercial fishery on the resource at such a time that the Atlantic States Marine Fisheries Commission (ASMFC) determines the run's sustainability. Once the run is deemed sustainable the resource will be monitored through spot checks and commercial harvesting records provided by the harvester to the Department of Marine Resources.

INVASIVE AQUATIC ANIMAL SPECIES

In addition to brown trout, small and largemouth bass which were introduced into the lake, Northern pike are known to have been introduced to China Lake. However, it is currently unknown whether there is an established population in the lake. With the construction of the fish ladder at the Outlet Stream, there is the potential for invasive fish species to enter the lake from downstream, including carp, white catfish and Northern pike. Monitoring of the fish ladder will be important to detecting the presence of invasive fish species in China Lake. MDMR will be monitoring for invasive/introduced species entering the lake along with the alewife monitoring over the next 8 years.

PLANKTON AND CYANOBACTERIA

Tiny aquatic plants (algae or phytoplankton) and animals (zooplankton) are the primary and secondary source of food and energy in a lake food web and play a key role in lake ecosystems. Because plankton float in the water column, they influence the transparency of the water throughout the season and from year-to-year as these communities undergo both seasonal and annual growth cycles. Secchi disk transparency is often at its lowest in the spring and fall when lakes undergo "turn over". This biannual mixing suspends nutrients and sediment in the water column for a period of time, stimulating the growth of certain algae. For example, silica from sediment that is suspended in the water column during spring and fall mixing fuels diatom blooms, often resulting in slight decreases in water clarity. Once the lake becomes thermally stratified in the summer, other types of algae will dominate the water column depending on weather, wind, nutrient availability, and water temperature, among other factors.

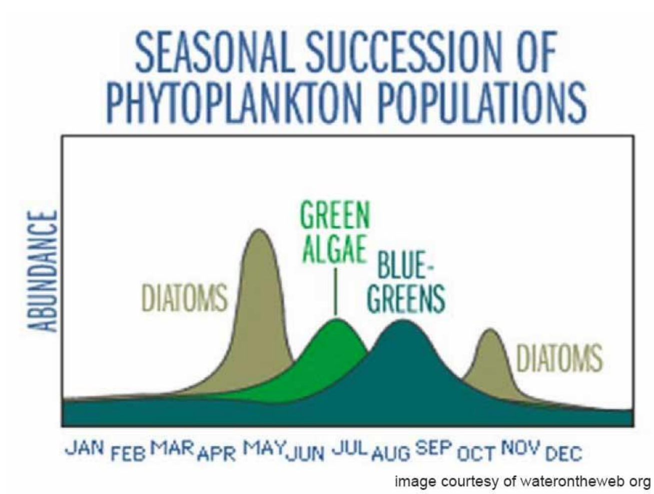


A typical lake food web. (Source: www.waterontheweb.com)

CHINA LAKE PLANKTON COMPOSITION

KWD collected raw water samples to test for phytoplankton species composition and abundance plankton at regular intervals in various areas of the lake between 1992-2013. *Aphanizomenon* and *Anabaena sp. (Dolichosperum)* were dominant in the majority of samples collected during this time period.

Phytoplankton are microscopic plants, also known as algae, that float in the water column of a lake. Phytoplankton photosynthesize using the sun's energy to turn carbon dioxide, nutrients and water into food for organisms higher in the food web such as zooplankton and small fish. Phytoplankton are sensitive to changes in lake ecosystems. The effects of environmental and watershed impacts can often be detected in changes in the plankton community species composition, abundance, and biomass.



Example of seasonal succession of phytoplankton communities within a lake. (Source: www.waterontheweb.com)

There are currently no zooplankton data available for China Lake. The watershed action plan recommends five years of plankton (phytoplankton & zooplankton) starting in the first year of the plan to document current baseline conditions within the plankton community, to establish successional patterns, and to monitor changes over time. This monitoring will be especially important to understanding the effects of the re-introduction of alewives on the water quality in China Lake, as well as monitoring the effects of an aluminum treatment.

CYANOBACTERIA

Cyanobacteria are present in China Lake and in lakes all around the world. Their presence, species composition, and abundance can be used as an indicator of water quality. Blue-green algae is a term formerly used to describe cyanobacteria, which are not true algae, but photosynthetic bacteria that can form dense growths (blooms) in lakes when nutrients are plentiful, water temperature is warm, and sunlight is abundant. These blooms are an indication that the ecology of the lake is out of balance.

Some forms of cyanobacteria initiate growth on the bottom, then form gas pockets in their cells and rise to the surface almost synchronously. Those cells tend to carry excess P, and once in the upper waters, they can grow with adequate light. When cells die, some portion of the P is released into the upper waters that can support other algae growth. Blooms that start on the bottom and move to the surface are therefore not just symptoms of increasing fertility, but vectors of it. Areas of fertile sediment subject to low oxygen that also recieve adequate light can be "nurseries" for cyanobacteria blooms, which is a concern as it relates to internal loading because these potential P inputs are not accounted for in the current loading model. Significant amounts of P from cyanobacteria movement might make the internal load in China Lake more important than currently estimated, but the quantity of P from this source is currently unknown.

Maine DEP is working on a statewide advisory for harmful algal blooms. Signage can be used to warn the public about HABs.

The effects of toxins produced by cyanobacteria (cyanotoxins) to humans, domestic animals, and wildlife, is closely associated with the occurrence of Harmful Algal Blooms (HABs) (US EPA, 2019). The effects are well documented, and can affect kidney, brain, and liver function. However, not all blue-green algae blooms are toxic. Microcystis is the most common bloom-forming genus, and is almost always toxic (US EPA, 2017). Microcystins are produced by several different species of cyanobacteria including *Microcystis* and *Dolichospermum*, the latter being most common in Maine. Both the Maine DEP and the US EPA are keeping an eye on HABs in Maine. Data collected on 24 blooming Maine lakes between 2008-2009 documented HAB toxins in 50% of all samples, but only three exceeded World Health Organization (WHO) drinking water guidelines, and all the samples were below the WHO guideline for recreational exposure (Maine DEP, 2017).

Microcystin samples were collected on various lakes throughout central Maine by Maine DEP in 2014 and 2015, and China Lake was included in this study. Samples were collected at four locations at Station 3 on August 25, 2014. Microcystin levels in China Lake exceeded 1.6 μg /L at both the deep hole and the downwind algae scum and exceeded 0.3 μg/L in the downwind 1 m core and deep area 3 m core. Several species of cyanobacteria were recorded in the sample, dominated by *Aphanizomenon flos-aquae* and *Anabaena variabilis* at 39% and 41% of the biovolume of the entire sample, respectively. A second sample was tested for microcystin at Station 1 on August 31, 2016. All results were below 0.1 μg/L.[22]

US EPA criteria for microcystin in **Drinking Water** are 0.3 μg/L for bottle-fed infants and pre-school children, and 1.6 μg/L for school-age children and adults. US EPA criteria for microcystin in **Recreational Water** is 8 μg/L for all ages. These recommendations stem from studies that consider magnitude, duration and frequency of exposure that are considered protective of human health. For more information on how to avoid exposure, visit the following pages at the Maine DEP website:

- https://www.maine.gov/dep/water/lakes/cyanobacteria.html
- https://www.maine.gov/dep/water/lakes/algalbloom.html

Results from hundreds of samples collected by Maine DEP from Maine lakes over the past decade indicate that only a few open water samples exceeded EPA's Drinking Water standard for the algal toxin microcystin for bottle-fed infants and pre-school age children, while no open water samples exceeded the Recreational Standard. However, very high concentrations of microcystin have been documented in algal scums that accumulate along the shore.[23]

While many states have implemented HAB response guidelines in the event of a significant bloom in recreational waterways (e.g., analyzing water, posting public advisories, beach closures, etc.), these criteria have not yet been finalized in Maine. Maine DEP is working closely with the Maine Center for Disease Control (Maine CDC) and a regional cyanobacteria working group to define these standards. A statewide advisory is expected to be released in the future similar to what was issued for the State's mercury advisory.[24] National criteria issued by US EPA are listed in the box above as well as links to more information on cyanobacteria and cyanotoxins and how to avoid exposure, visit the Maine DEP website.

Research at the University of New Hampshire has shown that reducing total phosphorus levels in lakes can significantly reduce the risks associated with cyanobacteria blooms. A survey of cyanotoxins in

[22] Personal Communication, Linda Bacon, Maine DEP. November 29, 2021.
[23] Personal Communication, Linda Bacon, Maine DEP. August 10, 2021.
[24] Personal communication (email), Linda Bacon, Maine DEP Biologist. August 8, 2017.

New Hampshire lakes has shown that in-lake P concentrations above 9-10 ppb result in a dramatic increase in the toxicity of phytoplankton.[25]

METAPHYTON

Metaphyton mass. (Photo Source: Lake Stewards of Maine, photo provided by Betsy & Dick Enright.)

Metaphyton describes filamentous algae that is typically observed in shallow littoral areas in lakes. Over the past decade, Maine DEP and Lake Stewards of Maine have received observational data and reports from volunteer lake monitors and watershed associations suggesting a significant increase in metaphyton growth in Maine lakes. Though common throughout the state, implications of an increasing trend are not well understood. There is also limited understanding of the physical, chemical, and biological role these algae play in aquatic ecosystems (Shute and Wilson, 2013). Lake Stewards of Maine has developed a standardized monitoring protocol to help lake associations and volunteer water quality monitors identify and document the location and density of metaphyton growth in their lake. It is well known that some filamentous algae favor environments with increased nutrients including nitrogen (septic systems, for example, can be a direct input of nitrogen into a lake) and phosphorus.

Metaphyton has not been tracked in China Lake, and coordinated monitoring is needed to confirm its presence and monitor its growth. Because metaphyton, like other freshwater algae, require sunlight and nutrients to survive and thrive, it is likely that watershed management, especially participation in LakeSmart, would help prevent metaphyton growth. Volunteer led surveys of the littoral zone would document the presence/absence of metaphyton in shallow areas of the lake and provide a baseline for changes in its growth overtime.

INVASIVE AQUATIC PLANTS

There are currently no reports of invasive aquatic plants China Lake, although the numerous shallow areas and recreational uses make it highly susceptible to accidental introductions. CRLA oversees the local Courtesy Boat Inspection (CBI) program that conducts boat inspections at the two public boat launches on China Lake, as well as two more boat launches on nearby Threemile and Webber ponds. The inspections aim to remove any plant material from boats entering China Lake, thereby preventing the spread of invasive aquatic plants.

[25] Personal Communication, Dr. Jim Haney, University of New Hampshire.

3. Water Quality Assessment

Water quality data have been collected by Maine DEP and certified volunteers from the Lake Stewards of Maine and KWD since 1970. This includes 48 years of data at Station 1, 46 years of data at Station 2, and 43 years of data at Station 3 over the 51 year sampling period (Figure 9).

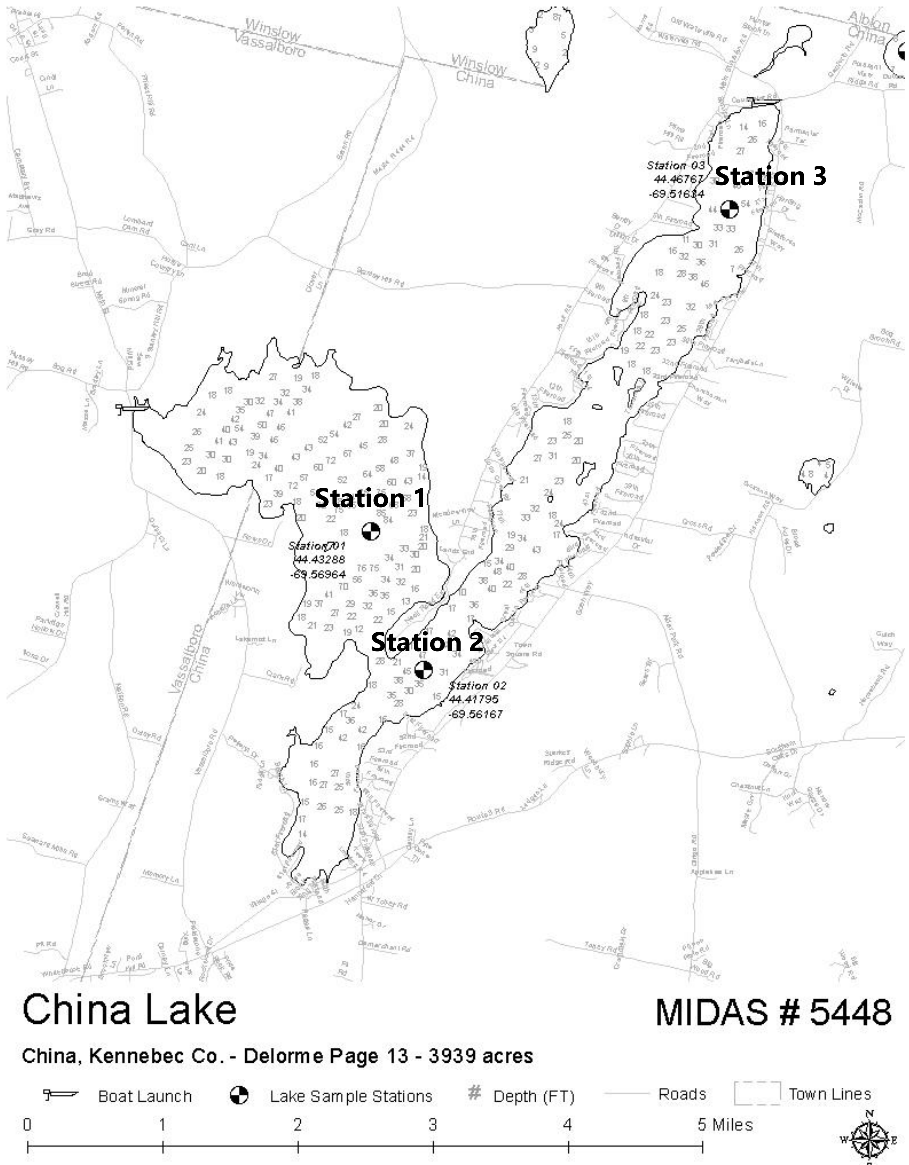


***Figure 9**. Water quality monitoring stations in China Lake. (Source: LakesofMaine.org)*

Water quality data analysis was conducted as part of the development of the 2022 WBMP. The analysis includes data collected at all three stations between April 15 and October 15, 1970 through 2020. There are two years (1974 and 1975) in which no data is available for any parameters. A more detailed summary of available data by station, year, and parameter is provided in Appendix E. In addition to the trophic state indicators described below, an analysis of color, conductivity, alkalinity, and minimum anoxic depth (MAD) was completed to assess both long-term (all data records) and short-term (last 10 years) trends. All data from a given month in a given year were averaged together, then all monthly means from that year were averaged to generate the annual average. A Mann-Kendall trend analysis was conducted on the full time series to determine if there were any significant trends in the data. Additionally, decadal medians and quartiles using all data were computed and presented as box plots for parameters with enough available data (Ecological Instincts, 2021a).

TROPHIC STATE INDICATORS

Trophic state indicators are key parameters for measuring lake productivity; when adequate data density exists, these can be used to calculate a Trophic State Index (TSI). The three primary trophic state parameters are SDT, Chlorophyll-a (Chl-a) and total phosphorus (TP). Statewide, TSI for SDT ranges from 8-136 with a mean of 45 (Lake Stewards of Maine, 2020b). The most recent year with TSI SDT data available is 2018, with TSI ranging from 47 (Station 3) to 56 (Stations 1 & 2). Lakes with a TSI >60 are considered productive, 30 – 60 are moderately productive, and <30 are unproductive. Less productive lakes are typically clearer, colder, and have less algae than productive lakes. The elevated TSI indicates that China Lake on the high end of a moderately-productive lake.

In order to calculate a reliable TSI, there must be five months of data during the open water monitoring season with a minimum of one reading/month. It is not permissible to be missing any two consecutive months of data. Consistent collection of these three parameters will provide the data to calculate annual TSI values for conducting short- and long-term trend analysis to determine if the lake is becoming more productive or less productive overtime.

WATER CLARITY

Measuring water clarity (aka transparency) is one of the most useful ways to show whether a lake is changing from year to year. Changes in transparency may be due to increased or decreased algal growth and/or the amount of dissolved or particulate materials in the lake from human disturbance or other impacts to the watershed. Since algal density is usually the most common factor affecting transparency in Maine lakes, transparency is an indirect measure of algal abundance. Water clarity is measured using a Secchi disk. Transparency readings of 2 m or less generally indicate an algal bloom is occurring.

SDT readings have been collected at China Lake from 1970 – 2020 including 48 years of measurements over the 51-year sampling period. SDT at all three stations has ranged from 1.0 m to 10.3 m, with the maximum SDT being recorded at Station 2 in 1988. Minimum SDT was 2 m or less, in 29 to 32 of the 48 years sampled, depending on the station (Figure 10). The 2020 average for all three stations was slightly lower than the historical mean of 3.7 m. Average SDT in China Lake is 3.4 m at Station 1 (Figure 11), which is below the statewide average of 4.8 m.

Secchi Disk Transparency (SDT)

A vertical measure of water transparency (ability of light to penetrate water) obtained by lowering a black and white disk into the water until it is no longer visible. Measuring SDT is one of the most useful ways to show whether a lake is changing from year to year.

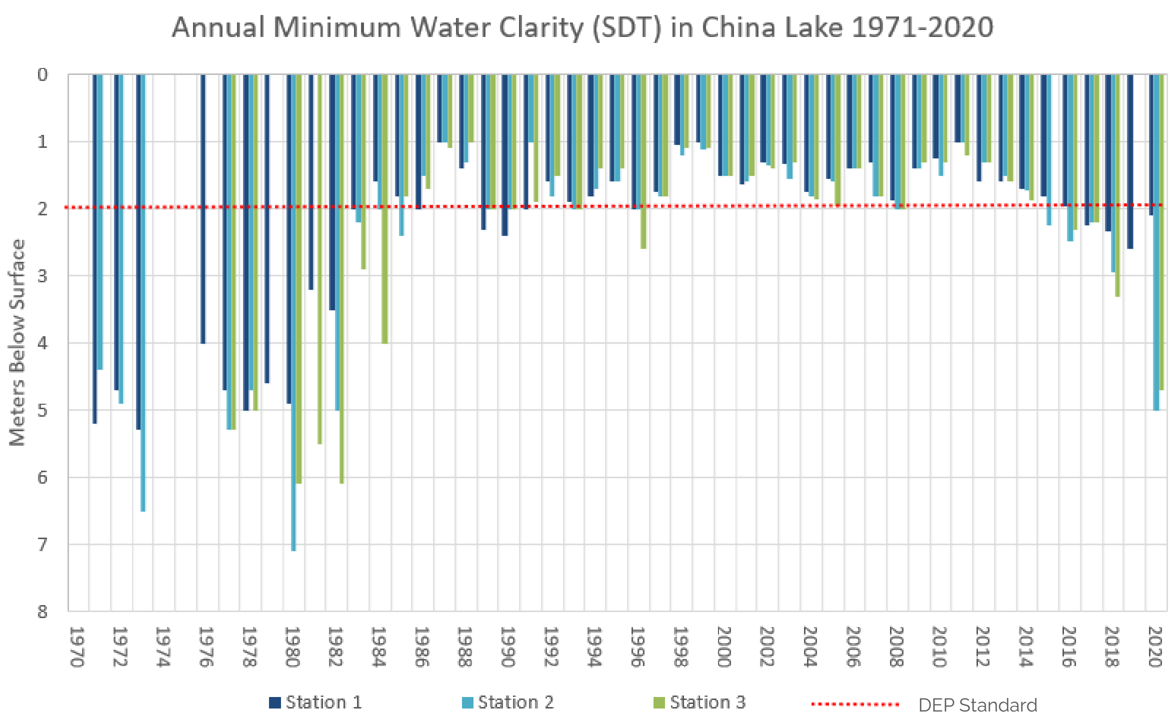


Figure 10. *Minimum annual SDT for China Lake, all Stations (1970 – 2020).*

A Mann-Kendall trend analysis was conducted on the time series of the yearly median to determine if there was any significant trends in the data for the whole time series and for the past 10 years. Decadal medians and quartiles using all data were also computed and presented as box plots.

The SDT trend in China Lake is significant for the full time series at all three stations, indicating a decrease in water clarity over time**.** Figure 11 (below) is representative of the long-term water clarity trend in China Lake showing an approximately 3m decline in clarity over a 30-year period between 1970 to 2000, which leveled off around 3 m depth over the past 20 years.

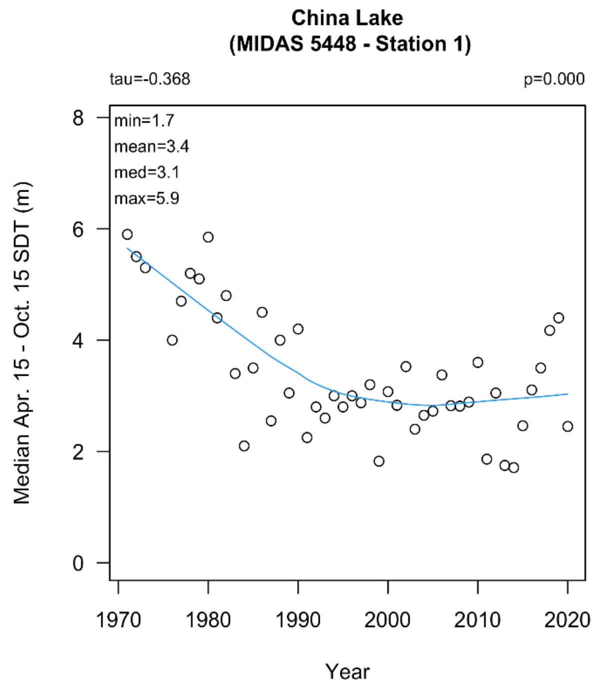


***Figure 11**. Trend plot of SDT at Station 1 over the entire sampling period with results of Mann-Kendall Trend Tests.*

The water clarity trend over the past 10 years is not significant at any station, likely due to the poor SDT in 2020. Decadal medians at Station 1 (Figure 12) show the lowest SDT in 2020 (the worst water clarity), while the 1970s had the highest SDT median (the best water clarity). This trend is similar at Stations 2 and 3 in the east basin as well.

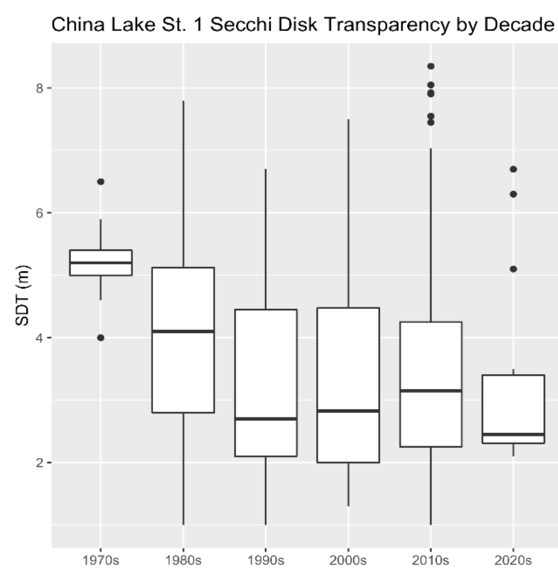


***Figure 12**. Decadal means for SDT in China Lake, Station 1.*

TOTAL PHOSPHORUS

Total phosphorus (TP) is the concentration of phosphorus found in the water, including organic and inorganic forms. P is one of the major nutrients for plant growth. It is generally present in small amounts and limits plant growth in freshwater ecosystems. As phosphorus increases, the amount of algae generally increases. Human activity adds phosphorus to a lake through stormwater runoff from developed land areas including agricultural land, logging operations, and residential development.

TP in China Lake has been measured by collecting both epilimnetic core samples, profile grabs, and bottom grab samples. Epilimnetic core sampling involves collecting an "integrated core sample" from the epilimnion of the lake (representing the water column from the surface of the lake to the bottom of the epilimnion). The depth of the epilimnion is determined by changes in the dissolved oxygen and temperature profiles which varies throughout the year. In China Lake, the depth of the epilimnion is typically between 6 and 9 m during the open water season. Profile grabs are collected at various depths throughout the water column, and bottom grab data includes any grab sample with a depth of 21 m or deeper at Station 1, and 14 m or deeper at Stations 2 and 3. Most bottom grab data was collected at Station 1.

Epilimnetic TP samples have been collected between April – October at China Lake with the total number of years varying by station (35 years at Station 1, 20 years at Station 2, and 29 years at Station 3). Epilimnetic TP samples at Station 1 have ranged from 2 ppb to 80 ppb with an average of 17 ppb. At Station 2, epilimnetic TP has ranged from 11 to 50 ppb, with an average of 18.5, and at Station 3 it has ranged from 9 to 32 ppb, with an average of 18 ppb. Statewide, total phosphorus ranges from 1 - 137 ppb with an average of 12 ppb, indicating that China Lake has higher levels of phosphorus compared to lakes statewide.

A Mann-Kendall trend analysis was conducted on the time series of the yearly median to determine if there were any significant trends in the data for the whole time series at all stations and for the past 10 years at Station 1. Stations 2 and 3 had insufficient data over the past 10 years to run an analysis for that time period alone. Decadal medians and quartiles using all data were also computed and presented as box plots (Figure 13).

None of the three stations showed a significant trend over the entire sampling period, however, the Mann-Kendall test shows a significant decreasing trend (less phosphorus) at Station 1 over the past 10 years (Figure 14) that could be related to drought conditions. Decadal medians for Station 1 showed the lowest TP in the 1970s; the 1990s and 2000s had the highest TP median. At Station 2, decadal medians show the lowest TP in the 1980s with the rest of the decadal medians (including 2020) not varying much. At Stations 2 and 3, 2020 had a lower 95th percentile of TP than previous decades. The

TP trend for bottom grabs was not significant at any of the three stations, either for the entire sampling period or the past 10 years.

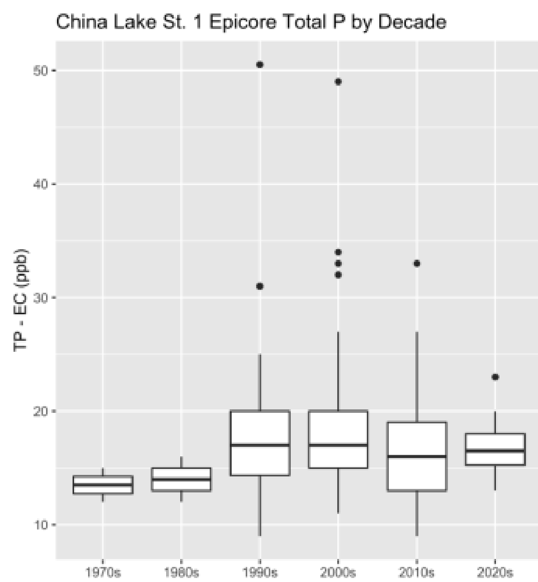


Figure 13. *Decadal medians for TP in China Lake, Station 1.*

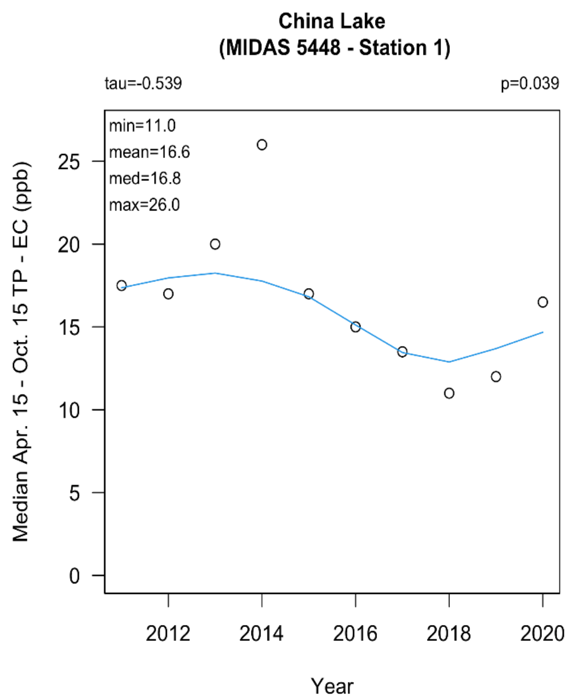


Figure 14. *Trend plots of epilimnetic TP over the past 10 years for China Lake, Station 1 with results of Mann-Kendall Trend Tests.*

CHLOROPHYLL-A

Chlorophyll-a (Chl-a) measures the green pigment found in all plants, including microscopic plants such as algae. It is used as an estimate of algal biomass; higher Chl-a equates to a greater amount of algae in the lake. Chl-a in China Lake was measured by collecting an integrated core sample from the epilimnion of the lake.

Chl-a samples from China Lake were collected in 40 years at Station 1, 36 years at Station 2, and 31 years at Station 3. Chl-a at Station 1 has ranged from a low of 1.1 ppb (2017) to a high of 53 ppb (2011), with an average of 11.5 ppb. (Figure 15). At Station 2, Chl-a has ranged from 2 ppb (2001) to 69 ppb (2011), with an average of 11.5 ppb. At Station 3, Chl-a ranged from 0.7 ppb (1992) to 82 ppb (2000), with an average of 11.1 ppb. Chl-a concentration in China Lake typically begins to increase as early as July in some years, peaking in late August, when the lake has warmed up and nutrients are readily available, and persisting through October. Statewide, Chl-a ranges from 0.7 - 182 ppb with an average of 5.4 ppb. Chl-a levels in China Lake are elevated, and higher than the state average, indicating there is an abundance of algae in China Lake during the open water season during most years. Since algae rise to surface waters for access to light and available nutrients, they can get blown by the wind, accumulating along shorelines and in coves. Though the concentration of algae may be noticeable to residents, these concentrated build-ups may not be fully reflected in the analysis.

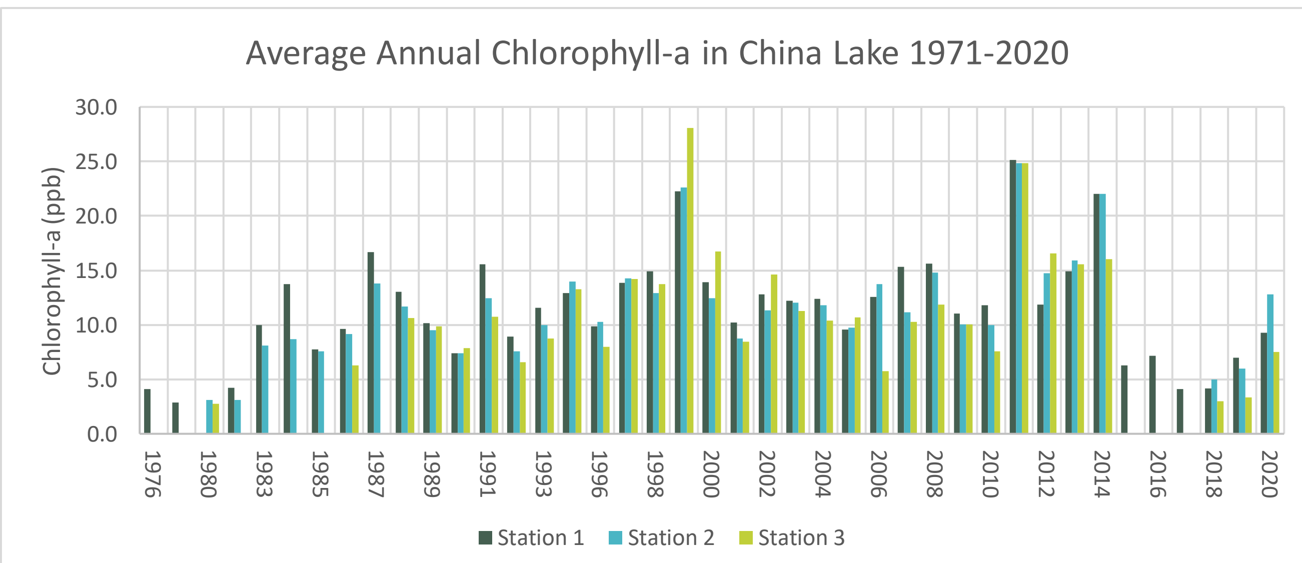


Figure 15. *Mean annual Chl-a for China Lake, Stations 1, 2, and 3.*

At Station 2, the Chl-a trend is significant across the time series (Figure 17) and indicates an increase in chlorophyll-a. Decadal medians show the lowest Chl-a in the 1980s; the 2010s had the highest average Chl-a median. 2020 saw a slight improvement over the 2010s (Figure 17b). At Station 3, the Chl-a trend is not significant, likely due to a peak in the 2010s. Decadal medians show the lowest Chl-a in the 1980s; the 2010s had the highest Chl-a median. 2020 saw an improvement over the 2010s.

At Station 1, the Chl-a trend for the full time series is not significant but the trend over the past 10 years (Figure 16) shows a significant decreasing trend (less chlorophyll) that could be related to drought conditions.

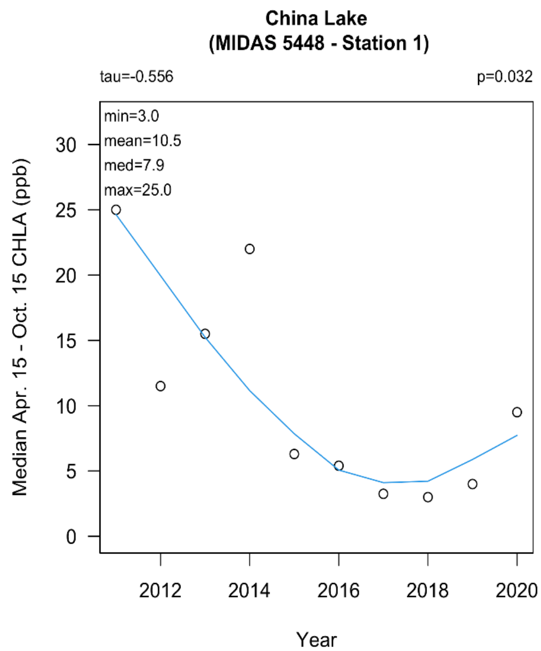


Figure 16. Trend plots of Chl-a over the past 10 years for China Lake, Station 1 with results of Mann-Kendall Trend Tests.

DISSOLVED OXYGEN

The concentration of oxygen dissolved in water is the "dissolved oxygen" or DO, measured in milligrams per liter (mg/L) or parts per million (ppm). It is a critical indicator of lake health and water quality. Oxygen is vital to fish, macrophytes, algae, and chemical reactions that support lake functions. Coldwater fish need at least 5 ppm of dissolved oxygen to survive, and even higher levels for young fish to grow and thrive. Coldwater fish also prefer water that is less than 18°C (64°F) but can tolerate temperatures up to 24°C (75°F). In the summer, the sun warms the surface water, forcing coldwater fish to move to areas with cool, well-oxygenated water. Fish kills can occur when the water warms up too quickly and there is not enough oxygen in the water for the fish to survive.

In addition to time of year and basin morphometry, DO concentrations in lake water are influenced by several factors, including water temperature, concentration of algae and other plants in the water, decomposition in bottom waters, and the amount of nutrients and organic matter flowing into the lake as runoff from the watershed. DO is measured using a dissolved oxygen meter and probe that is lowered through the water column with readings generally obtained at one-meter increments.

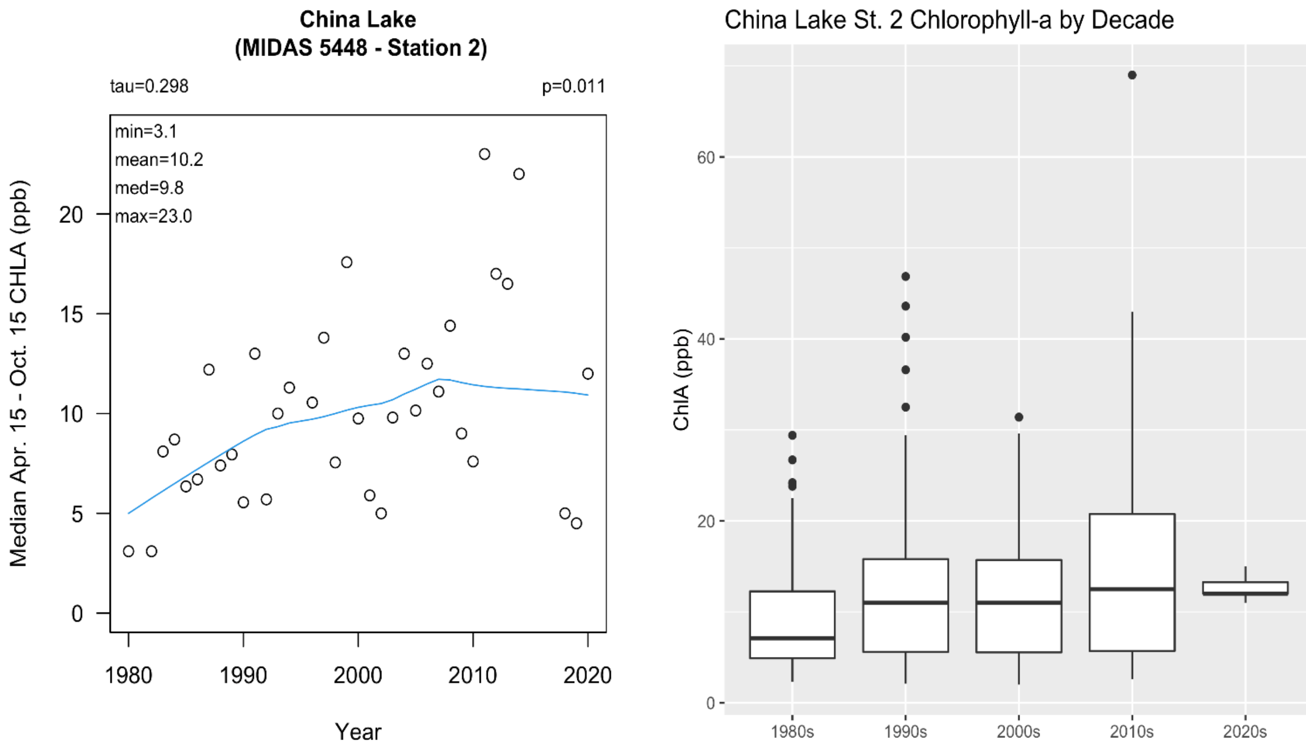


Figure 17a & 17b. *Trend plot of Chl-a over the entire sampling period (left) and decadal means (right) for Chl-a in China Lake, Station 2.*

Summer DO concentrations can change dramatically with lake depth, as oxygen is produced in the top portion of the lake (where sunlight drives photosynthesis) and oxygen is consumed near the bottom of the lake in the hypolimnion (where organic matter accumulates and decomposes). In stratified lakes, such as China Lake, the DO concentrations from top to bottom can be very different, with high levels of oxygen near the surface and little to no oxygen near the bottom, especially during the summer and fall when water temperature and decomposition are at their highest.

> ***Hypolimnion –*** the bottom layer of a thermally stratified lake. The hypolimnion is typically cooler and may be lower in oxygen than the warmer, oxygenated epilimnion above.

Stratification prevents atmospheric oxygen from reaching the deep areas via wind and wave action, cutting off the oxygen supply for coldwater fish that need cool, well-oxygenated water to survive. In addition, microbial respiration (microbes breaking down decaying plant and animal matter) at the bottom of the lake consumes oxygen resulting in loss of DO in deep areas of the lake (anoxia). In China Lake, excess P in the bottom sediments, thermal stratification, anoxia, and sediment chemistry results in the release of P from the sediments (internal loading). This P can diffuse into overlaying waters fueling algal growth and persistent, recurring nuisance algal blooms.

A review of 38 years of available dissolved oxygen profiles was conducted to determine the extent of anoxia at the bottom of the lake. This included plotting the 2020 DO profiles to assess the onset of hypoxia (DO<5 ppm), onset of anoxia (DO<2 ppm), and running a Mann-Kendall Trend Analysis on minimum anoxic depth (MAD-the shallowest depth where DO is <2 ppm). MAD is an indicator of the volume of anoxic water in lakes - the shallower the MAD, the larger the anoxic volume.

The shallowest depth where DO <2 ppm at Stations 1 and 2 is 7 m. At Station 3, the shallowest depth where DO <2 ppm at is 6 m, recorded in 2013 and 2020. Generally, the lake is well mixed in April and May due mainly to cool air temperatures, with DO ranging from 10 – 13 ppm from the surface to depth at Station 1. The lake begins to stratify in June due to warmer air temperatures and sufficient periods of calm days. By early July anoxia begins to set in with DO <5 ppm at depths >20 m at Station 1, and below 7 m by early August. Oxygen in the deepest areas in the lake low until the lake mixes in mid to late-October. The higher the extent of anoxia, the more likely that an algal bloom will occur as phosphorus rich bottom water becomes more available to light-loving organisms. By mid-October, the lake begins to mix again and remains mixed through the end of the sampling season limiting anoxic conditions in the lake bottom but bringing P-rich bottom water to the surface.

Anoxia sets up even earlier at Stations 2 and 3, with DO <5 at Station 2 before the end of June at 10 m and deeper, extending up to 6 m and deeper by mid-August (Figure 18), but mixing earlier in October than at Station 1. A similar pattern was observed at Station 3 in 2020.

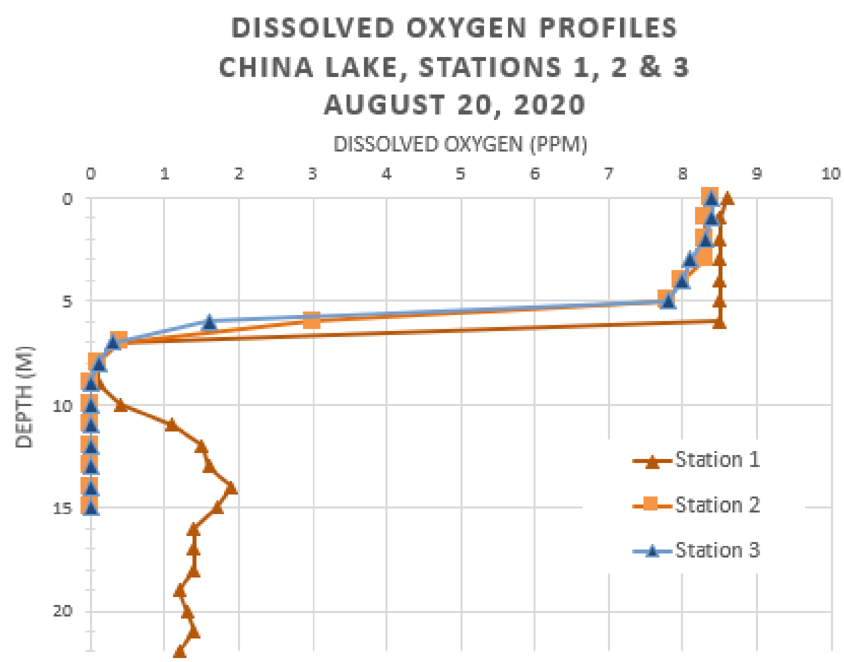


Figure 18. *August 2020 dissolved oxygen profiles at China Lake, Stations 1, 2 & 3.*

Phosphorus mass graphs were completed for each station highlighting the timing of phosphorus release and the magnitude of change in the amount of phosphorus in the lake. P mass graphs are presented in Appendix F. In 2020, the mass of P at Stations 1 and 2 (east basin) peaked in mid-September and was driven by anoxia and internal P loading. P peaked slightly later at Station 1 (west basin), reaching its maximum in mid-October when the lake began to mix. An increase in water temperature is directly correlated with the decrease in dissolved oxygen. High temperatures in China Lake occur in July and August when anoxia is at its peak. [26] Over the last several decades air and surface water temperatures have been increasing. Surface water temperatures in northern New England have increased 1.4°F per decade from 1984-2014, which is faster than the world-wide average, with Maine lakes warming on average by nearly 5.5°F during this time period (MCC STS, 2020). Data also show that smaller lakes and ponds are warming more rapidly than larger lakes.

Ongoing monitoring of the changes in both temperature and dissolved oxygen will be critical for documenting localized changes in China Lake. Oxygen demand is affected by temperature, with a doubling of demand with as little as a 4ºC increase. Increased demand could increase the area exposed to low oxygen and the duration of that exposure, leading to an increase in internal loading.

A Mann-Kendall trend analysis was conducted for MAD at each station on the full time series and the past 10 years to determine if there were any significant trends in the data. At Station 1 and Station 2, the MAD trend is significant for the full time series and indicates an increase in the amount of anoxic volume over time. There was no trend over the full time series at Station 3, or over the past 10 years for any station.

Duration of stratification and oxygen demand were assessed by WRS as part of the internal loading analysis and determined not to have changed appreciably over time in China Lake (WRS, 2021). Based on selected years in each of the last four decades, oxygen demand at both stations in the east basin is between 1.2 and 1.3 $g/m^2/d$ with a range of 0.8 to 2.3 $mg/m^2/d$. This is enough oxygen demand to cause anoxia in early summer but is not an extreme range or average. Oxygen demand in the west basin averages 2.3 $g/m^2/d$, about twice that of the east basin, with a range of 1.9 to 2.8 $g/m^2/d$. While the demand is higher, the volume of water affected is also larger, and low oxygen is not experienced until late in July in nearly all years examined. A higher oxygen demand was expected for at least the northern portion of the east basin, with highly organic sediment and a faster onset of low oxygen but is not supported by the available data. The depth at which oxygen gets lower than 2 ppm did get shallower between about 1980 and 2005 but has not gotten shallower since then and oxygen status has been an issue since at least 1980.

[26] In 2020 surface water temperatures were highest at Station 3 on 7/9/20 (25.9°C) and 25.3°C at Station 1 on 8/6/20.

OTHER PARAMETERS

Color, alkalinity, pH, and specific conductance data for China Lake were included in the water quality analysis but no statistically significant trends were identified. A summary of these results are presented in a water quality memo prepared by Ecological Instincts (2021). A summary of results for these parameters is provided below:

- Color data has been collected at China Lake in four years at Station 1, three years at Station 2, and two years at Station 3. Average annual true color ranges from 6.0 (Station 1 in 2016) to 9.0 (Station 2 in 2013). Based on limited available data, the highest average color is at Station 2 (8.1 PCU) compared to 7.1 PCU and 7.4 PCU at Stations 1 and 3, respectively. **China Lake is considered a lightly-colored lake.**
- At Station 1, alkalinity ranges from 15 – 25 annually, with an average of 19 ppm. At Station 2, alkalinity ranges from 17 – 20 ppm, and from 13 – 24 ppm at Station 3, similar to the range at Station 1. **Alkalinity at all three stations is slightly higher than the average for all Maine Lakes (12 ppm), ranging from 13-25 ppm.**
- pH was measured at China Lake in eight years at Station 1, six years at Station 2, and seven years at Station 3, and found to be slightly alkaline, averaging 7.3 at Stations 1 and 2, and 7.4 at Station 3. **These values are slightly higher than the average for lakes statewide (6.8), but well within the expected range for lakes in the northeast (6 – 8).**
- Specific conductance (SpC) has been collected at China Lake in five years at Station 1, and four years at Stations 2 and 3.[27] The range of conductivity in China Lake is 49 µS/cm (2007, Station 1) to 100 µS/cm (2001, Station 3) with average annual averages ranging from 76 - 89 µS/cm. **This is higher than both the statewide average for Maine lakes (50 µS/cm), and the reference range for lakes with similar hydrogeomorphic characteristics.** The highest readings have been recorded at Station 3 in the north end of the east basin. Higher levels of conductivity may indicate a greater concentration of pollutants in the water. Reference lakes in the Central Maine Embayment/Coastal Deep Lakes (>10 m) exhibit specific conductivity values less than 31 – 37 µS/cm, whereas altered lakes have conductivity values greater than 62 - 70 µS/cm (Deeds, et. al., 2020).[28]

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[27] Additional conductance data was collected by KWD using a YSI hand-held meter between 2009 – 2013 but was not used for the analysis due to difference in methods. The last recorded sample in the state database was collected by DEP in August 2016 using a different method than the previous data at Station 1 with a value of 85 µS/cm, similar to results from previous years using different methods.

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CONDITION ANALYSIS

Maine DEP recently published a classification and condition analysis for Maine lakes (Deeds, 2020). Based on this analysis, China Lake is classified as a “coastal deep lake”, and its watershed is considered “altered” due to the level of human activity it contains. Table 6 (below) presents the ranges of water quality parameters observed in coastal ponds for each condition class.

According to this analysis, China Lake falls within the range for ‘Altered’ coastal lakes in total phosphorus and specific conductance. Total phosphorus can be indicative of watershed development, while specific conductance is directly related to the level of dissolved ions in the water. Higher levels of conductivity can indicate a greater concentration of contaminants such as septic systems or road salt that suggest human activity in the watershed.

Table 6. *Coastal pond lake type: water quality parameter ranges for China Lake, Station 1.*

	Condition Classes			**China Lake**
Parameter	**Reference**	**Intermediate**	**Altered**	
Total Phosphorus - Epilimnion Core (ppb)	< 8.3 ± 0.7	8.3-13.4	>13.4 ± 4	**17-18.5**
Specific Conductivity (μS/cm)	< 34.2 ± 3.2	34.2-66.3	≥ 66.3 ± 4	**76-89**

4. Watershed Modeling

The Lake Loading Response Model (LLRM) is an Excel-based model that uses environmental data to develop a water and P loading budget for lakes. Water and P loads (in the form of mass and concentration) are traced from various sources in the watershed to the lake. The model requires detailed and accurate information about the waterbody, including the type and area of land cover, water quality data, lake volume, septic systems, and internal loading estimates, among other important information.

The following describes the process by which these critical inputs were determined and utilized for the China Lake LLRM using available resources and presents predicted outputs including how much and where P is coming from in the watershed, as well as in-lake annual average predictions of TP, Chl-a, and SDT. The outcome of this model can be used to identify current and future pollution sources, estimate pollution limits, set water quality goals, provide insight on where future monitoring is needed, and guide prioritization of on-the-ground watershed improvement projects (Ecological Instincts, 2021b).

WATERSHED AND SUB-BASIN DELINEATIONS

China Lake (3,939 acres) has a moderate surface area and a moderately large watershed (27 sq. mi.; 17,577 acres), which is drained by several perennial tributaries (Ward Brook, Hunter Brook, Starkey Brook, and Jones Brook), numerous intermittent streams, and the direct shoreline drainage areas. All watershed boundaries were obtained from USGS as part of the National Hydrography dataset – HUC 12 watershed boundary data. China Lake is part of the HUC12 (Region 1) 010300032104 watershed which includes all of the sub-basins of the China Lake watershed.

The LLRM is set up to estimate the loading from up to ten contributing subwatersheds. Sub-basin delineations were completed in ArcMap using NHDPlusHR "Catchments" data downloaded for this region of the USGS National Map in view[29], ME Drainage divides layer from Maine GeoLibrary[30], and Maine State Elevation Contour layer from MaineGeoLibrary[31] as guides to determine topography breaks between each sub-basin (Figure 19).

[29] https://viewer.nationalmap.gov/basic/?basemap=b1&category=nhd&title=NHD%20View
[30] https://www.arcgis.com/home/item.html?id=d1ecbcdb35a84dc28958169246e784af
[31] https://gis.maine.gov/arcgis/rest/services/Elevation/Maine_Elevation_Contours_2_Feet_19T/MapServer

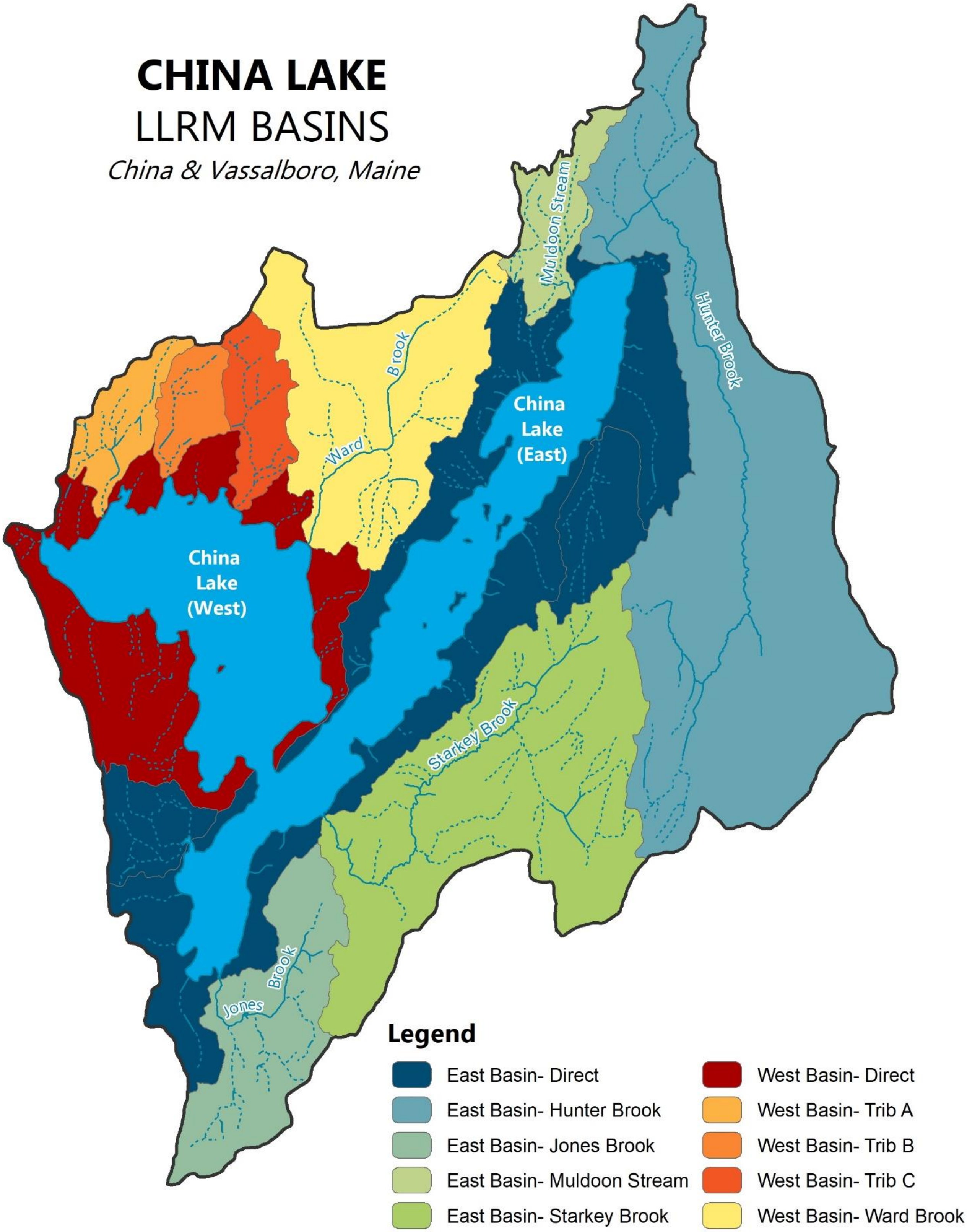


Figure 19. *China Lake direct and indirect watersheds and sub-basins used in the China Lake LLRM.*

LAND COVER

The delineated basins layer was combined with the updated land cover layer to create a land cover breakdown for each major and minor basin for use in the watershed model. Table 7 displays the combined land cover types and the associated P export coefficients selected for the China Lake model.

Table 7. *Land cover phosphorus coefficients and land cover areas for China Lake.*

LAND COVER TYPE	Runoff phosphorus export coefficient	Baseflow phosphorus export coefficient	Area (hectares) China Lake Watershed
Urban 1 (Low Density)	0.50	0.010	412
Urban 2 (Med Density Res/Comm)	0.70	0.010	75
Urban 3 (Roads)	0.50	0.010	131
Urban 4 (Unpaved Roads)	0.70	0.010	14
Urban 5 (Mowed Fields)	0.45	0.010	271
Agric 2 (Row Crops)	1.00	0.010	434
Agric 3 (Pasture/Hayland)	0.60	0.010	251
Agric 4 (Feedlot)	0.30	0.010	143
Forest 1 (Upland Forest)	0.08	0.005	3814
Forest 4 (Forested Wetland)	0.10	0.005	1050
Forest 5 (Scrub Shrub)	0.08	0.005	62
Open 1 (Water) –*not including China Lake*	0.10	0.005	89
Open 3 (Bare/Excavation)	0.70	0.010	49
Other 1 (Freshwater Emergent Wetland)	0.15	0.005	193
Other 2 (Timber Harvesting)	0.25	0.005	124
TOTAL			**7,101**

Figure 20 presents an overview of general land cover types for the China Lake watershed (below, left), and the corresponding total phosphorus load (below, right). Agricultural land accounts for approximately 12% of the watershed area but contributes approximately 38% of the (external) watershed phosphorus load. Forestland (including timber harvesting) covers the largest area of the watershed (56%) yet accounts for just 21% of the phosphorus load to China Lake (Figure 20). Phosphorus loading from the east basin accounts for 74% of the total P load compared to 26% from the west basin indicating that land cover types are not uniform across sub-basins.

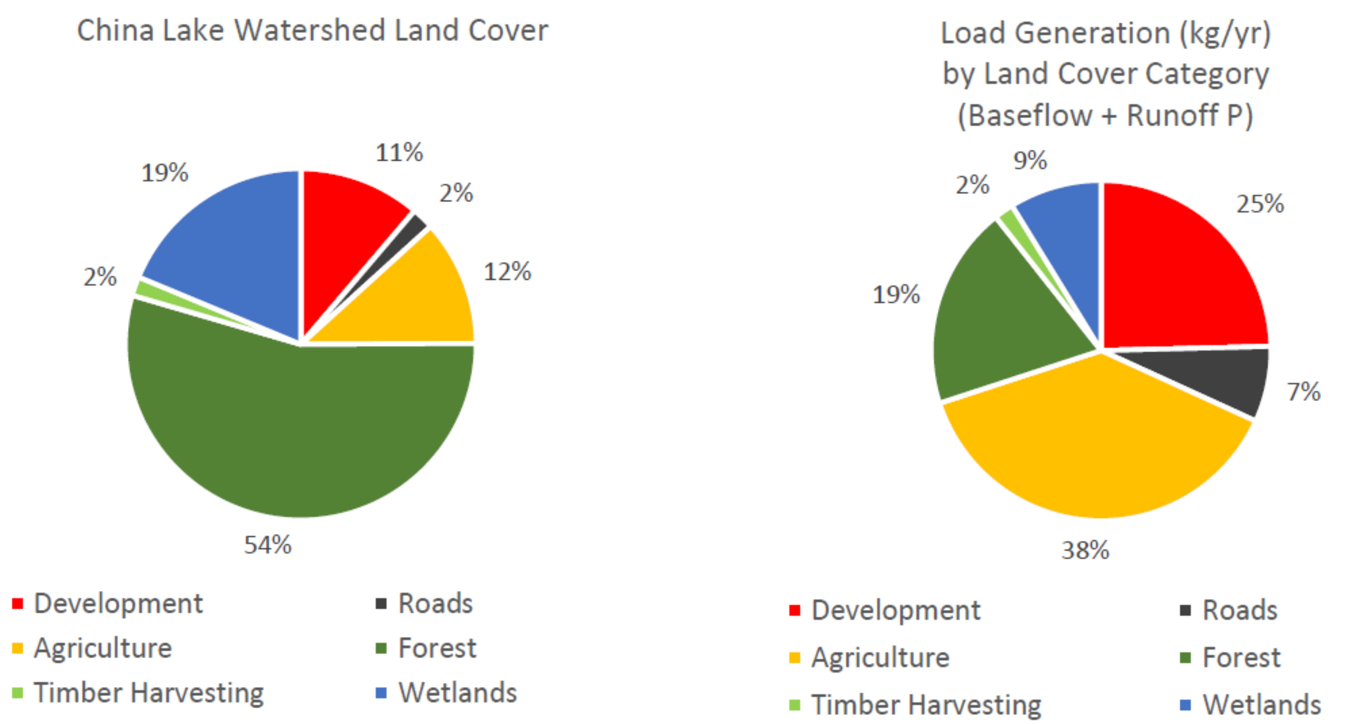


Figure 20. *Watershed land cover area by general category and total phosphorus (TP) load by general land cover type.*

OTHER MAJOR LLRM INPUTS

Other variable sources and assumptions used in the China Lake LLRM include:

- *Annual precipitation* data were obtained from NOAA National Climatic Data Center (NCDC) from 2010-2020 to calculate a 10-yr. average for annual rainfall. The station in Waterville, ME (Station ID: USC00179151) was selected for this exercise.
- *Atmospheric Deposition* a P export coefficient of 0.1 kg/ha/yr was used in the model, which aligns with coefficients being used in current LLRM models for other Maine lakes with mainly forested watersheds.

- *Lake area* was updated from the Maine DEP reported surface area and is based on results of the bathymetric survey completed by Dan Buckley (UMF) and updated in 2021 by Tara King (USDA/NRCS).
- *Lake volume* was also updated from the Maine DEP reported value and is based on results of the bathymetric survey completed by Dan Buckley (UMF), updated in 2021 by Tara King (USDA/NRCS), and revised by Amanda Pratt (Maine DEP) in October 2021.
- *Septic system data* estimates are based on numbers provided by Janet Preston (Town of China) in 2021 that includes details on the total number of septic systems around China Lake, location, type, seasonality of use, and distance from the lake.
- *Water quality data* were obtained from Maine DEP and KWD. Data was sorted by station and parameter. Target in-lake phosphorus concentration used to calibrate the model is based on the recent 10-year annual average of epilimnetic core samples collected at all stations.
- *Waterfowl counts* assumed to be roughly 100 waterfowl units contributing to the phosphorus load for half the year. There are no available data on the number of waterfowl on the lake, so 100 was used as a conservative estimate. Waterfowl can be a direct source of nutrients to lakes, however, if they are eating from the lake, and their waste returns to the lake, the net change may be less than might otherwise be assumed; however, the phosphorus excreted may be in a form that can readily be used by algae.
- *Internal phosphorus loading* was calculated by WRS, Inc. in 2021 utilizing available bathymetry, water quality, and sediment data for China Lake.
- *Separation of east and west basins-* Because the east and west basins of the lake function as separate waterbodies with the east flowing to the west, the LLRM better represents observed conditions when the basins are split, and the east basin is treated as one of the drainage areas for the west basin. For modeling purposes all sub-basins draining to the east basin were combined into a single drainage area to estimate P loading to the west basin.

Information about model calibration, limitations, and assumptions are provided in Appendix G.

BACKGROUND CONDITIONS

Once the China Lake LLRM was calibrated for the current in-lake P concentration, land cover and various other model factors were adjusted to estimate pre-development loading conditions to provide an approximation of the in-lake P concentration prior to human development in the watershed. Methodology for the background conditions scenario include:

1. Converted all human land cover (Urban related and Agricultural land cover categories) to upland forest (Forest 1) for all sub-basins A through J.
2. Removed all septic inputs (set # of dwellings to zero).

3. Reduced internal loading to about 10% of the current modeled internal load.
4. Reduced atmospheric loading coefficient to 0.05 kg/ha/yr.
5. Matched outflow TP to predicted in-lake TP.

RESULTS

Internal loading is the largest contributor of P to China Lake, representing approximately 45% of the P load in the east basin (729 kg/yr) and 40% in the west basin (643 kg/yr)[32] followed by the watershed load (40% east basin, 38% west basin) (Table 8 & Table 9, Figure 21 & Figure 22). In the east basin where the majority of shoreline development is located, septic systems make up 7% of the P load with atmospheric deposition and waterfowl accounting for an estimated 5% and 1% of the remaining load, respectively. In the west basin, where the immediate shoreline has been protected from development by KWD as a source water protection measure, septic systems make up <1% of the P load, and atmospheric deposition and waterfowl accounts for an estimated 5% and 1% of the remaining load, respectively.

The background watershed P load to the east basin of China Lake is estimated at 372 kg/yr (4.2 ppb in-lake concentration), representing a small fraction the current watershed load to the east basin (1,612 kg/yr; 18.3 ppb in-lake concentration) (Table 8, Figure 21). The background watershed P load to the west basin of China Lake is estimated at 376 kg/yr (3.5 ppb in-lake concentration), compared to the current P load to the west basin of 1,611 kg/yr (15 ppb in-lake concentration) (Table 9, Figure 22).

This exercise indicates a significant increase in not only the watershed P load to China Lake in both basins from pre-development to present, but also a large increase in the internal P load. In both basins, the watershed load, which was once the dominant pre-development source of P to the lake is now second to the internal load.

[32] It is estimated that approximately 55% of the east basin load to the west basin is from the watershed of the east basin, and 45% is derived from the internal load in the east basin delivered to the west basin. Combining the internal load in the west basin with the internal load delivered from the east basin, internal load derived P is 56% of the total load to the west basin.

***Table 8**. Total phosphorus and water loading summary from internal and external watershed sources for the East Basin of China Lake.*

LLRM LOAD SUMMARY COMPARISON	BACKGROUND (EAST BASIN)			CURRENT (EAST BASIN)		
	P (kg/yr)	%	Water (m^3/yr)	P (kg/yr)	%	Water (m^3/yr)
INTERNAL	**54**	**15%**	**0**	**729**	**45%**	**0**
EXTERNAL						
ATMOSPHERIC	44	12%	9,328,260	87	5%	9,328,260
WATERFOWL	20	5%	0	20	1%	0
SEPTIC SYSTEM	0	0%	0	112	7%	102,656
WATERSHED LOAD	254	68%	27,920,372	664	41%	27,679,514
SUBTOTAL EXTERNAL LOAD	***318***	***85%***	***37,248,682***	***883***	***55%***	***37,110,431***
TOTAL LOAD TO LAKE	**372**	**100%**	**37,248,632**	**1,612**	**100%**	**37,110,431**

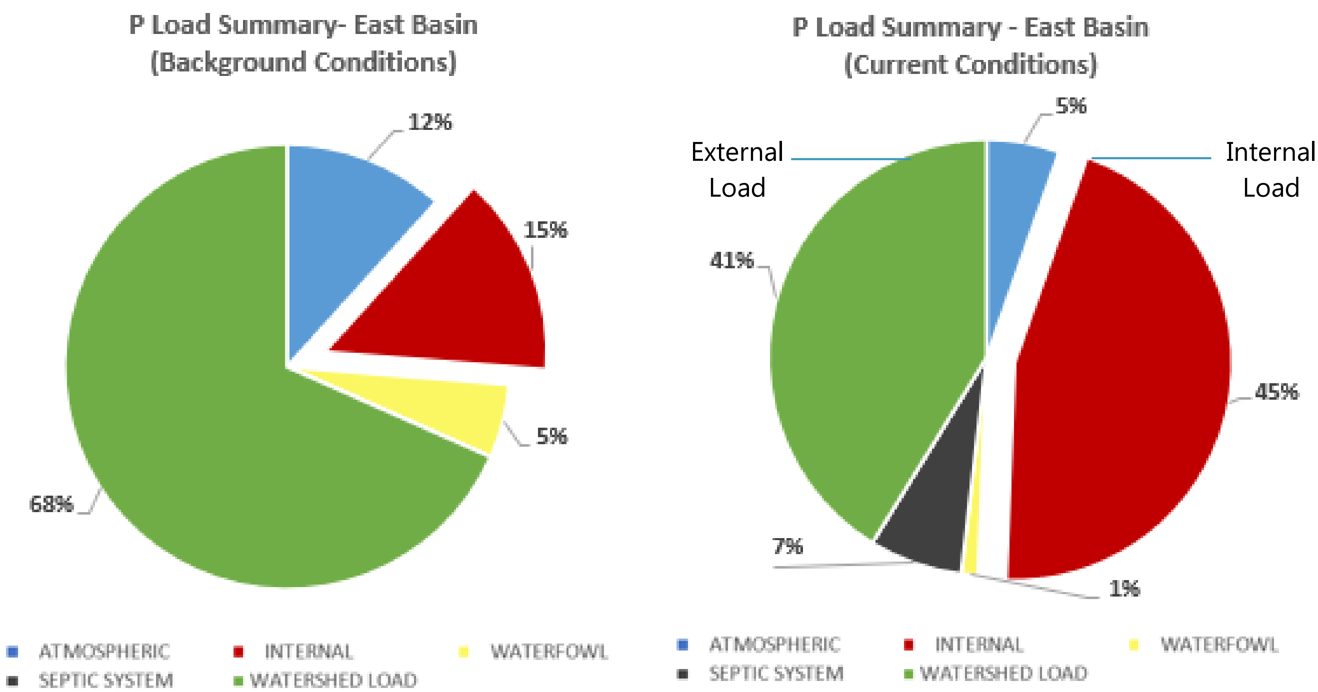


***Figure 21**. Percentage of total phosphorus loading (kg/yr) by source (atmospheric, internal loading, waterfowl, septic systems, watershed load) to China Lake, East Basin.*

Table 9. *Total phosphorus and water loading summary from internal and external watershed sources for the West Basin of China Lake.*

LLRM LOAD SUMMARY COMPARISON	BACKGROUND (WEST BASIN)			CURRENT (WEST BASIN)		
	P (kg/yr)	%	Water (m^3/yr)	P (kg/yr)	%	Water (m^3/yr)
INTERNAL	**75**	**20%**	**0**	**643**	**40%**	**0**
EXTERNAL						
ATMOSPHERIC	37	10%	7,860,220	73	5%	7,860,220
WATERFOWL	20	5%	0	20	1%	0
SEPTIC SYSTEM	0	0%	0	1	<1%	456
LOAD FROM EAST BASIN	130	35%	29,798,906	564	35%	296,88,345
WATERSHED LOAD	114	68%	9,806,106	309	19%	9,971,947
SUBTOTAL EXTERNAL LOAD	***301***	***118***	***47,465,232***	***967***	***60%***	***47,520,968***
TOTAL LOAD TO LAKE	**376**	**100%**	**47,465,232**	**1,611**	**100%**	**47,520,968**

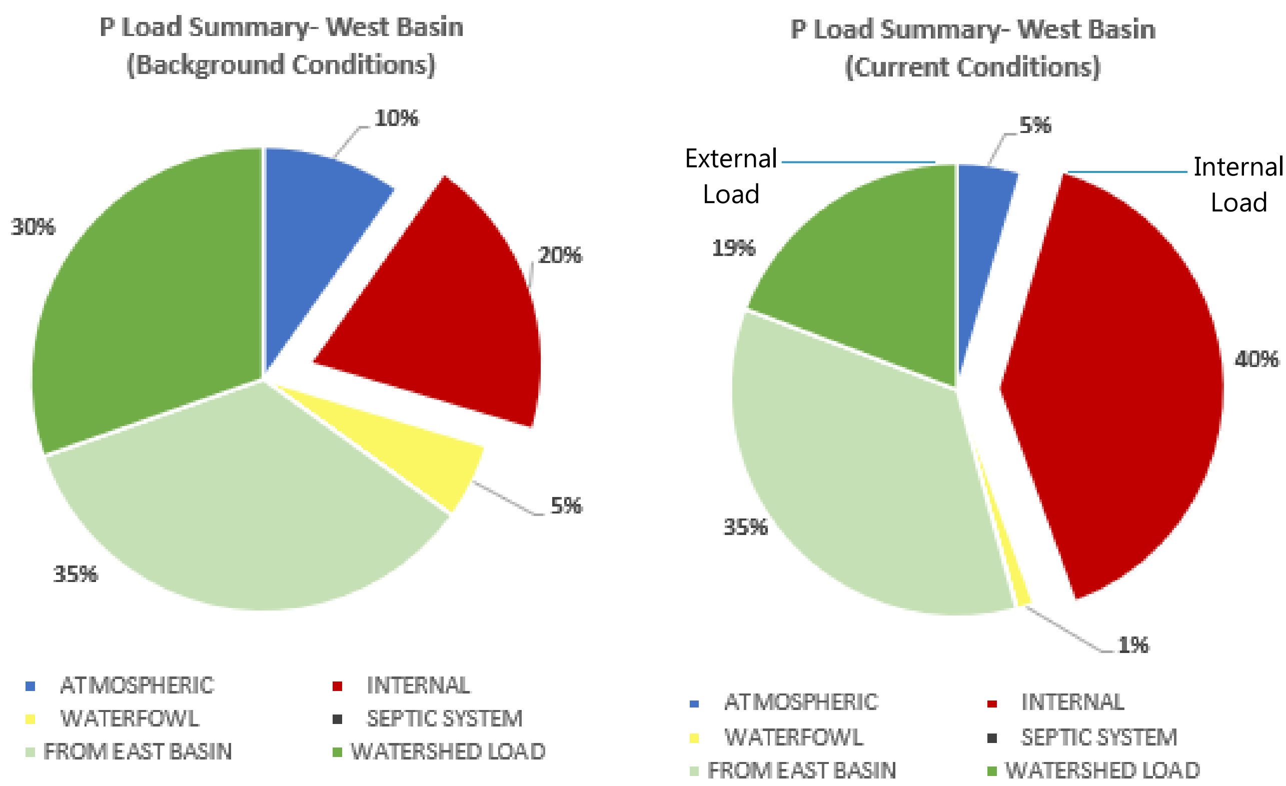


***Figure 22**. Percentage of total phosphorus loading (kg/yr) by source (atmospheric, internal loading, waterfowl, septic systems, watershed load) to China Lake, West Basin.*

BASIN PHOSPHORUS LOADING RESULTS

Ten major basins (A through J) were included in the model to estimate P loading at different scales throughout the watershed of China Lake (Figure 25 & Figure 26). The basin approach helps watershed managers prioritize on-the-ground restoration projects and education and outreach activities in the basins that contribute the greatest amounts of P. Collecting tributary data and tracking ongoing P reduction efforts within these basins would result in a more robust model over time.

Basin A (direct shoreline drainage) is estimated to contribute the largest load (276 kg/yr) to the east basin. When estimating the P load to the west basin, all the watershed basins draining to the east basin of the lake were combined into a single source, to account for the P load from the east basin to the west basin. The east basin is estimated to be the largest source of P to the west basin in terms of total mass, contributing 586 kg/yr of P. The greatest P load from the watershed of the west basin is estimated to come from Basin F (direct shoreline drainage), at 138 kg/yr. Drainage areas directly adjacent to waterbodies do not have adequate treatment time and are often most desired for development in a lake watershed. This increases the possibility for greater P export now and in the future. Basins A and F are the largest contributors of P by total mass, while Basin I is the largest contributor per hectare. Land cover in Basin I is 43% developed, with agriculture accounting for 35% of the land area. Sub-basins with the highest loading based on area should be prioritized for P reduction programs and activities.

After normalizing for area (P mass per hectare), Basin A (east basin direct shoreline drainage) and Basin C (Jones Brook) are estimated to contribute the greatest mass of P per hectare to the east basin at 0.19 and 0.18 kg/ha/yr, respectively (Figure 23). The largest contributors of the P load to the west basin are Basin I (tributary south of Maple Ridge Road), and Basin F (west basin direct shoreline drainage), at 0.27 and 0.20 kg/ha/yr, respectively (Figure 24).

Generally, basins with high annual P export in the China Lake watershed also have more development (i.e., shoreline development, roads, agriculture). This reinforces the fact that developed land, and other human-related impacts, can result in an increased export of P to the lake. Addressing erosion and nutrient management in these areas and adding effective natural buffers to disturbed shorelines on China Lake will help reduce the amount of sediment and P entering the lake.

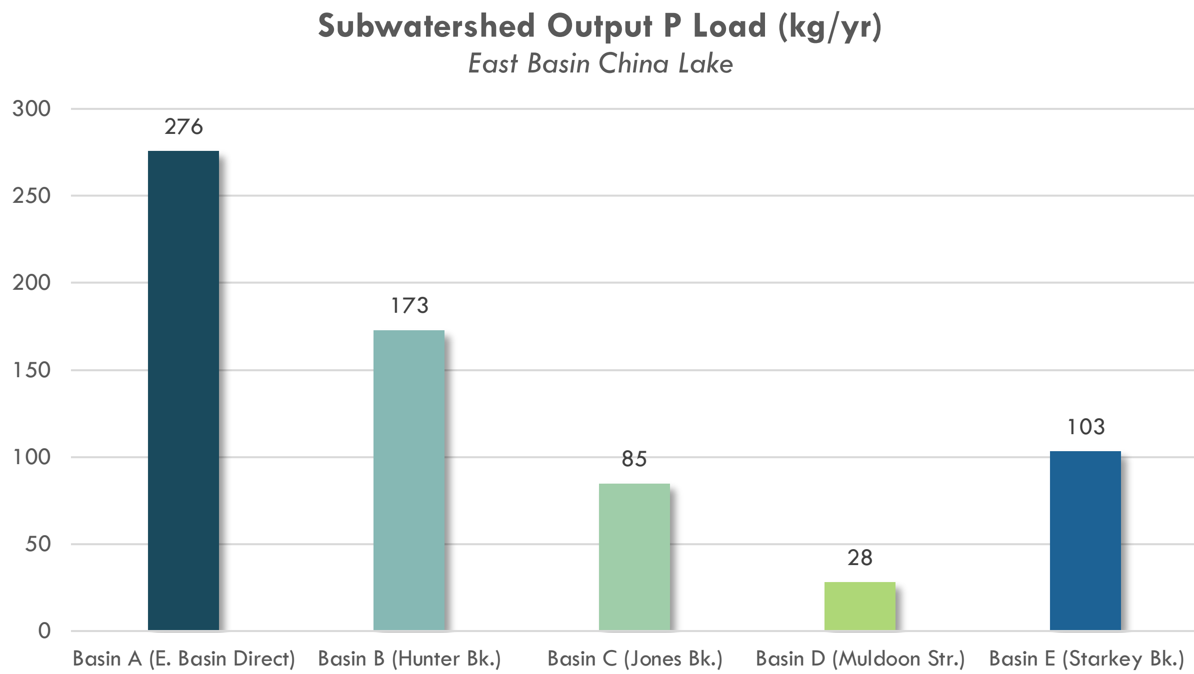


Figure 23. *Phosphorus load by minor basin in the China Lake Watershed, East Basin.*

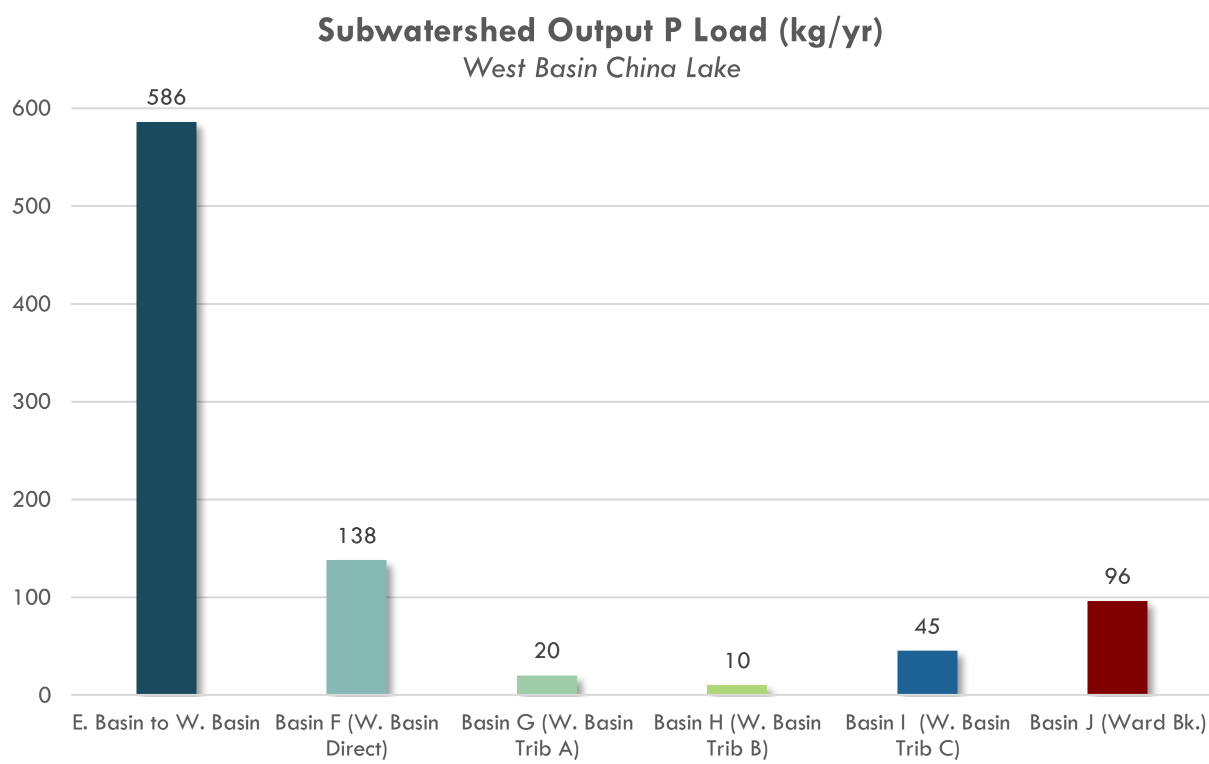
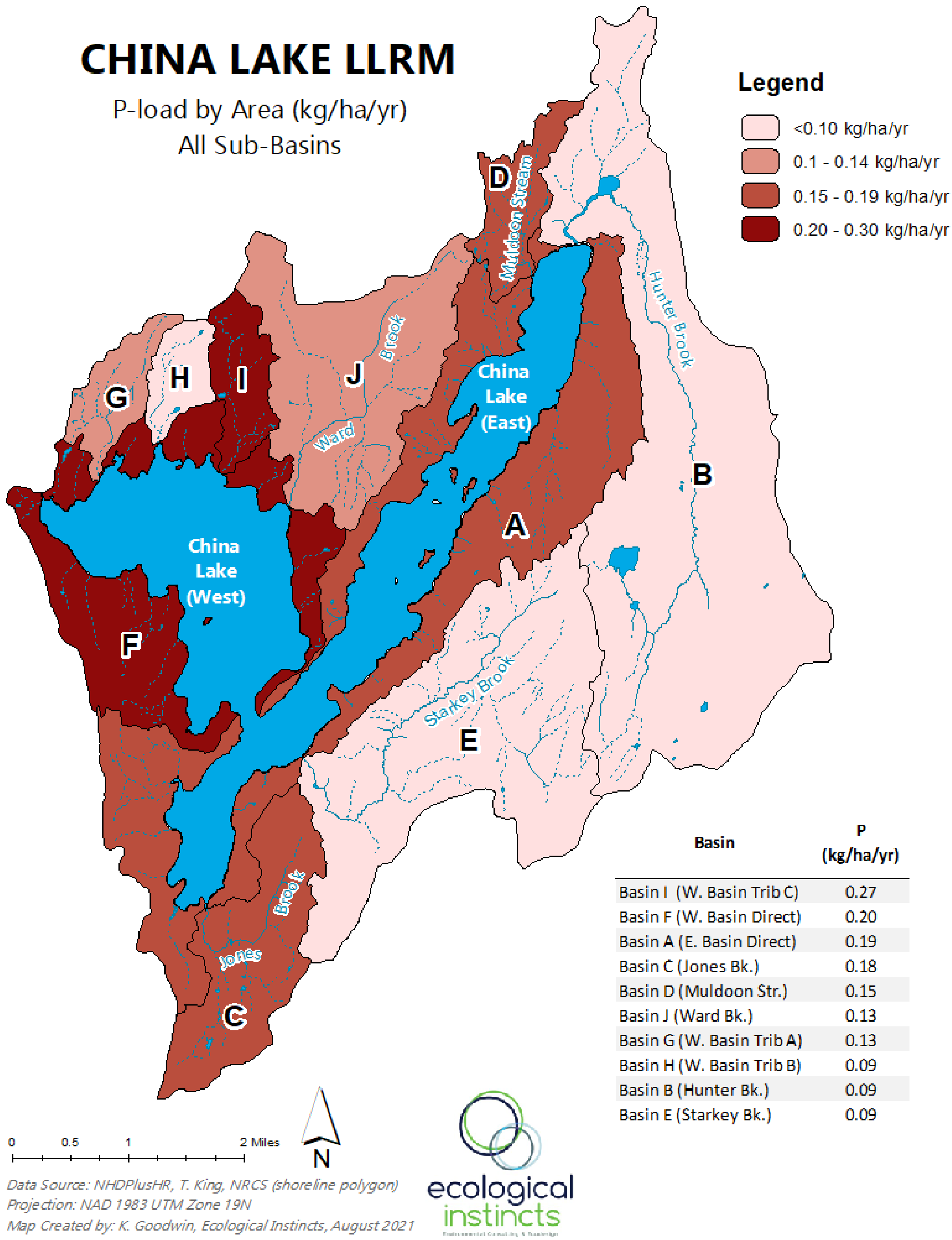


Figure 24. *Phosphorus load by minor basin in the China Lake Watershed, West Basin.*



Basin	P (kg/ha/yr)
Basin I (W. Basin Trib C)	0.27
Basin F (W. Basin Direct)	0.20
Basin A (E. Basin Direct)	0.19
Basin C (Jones Bk.)	0.18
Basin D (Muldoon Str.)	0.15
Basin J (Ward Bk.)	0.13
Basin G (W. Basin Trib A)	0.13
Basin H (W. Basin Trib B)	0.09
Basin B (Hunter Bk.)	0.09
Basin E (Starkey Bk.)	0.09

***Figure 25**. Phosphorus load by basin (A through J) in the China Lake watershed (all lake basins).*

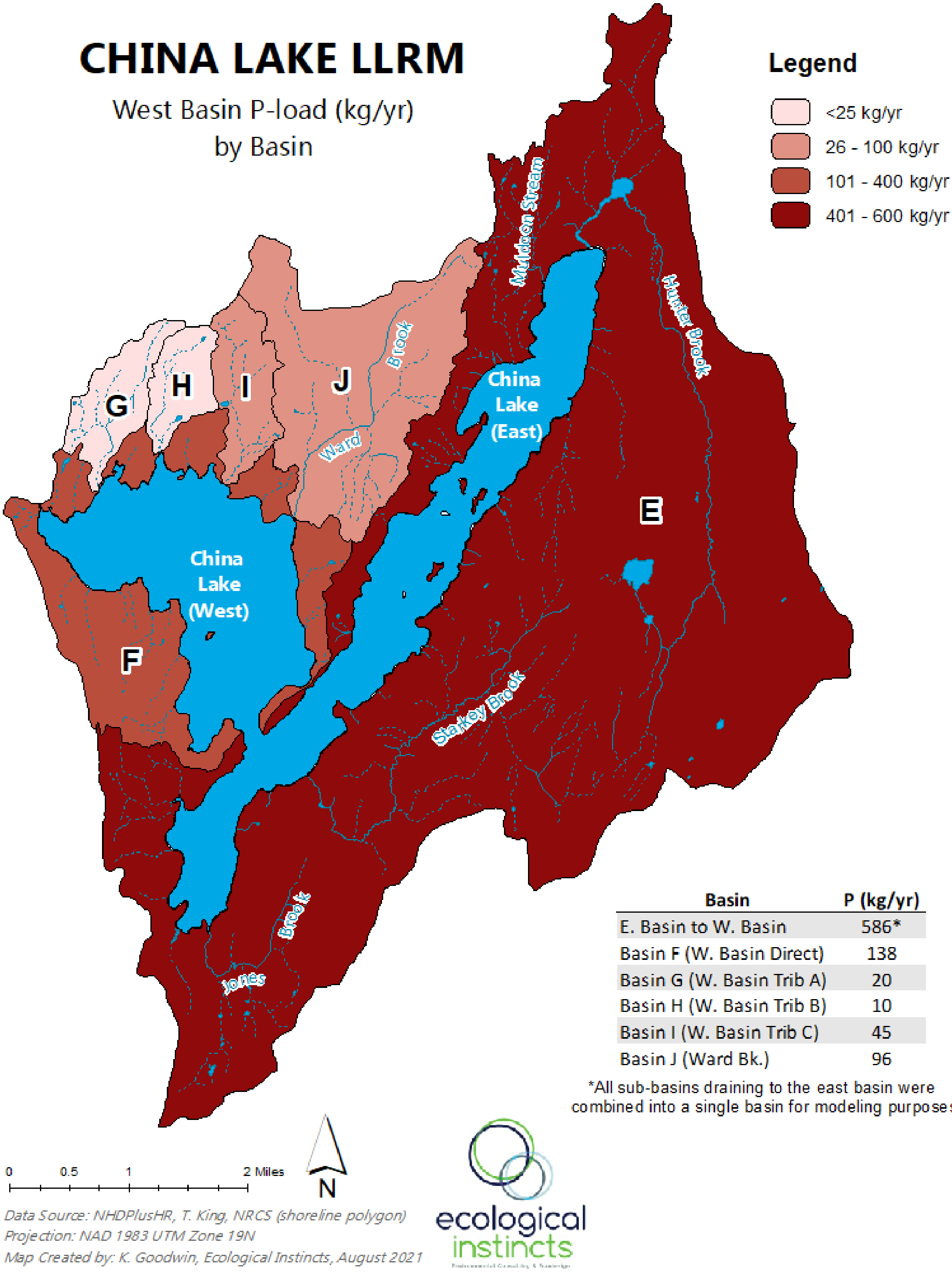


Figure 26. *Phosphorus load by basin (E through J) in the China Lake Watershed (West Basin only).*

ASSESSMENT OF THE INTERNAL LOAD

An analysis of internal loading of P to China Lake was conducted by WRS, Inc (2021) using all available water data collected between 1970 and 2020 and analysis of China Lake sediment samples collected in 2020. Internal P loading via release from sediments exposed to low oxygen is a major source of P from sediments in China Lake. However, upward transfer of P accumulating in deep water varies and is incomplete in at least the deeper east basin. Best available estimates of internal loading result in the internal load being a major contributor of P to both basins and the dominant source during late summer as described in the previous section (729 kg/year east basin, 643 kg/yr west basin).

Internal P loading estimated from water column changes (change in mass over time) is lower than the load estimated from sediment features (10% of the P mass in the surficial sediment exposed to low oxygen) for the west basin, suggesting that only a portion of the internally loaded P reaches the upper waters. The estimates are based on very limited sediment data and more sampling is needed to firm up the internal loading estimate. The internal load generated from P profile data for the east basin is slightly higher than the projection from sediment P, however. The discrepancy is not especially large and may relate to either interpolation of P concentrations over depths in the P mass calculations with limited data or to limited sediment data. ***The internal load will need to be reduced to meet desired water quality targets and to restore the lake.***

P MASS IN CHINA LAKE IN 2020

Data from 2020 were used to calculate the mass of P in discrete depth intervals within the defined basins of China Lake over time (Appendix F). The west basin and east basin are functionally separate waterbodies, but the east basin was also divided into north and south sections for the analysis.

The transition between shallow and deep water layers occurs over a water depth of 6-10 m at all three stations, with the point of greatest inflection (the thermocline) at 7 or 8 m in most cases. While some settling from upper waters occurs, most of the P increase in deeper water once stratification sets in is usually assumed to come from release from sediments exposed to low oxygen (defined as DO<2 mg/L in the overlying water).

P RELEASE RATE

All three stations for which P mass calculations were derived show an increase in P below depths of 7 m through the summer. The rise is sharper for the two east basin stations than for the west basin station, which is deeper and loses oxygen more slowly. For the east basin, low oxygen is minimal until the end of June, but then increases in extent rapidly in July, peaks in coverage in late August, and declines in September as the surface water cools and the thermocline “sinks”. Internal loading of P by redox reactions involving Fe-P could therefore occur in July through September, although Fe-P dissociation usually takes a few weeks to ramp up and is pretty quickly squelched as oxygen is re-introduced in late summer. There will be about 60 days of internal loading at depths >9 m and 30 days of loading over additional area 7-9 m deep. Low oxygen starts a little sooner in the north end than in the south end of the east basin and seems to be more intense in the north basin.

The result is a major increase in P in deep water in the east basin from late July until late September resulting in an increase of 443 kg over 60 days in a 175 ha area of the northern section of the east basin and 314 kg over 50 days in a 281 ha area of the southern section of the east basin. This increase equates to an average release rate of 4.2 mg/m^2/d in the northern section and 2.2 mg/m^2/d in the southern section, both well within the expected range for lakes in New England that experience low oxygen conditions. Oxygen demand is higher in the northern part of the east basin, due to high organic content of the sediment, leading to greater release of P.

While P accumulation is substantial, not all of that accumulated deep water P appears to make it into upper waters. Note that the 0-7 m depth layer (see Appendix F) does not increase as much in thickness as the deeper areas decreased in thickness as stratification breaks down, suggesting that some P recombines with iron and settles out.

In the west basin, accumulation of decaying organic matter at the thermocline results in loss of oxygen at 7-8 m at the same time (late July/early August) that oxygen is being lost in the deepest area, resulting in low oxygen at two separate depths simultaneously. The hypolimnetic zone in between loses the rest of its oxygen by the end of August, creating a smaller contributory zone (65 ha) for internal P loading from August through October (90 days) and a much larger contributory zone (380 ha) from late August to mid-October (50 days). The increase in P below 7 m of water depth was about 300 kg over 84 days in an area of 487 ha equating to a release rate of 0.73 mg/m^2/d, a low release rate. However, the P mass in the upper waters increases over time in a way that suggests that upward transfer is occurring, with as much as 600 kg involved. This suggests a rate of 1.5 mg/m^2/d, still a fairly low rate but resulting in a substantial internal load in the west basin.

Weather factors have a lot of influence on whether or not a surface algae bloom develops over the summer in China Lake.

The possible internal load in China Lake is actually higher than applied in the model, but much of the P is trapped in deeper water and may not be available to algae. Algae, and cyanobacteria (aka blue-green algae but technically photosynthetic bacteria), may grow near the thermocline using light from above and P from below, or at the sediment-water interface in water shallow enough to have sufficient light penetrating to that interface but deep enough to have P being released from the sediment. Weather factors will have a lot of influence on whether or not a cyanobacteria bloom develops over the summer. Blooms in late summer or early fall can be expected in many years as stratification breaks down, but even then, some of the hypolimnetic P will be naturally inactivated in the presence of oxygen and precipitate back to the sediment surface. P dynamics and resultant algal response are therefore more complicated than a simple estimate of load generation. Cyanobacteria are more concerning than algae because of their potential toxicity.

While a focus on the internal loading of P in the east basin is justified by the available data, and may be sufficient to meet water quality goals, it may prove necessary to address internal loading in the west basin to minimize cyanobacteria blooms.

WATER QUALITY TARGET SELECTION

The LLRM can be used not only to estimate pollutant loading to a lake, but also to evaluate possible water quality goals/targets for lake restoration projects. There are several alternative ways to proceed with water quality target selection. This includes setting a phosphorus target based on desired average chlorophyll-a concentration or depth of water clarity, selecting a target based on achieving a desired chlorophyll-a or water clarity value at some high level of probability (e.g., 90% of the time), or calculating practical watershed P reductions (and resulting in-lake P concentration) that will result in meaningful water quality improvements, among other methods. The approach depends on the desired use of the resource as well as regulatory considerations.

For China Lake, with an estimated pre-settlement phosphorus average concentration of 4.2 ppb in the east basin and a 3.5 ppb in the west basin, and a current (modeled) average concentration of 18.3 ppb in the east basin and 15 ppb in the west basin, the difference is quite large. However, moving the lake substantially toward pre-development conditions will be exceedingly difficult given the present level of development and continuing pressure for development over time.

The obvious phosphorus sources with the greatest variability are polluted runoff and internal loading. By managing land in the watershed to minimize runoff and improve its quality we can reduce NPS inputs that are causing algal blooms and contributing the most to the sediment reserves in the lake that ultimately provide the seasonal internal load. The influence of the P load from the east basin on the water quality of the west basin is an important result of the watershed modeling and an important consideration for lake and watershed management in the 2022 update to the China Lake WBMP. Ultimately, anything that is done to reduce P inputs from reaching the east basin will help improve water quality in the west basin.

The LLRM was used to create an in-lake phosphorus target for each basin based on achievable P load reductions over the next 10 years (Table 10 & Table 11). In-lake TP concentrations of 10.2 ppb and 12.5 ppb can be expected for the east and west basins, respectively, based on modeling results. These results were used to set the water quality goal for the WBMP of 10 ppb and 13 ppb for the east and west basins, respectively.

Load reduction estimates were derived within the LLRM for both the internal and external load and for future development and climate change scenarios. The US EPA Region 5 model and Maine DEP Relational Method were used to estimate P load reductions from the watershed (Appendix H).

Reducing the internal P load by 90% (656 kg/yr) in the east basin in addition to reducing the watershed load by 56 kg/yr[33] is projected to achieve this goal. An estimated 21 kg P will need to be reduced in the watershed of the west basin- in addition to the reductions described above for the east basin to meet the water quality target for the west basin.

While not a management recommendation for the 2022 WBMP, should future management strategies require reducing the internal load in the west basin (by 90% or 579 kg/yr), in addition to all the other P reductions strategies in the lake and watershed, the in-lake TP concentration is expected to decrease to 7.1 ppb.[34] In-lake water quality targets can be adjusted to reduce overall costs for the 10-year WBMP, however, improvements will be largely dependent on addressing internal loading in the east basin, since water flowing in from the east basin is the greatest source of P loading to the west basin.

[33] Reduction estimates based on the Relational Method developed by Jeff Dennis at Maine DEP. P reductions apply to various land-use types including agriculture, roads, timber harvesting, and other types of development in the watershed (Appendix H).

[34] The cost of an alum treatment in the west basin is estimated at $2.1 million and is not a recommendation for the 2022 WBMP.

Table 10. *Modeled water quality and P loading predictions under background conditions, target load reduction conditions, current conditions, and various future development and climate change scenarios for China Lake, East Basin.*

China Lake (East Basin)	**Background Conditions**	**2022-2031 Load Reduction Target**	**90% Reduction Internal Load (East Basin)**	**CURRENT (model prediction)**	**Future Development***	**10% Climate Change Scenario**	**Future Development + Climate Change**
In-Lake P Conc.	*-14 ppb*	**-8.1 ppb**	**-7.5 ppb**	18.3 ppb	**+0.5 ppb**	**+ 1 ppb**	**+ 1.5 ppb**
% Change	*n/a*	**-44%**	**-41%**	**0%**	**+3%**	**+5%**	**+8%**
	Represents pre-development conditions in the watershed	656 kg reduction internal load + 56 kg reduction watershed load	656 kg reduction internal load only	No change	50 kg increase to the watershed load	71 kg increase internal load + 119 kg increase watershed load	147 kg increase internal load + 169 kg increase to watershed load
DIRECT LOADS TO LAKE	P (KG/YR)	P (KG/YR)	P (KG/YR)	P (KG/YR)	P (KG/YR)	P (KG/YR)	P (KG/YR)
ATMOSPHERIC	44	87	87	87	87	87	87
INTERNAL	54	73	73	729	729	800	876
WATERFOWL	20	20	20	20	20	20	20
SEPTIC SYSTEM	0	100	112	112	112	112	112
WATERSHED LOAD	254	620	664	664	714	783	833
TOTAL LOAD TO LAKE	**372**	**900**	**956**	**1,612**	**1,662**	**1,801**	**1,851**
PREDICTIONS							
In-Lake TP (ppb)	**4.2**	**10.2**	**10.8**	18.3	18.8	19.3	19.8
Mean SDT (m)	7.6	3.9	3.7	2.5	2.4	2.4	2.3
Peak SDT (m)	6.5	5.1	5.0	4.3	4.3	4	4.2
Mean Chl-a (ug/L)	0.7	3.0	3.3	6.6	6.9	7	7.4
Peak Chl-a (ug/L)	3.5	11.2	12.1	23.1	23.9	25	25.4
% of time Chl-a >8 ug/L	0.0%	1.4%	2.2%	26.7%	29.2%	31.3%	33.9%

Table 11. *Modeled water quality and phosphorus loading predictions under background conditions, target load reduction conditions, current conditions, and various future development and climate change scenarios for China Lake, West Basin.*

China Lake (West Basin)	**Background Conditions**	**2022-2031 Load Reduction Target**	**90% reduction Internal Load (East Basin)**	**CURRENT (model prediction)**	**Future Development***	**10% Climate Change Scenario**	**Future Development + Climate Change**
In-Lake P Conc.	*-11.5 ppb*	***-2.5 ppb***	***-2.1 ppb***	***15 ppb***	***+0.6 ppb***	***+ 1.1 ppb***	***+ 1.7 ppb***
% Change	*n/a*	***-17%***	***-14%***	***0%***	***+4%***	***+7%***	***+11%***
	Represents pre-development conditions in the watershed	229 kg reduction EB alum treatment + 20 kg reduction EB watershed + 21 kg WB watershed	229 kg reduction from EB alum treatment	No change	68 kg increase from future development	65 kg increase to internal load + 119 kg increase from watershed	65 kg increase to internal load + 187 kg increase from watershed
DIRECT LOADS TO LAKE		P (KG/YR)		P (KG/YR)	P (KG/YR)	P (KG/YR)	P (KG/YR)
ATMOSPHERIC	37	73	73	73	73	73	73
INTERNAL	75	643	643	643	643	708	708
WATERFOWL	20	20	20	20	20	20	20
SEPTIC SYSTEM	0	1	1	1	1	1	1
FROM EAST BASIN CHINA LAKE	130	315	335	564	582	630	648
WATERSHED LOAD	114	288	309	309	359	362	412
		21	229	21			
TOTAL LOAD TO LAKE	376	1,340	1,381	1,611	1,678	1,795	1,862
PREDICTIONS							
In-Lake TP (ppb)	**3.5**	**12.5**	**12.9**	**15.0**	**15.6**	**16.1**	**16.7**
Mean SDT (m)	8.8	3.3	3.3	2.9	2.8	2.7	2.7
Peak SDT (m)	6.9	4.8	4.8	4.6	4.5	4.5	4.4
Mean Chl-a (ug/L)	0.5	4.0	4.2	5.1	5.4	5.6	5.9
Peak Chl-a (ug/L)	2.6	14.4	15.0	18.1	19	19.7	20.6
% of time Chl-a >8 ug/L	0.0%	5.1%	6.0%	12.7%	15.1%	16.9%	19.4%

5. Climate Change Adaptation

Current Maine DEP guidance calls for developing WBMPs that incorporate climate change considerations. This can be addressed to a large extent by a plan that aims to reduce nonpoint source pollution and minimizes internal P recycling. The factors that appear to be of greatest importance to water quality conditions in China Lake are also those most influenced by climate change. Primary climate change impacts to lakes include variation in both precipitation and temperature. This presents a big challenge for watershed management efforts as more intense rainfall will increase the amount of nutrient transport to the lake from the watershed via stormwater runoff.

Higher (air and water) temperatures lead to increased algal growth, greater oxygen demand due to decomposition, lower oxygen near the lake bottom, and increased P release from surficial sediments where iron is a major P binder (internal loading). Warmer water temperatures and increased P also favor invasive species, cyanobacteria, and harmful algal blooms (HABs) that produce toxins harmful to humans and wildlife. Warmer water also influences the period of ice coverage, with less ice coverage due to lakes freezing later in the season, and ice breaking up earlier in the spring.[35] Climate change will surely make this task more complex and will require additional load reductions from watershed sources to offset the anticipated increase.

Between 2015 – 2020, the Gulf of Maine experienced its warmest 5-year period on record (Pershing, et. al., 2021), warming at a rate seven times faster than the rest of the ocean. A 2020 report from the Maine Climate Council confirms that over the last several decades, air and surface water temperatures have been increasing in Maine. Surface water temperatures in northern New England increased 1.4°F per decade from 1984-2014, which is faster than the world-wide average, with Maine lakes warming on average by nearly 5.5°F during this time. Data also show that smaller lakes and ponds are warming more rapidly than larger lakes. Increased precipitation and bigger, more frequent storms have resulted in many effects observed in Maine Lakes including an increase in dissolved organic carbon (DOC) and increased stormwater runoff volumes from surrounding watersheds. Increasing temperature and DOC in lakes has a direct effect on thermal and biological dynamics, ultimately favoring nutrient-loving species (like toxin-producing cyanobacteria) over species adapted to cooler water temperatures. Though water quality in many Maine lakes has improved because of laws and regulations that protect

[35] A study by USGS for 29 New England states showed ice-out occurring 9 to 16 days earlier since 1850. Online: https://pubs.usgs.gov/fs/old.2005/3002/

water quality by mitigating the effects of human development, the effects of climate change threaten the effectiveness of these dated laws that may need adjusting to adequately protect natural resources in the future (MCC, 2020).

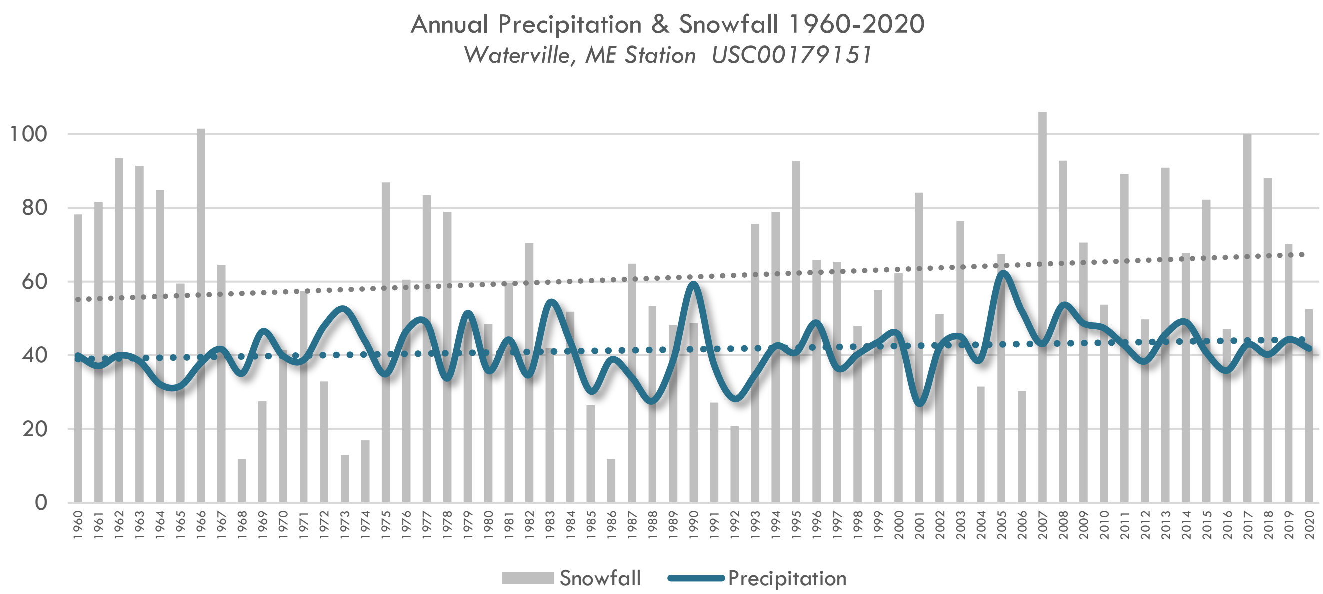


Figure 27*. 50-year annual precipitation and snowfall in Waterville, ME 1960-2020. Daily climate summaries from NOAA - National Climatic Data Center: https://www.ncdc.noaa.gov/cdo-web/datatools/findstation*

Precipitation amounts in Maine have oscillated over time, but the annual statewide average precipitation has increased 15% from 1895 to 2018, and 30% from 1960 to 2018 (Fernandez, et al. 2020). Figure 27 shows the total annual precipitation observed in Waterville, Maine has increased in the last 60 years (1960-2020). Average annual precipitation between 1960 and 1989 was 40 inches, whereas the average between 1990 and 2020 was 42 inches (4% increase). A recent study of Maine lakes found that the amount of precipitation during the summer lake stratification season was the best predictor for annual water clarity values with more precipitation associated with lower water clarity (Deeds, et al. 2021)

The approximate influence of climate change can be evaluated in LLRM by varying the inputs in accordance with projected climate change effects, generally set at a 10-20% increase based on long-term trends of lakes in the northeast. Climate change influence on internal loading can be similarly evaluated by increasing the LLRM inputs in accordance with expected oxygen depletion rates, affected areas, and the period of release. An increase in oxygen demand will raise the area exposed to low oxygen and the duration of that exposure, leading to an increase in internal loading where iron-bound P is an important sediment form of P.

It is important to remember that the watershed is not a static system, and the P load will continue increasing over time if actions are not taken to address these changes. The estimated increases mentioned above could be exceeded with just a few unforeseen large-scale climatic events that deliver significant amounts of sediment to the lake in a single pulse. These inputs could have major consequences for water quality resulting in costly remediation measures to address the negative effects of the increased loading.

Climate change adaptation planning, such as upgrading infrastructure on roads (i.e., undersized culverts), infiltrating stormwater runoff on commercial and residential properties, planting buffers, and conserving undeveloped land can all help to counteract the effects of the anticipated increase in precipitation and runoff.

The following climate change activities should be factored into the future watershed planning activities:

1. **Establish a precipitation monitoring program** (e.g., automated rain gauge) to document occurrence and intensity of rainfall or drought conditions in the watershed over time.
2. **Review and prioritize existing stream-crossing survey** to assess whether culverts at road/stream crossings require upgrades.
3. **Work with municipal officials** to identify areas of the watershed with the greatest threat to infrastructure.
4. **Host climate change workshops** or webinars to provide information about ways landowners can adapt to climate change and help protect water quality.

FUTURE DEVELOPMENT

A conservative estimate of 50 kg/yr (or a 0.5 ppb in-lake concentration increase) was selected within the LLRM to reflect additional loading that could be expected from future development. In addition to new development on the shoreline, population growth (and an increase in the developed land area in watershed) is expected in the form of conversion of small seasonal camps to larger year-round homes on the shoreline, infill development on the remaining developable shorefront lots, as well as residential and commercial development within the watershed outside of the shoreland zone, all of which will ultimately lead to new sources of P to China Lake if not factored into planning and development standards for new construction.

MODEL SCENARIOS

Predicted P increases associated with future development and climate change include (Table 10 & Table 11, Figure 28 & Figure 29):

- Future Development – Estimated increase of 0.5 ppb in-lake P concentration, or 50 kg/yr increase to the total watershed load in each basin.
- 10% Climate Change Scenario – 10% increase in precipitation, runoff coefficient for human-related land uses, overall watershed load, and affected area of internal load.

The estimated in-lake P concentration is expected to increase by 1.5 ppb and 1.7 ppb in the east and west basins, respectively as a result of future development and climate change. Management of new development, and proactive climate change planning at the municipal level will be critical for ensuring that P reduction targets can be met.

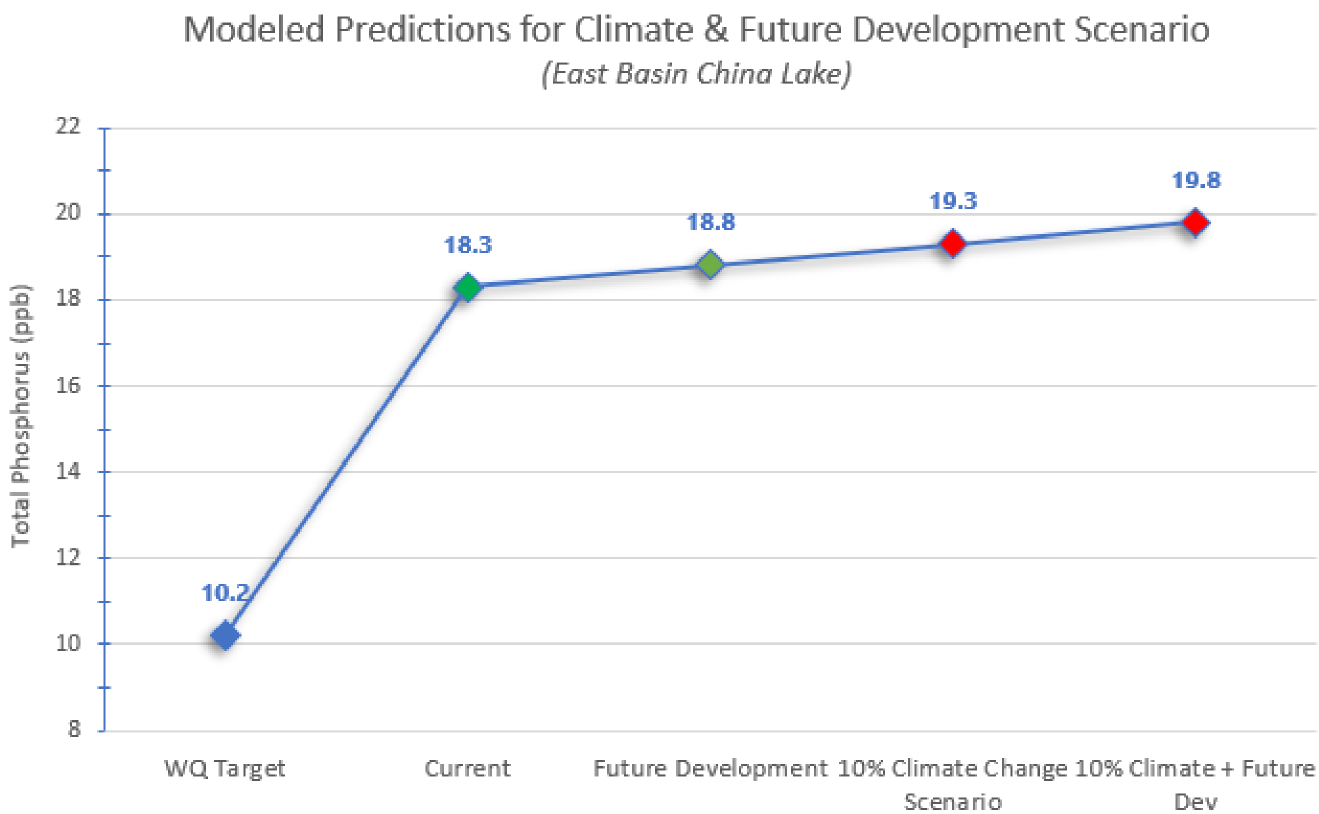


***Figure 28**. Predicted in-lake phosphorus concentration with future development and climate change scenarios for China Lake, East Basin.*

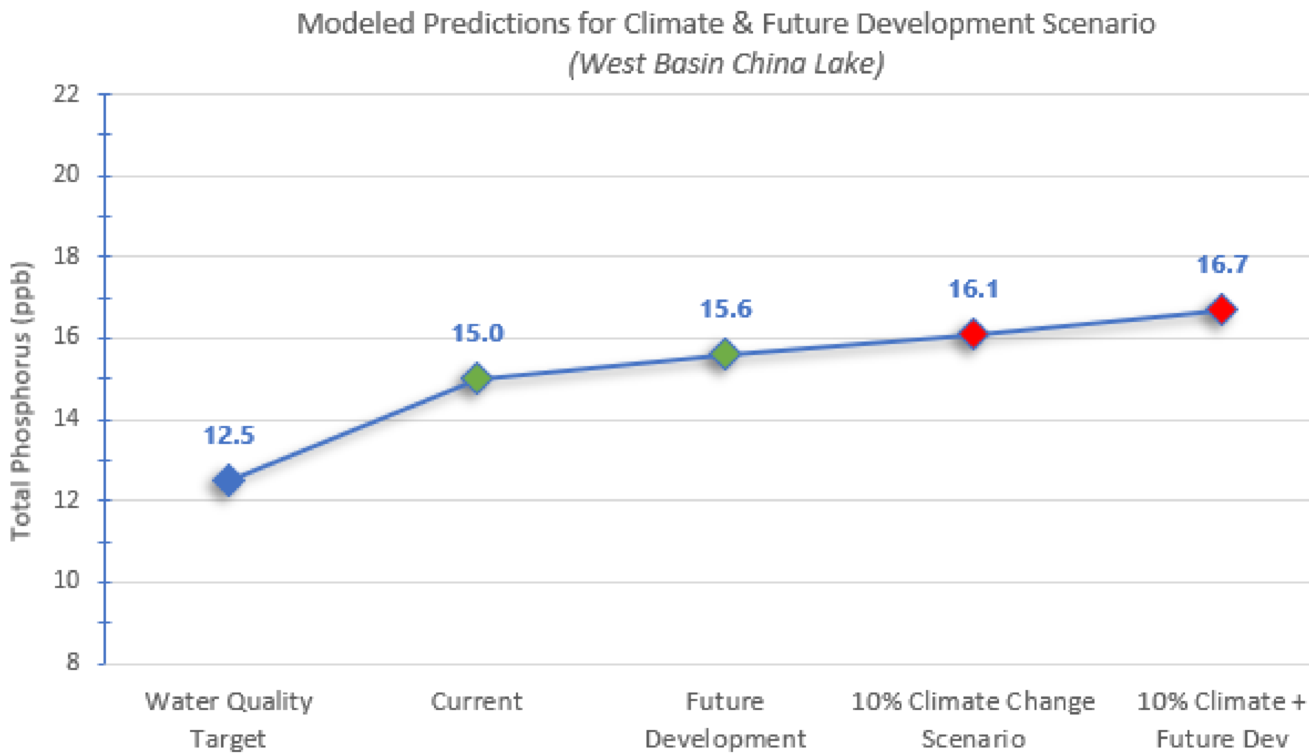


Figure 29. *Predicted in-lake phosphorus concentration with future development and climate change scenarios for China Lake, West Basin.*

6. Establishment of Water Quality Goals

Establishment of water quality restoration goals for this 10-year WBMP is the result of work completed over a two-year planning period with input from the China Lake TAC, the project Steering Committee, and public input. Specifically, these goals were based on a detailed review and discussion of the 2020 water quality monitoring conducted by KWD, the water quality analysis and watershed modeling conducted by Ecological Instincts, the internal loading analysis conducted by Water Resource Services, and the sediment analysis conducted by Colby College. Watershed assessment work including the 2020 watershed survey and an inventory of septic systems, agriculture, and forestry activities were also used to help set water quality goals and to determine if goals could be met by addressing NPS pollution from the watershed alone.

WATER QUALITY RESTORATION GOAL

China Lake has a stable or improving water quality trend and is free of nuisance algal blooms.

In-Lake Phosphorus (East Basin) = 10 ppb

In-Lake Phosphorus (West Basin) = 13 ppb

"P" REDUCTIONS NEEDED

East Basin- 712 kg/yr
656 kg/yr internal load
56 kg/yr external load

West Basin- 270 kg/yr
249 kg/yr east basin reductions;
21 kg/yr external load only

Timeframe: 2022- 2032

Projects: Erosion Control BMPs LakeSmart, Alum treatment (East Basin only)

The findings of this analysis show that reducing the watershed load is not expected to result in a noticeable water quality improvement, reduce the probability of reoccurring algal blooms, or achieve the desired water quality goal due to the influence of the large annual P load from the sediments in the east basin, and the relative influence of P loading to the west basin from the east basin. Addressing the internal load in the east basin and the external load in the watersheds of both basins will reduce total phosphorus loading from the watershed by 30% (982 kg/yr), increase annual average water clarity readings by 1.4 m and 0.4 m in the east and west basins, respectively, and reduce the probability of algal blooms from 27% to 1% in the east basin, and from 13% to 5% in the west basin. [36]

An in-lake P concentration of 10 ppb in the east basin, and 13 ppb in the west basin is achievable by:

- Addressing the internal load through P inactivation in the sediments of the east basin (656 kg/yr);
- Reducing the external load in the east basin by addressing runoff from developed land in the direct watershed of the east basin (56 kg/yr);
- Reducing the external load in the west basin by addressing runoff from developed land in the direct watershed of the west basin (21 kg/yr). Additional load reductions of 249 kg/yr are estimated for the west basin as a direct result of reducing the internal and external load for the east basin.

All strategies are needed to meet the water quality goal.

[36] Defined as Chl-a concentrations >8 ppb.

7. Watershed Action Plan & Management Measures

The China Lake WBMP provides strategies for achieving the water quality goal. The loading analysis for China Lake weighed the pros and cons of different management options for reducing in-lake P concentrations. These recommendations are outlined in detail in the plan and were presented to the TAC for review and feedback. The watershed action plan was developed with input from both the TAC and the watershed steering committee. The action plan represents solutions for improving water quality in China Lake based on the best available science.

The action plan is divided into six major objectives, along with a schedule for completion, description of potential funding sources, and a list of project partners assigned to each task. The objectives focus on:

1) **Addressing the External P Load**
2) **Addressing the Internal P Load (East Basin)**
3) **Addressing New Sources of NPS Pollution**
4) **Education & Outreach**
5) **Building Local Capacity**
6) **Long-Term Monitoring & Assessment**

ADDRESSING THE EXTERNAL LOAD

Addressing NPS pollution from watershed sources is an important part of a multi-step process to improve the water quality in China Lake, and the first step in reducing phosphorus loading to the lake before pursuing an aluminum treatment. Addressing the external load will require ongoing work annually over the ten-year period and beyond. Cooperation from private landowners will be needed to successfully reduce the watershed P load by 56 kg/yr in the east basin and 41 kg/yr in the west basin.

Load reduction estimates were calculated for the 2020 NPS survey sites using the US EPA Region 5 model. This accounts for 30 kg/yr, or approximately half of the 56 kg/yr reduction needed in the east basin, with the remaining reductions estimated using the Maine DEP Relational Method applied to agricultural land (25 kg/yr), other urban development including paved and gravel roads (10 kg/yr), septic systems (8 kg/yr), and timber harvests (1%) (see Appendix H).

The 21 - 41 kg/yr reduction in the west basin can be achieved by addressing 25% of agricultural land (15 kg/yr), other urban development (including paved and gravel roads) (4 kg/yr), and timber harvests (2 kg/yr). In addition to NPS remediation at NPS sites, effective LakeSmart programming, and preventing new sources of NPS from getting into the lake will be important NPS planning measures.

WATERSHED NPS SITES

In 2020, volunteers and technical staff identified 161 sites across the watershed that have a negative effect on the water quality of China Lake (Figure 30 & Appendix I).

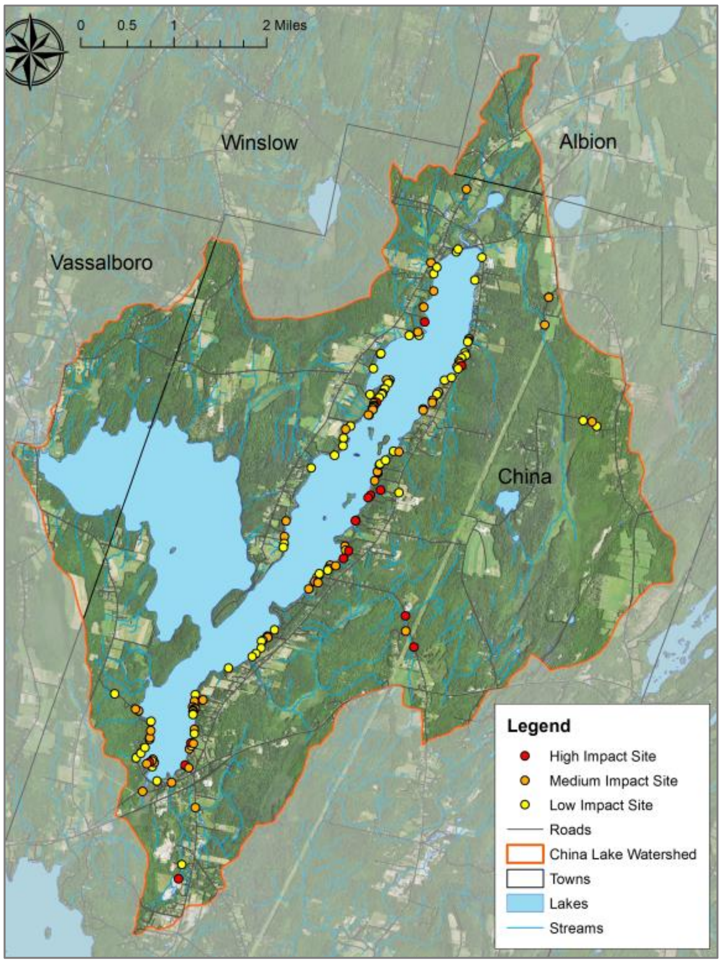


Figure 30. *Map of high, medium, and low-impact NPS sites from the 2020 China Lake watershed survey. (Source: Maine DEP)*

Sites were documented across 11 different land-use types (Figure 31 & Table 12). The number of residential properties far outweighed the other land-use types. The impact that documented NPS sites may have on the water quality of China Lake was determined during the survey based on the proximity to a waterbody and the magnitude of the problem. Factors such as slope, amount of eroding soil, and buffer size were also considered. A closer look at the estimated impact of these sites shows that while there are a total of 161 sites documented, only 20 rank high-impact compared to 59 medium, and 82 low-impact sites (Table 12). Residential NPS sites make up the greatest number of high, medium, and low-impact sites, accounting for 66% of all sites, and almost 80% of the low-impact sites.

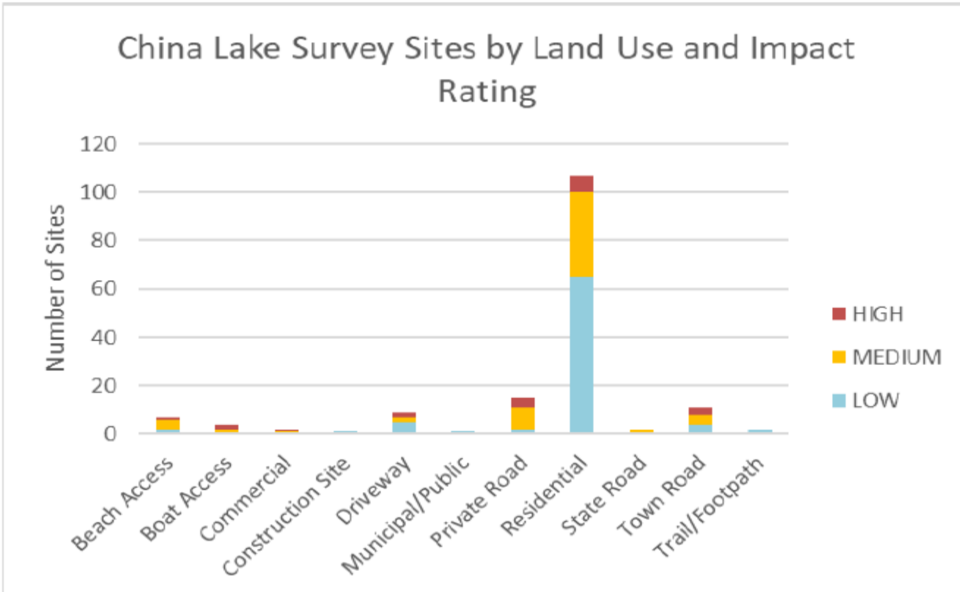


***Figure 31**. Number of NPS sites identified in the China Lake watershed by land use and impact rating.*

***Table 12.** Summary of NPS sites in the China Lake watershed by land use and impact rating.*

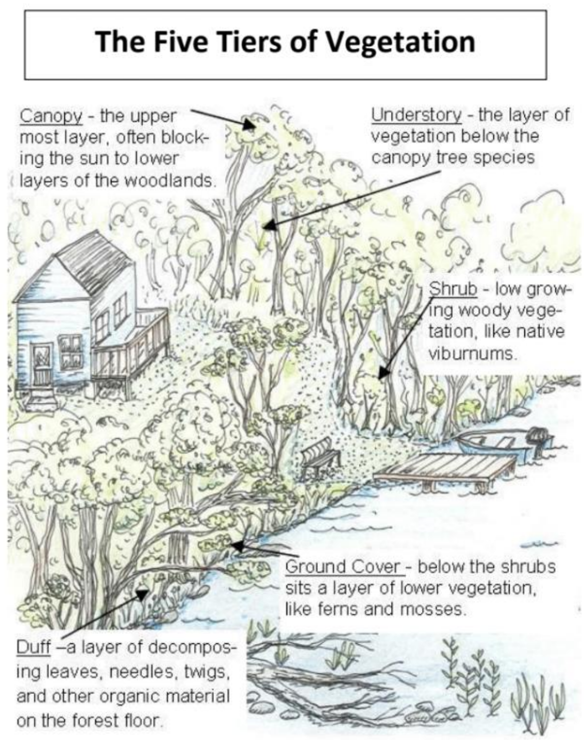
Land Use	HIGH	MEDIUM	LOW	TOTAL	% of total
Beach Access	1	4	2	7	4.4%
Boat Access	2	2	0	4	2.5%
Commercial	1	1	0	2	1.2%
Construction Site	0	0	1	1	0.6%
Driveway	2	2	5	9	5.6%
Municipal/Public	0	0	1	1	0.6%
Private Road	4	9	2	15	9.3%
Residential	7	35	65	107	66.5%
State Road	0	2	0	2	1.2%
Town Road	3	4	4	11	6.8%
Trail/Footpath	0	0	2	2	1.2%
TOTAL	20	59	82	161	100%

BUFFERS

Shoreline buffer installation on a lakefront property. (Source: https://www.uwp.edu)

Installing an effective shoreline buffer can be one of the easiest ways to help improve water quality. Natural vegetated shorelines are often the "last line of defense" for trapping and treating polluted stormwater runoff before it gets to the lake. A healthy, vegetated shoreline will not only act as a buffer between the lake and adjacent shoreline development but will also provide great benefit to wildlife as more species live in (and rely on) shoreline riparian zones than any other habitat type (Maine Audubon, 2006). Increasing development pressure throughout the watershed, and especially within the shoreland zone of China Lake, and the effects of climate change (more frequent and more intense precipitation and increased volume and velocity of stormwater runoff) means that healthy, vegetated shoreline buffers will be even more important for achieving water quality goals and maintaining a healthy lake ecosystem.

The 2020 watershed survey confirmed a general lack of effective shoreline buffers at residential properties on China Lake, representing 66% of all NPS sites documented. The CLA currently runs a LakeSmart program that has certified 35 properties on China Lake. This plan recommends continuing to encourage shorefront property owners to participate in the program, with the goal of 25% of shorefront properties participating by 2032. LakeSmart currently requires a vegetative buffer zone that is at least 10-feet deep (on average) comprised of at least three of the five total vegetation stand types (duff layer, ground cover, shrubs, understory, and canopy) to ensure that stormwater runoff is captured and infiltrated within the buffer, raindrops are interrupted by overstory vegetation, and the overall function of the shoreline is maximized.



Example of an effective shoreline buffer with five tiers of vegetation. (Source: Maine Lakes)

Outreach efforts will include a buffer campaign with easy-to-follow guidance for installing effective shoreline buffers highlighting the importance of **buffer quality**- as a healthy and functioning shoreline buffer includes more than just the installation of native plantings. The quality of the soil and a healthy duff layer is just as important when constructing an effective vegetated shoreline.

In addition to starting a LakeSmart program at China Lake, several phases of federal grants (particularly Clean Water Act Section 319 grants awarded by the US EPA to Maine DEP) will be sought to address high and medium-impact sites on commercial properties, driveways, and residential properties on the shoreline, with a goal of addressing 20 high-impact sites, 59 medium-impact sites, and 50 low-impact sites over the next 10 years. If time and resources permit, the additional 32 low-impact sites will be addressed during this planning period or will be incorporated into a future plan.

The following actions are recommended for reducing the external load by addressing known NPS sites in the watershed. A detailed planning schedule, potential funding sources, and estimated costs for 18 related actions is provided below.

AGRICULTURE AND FORESTRY

As part of the 2020 watershed NPS survey, agricultural and forestry practices used in the watershed were reviewed. The information provided in these reviews was used to help refine the land cover update and P loading estimates. An estimated 2,044 acres of land in the watershed are in agricultural production, including 1,072 acres of row crops, 620 acres of pasture/grazing, and 353 acres of hayfield- representing 12% of the total land area in the watershed (see land cover map in Appendix C). Many of these farms already work with the Natural Resources Conservation Service (NRCS) to manage their land for nutrient retention, waste storage, and runoff prevention among other things. A total of 860 NRCS practices were applied in the China Lake watershed between 2007 and 2020. These NRCS programs provide an established way to reduce P on agricultural properties in the watershed.

A review of forestry in the watershed resulted in improved estimates of the amount of recently harvested areas in the watershed. Approximately 55% (9,578 acres) of the watershed is forested, while 2% (306 acres) of the watershed is recently harvested forestland. More information is needed to determine what impact these harvests may have had on P loading to China Lake, including surface hydrology at the harvest sites and BMPs used during harvesting. This plan recommends meeting with the Maine Forest Service to better assess these impacts and offer technical assistance to address NPS impacts from timber harvesting. Where possible, watershed lands should be maintained as, or restored to, forestland. A healthy, well managed forest with a mixed aged and species canopy provides the most protective land use for maintaining or improving water quality in China Lake. Because clean water is a natural by-product of a healthy forest, policy makers should promote land-use practices that encourage landowners to maintain forested watershed parcels whenever practical.

ADDRESS DOCUMENTED NPS SITES

ACTION ITEMS & MANAGEMENT MEASURES

Action Plan & Management Measures		Schedule	Who	Potential Funding Sources	Estimated Cost (10 years)
A. Reduce External Phosphorus Load (NPS Sites)					
A1	Review prioritized list of 79 high and medium impact sites from the 2020 watershed survey and develop a **candidate site list** for future 319 grant applications	Year 1	CRLA, CLA, KCWCD, Consultant	CLA	$500
A2	Reduce phosphorus export from **agricultural land** in the watershed through increased landowner participation in USDA/NRCS programs that provide financial support for agricultural BMPs	Years 1 - 10	USDA/NRCS, KCSWCD, agricultural landowners	USDA/NRCS (EQIP, CSP)	$500,000
A3	Assess the impact of **logging** in the watershed by hosting a meeting with the Maine Forest Service to create an inventory, better understand extent of impact, and offer technical assistance to address NPS problems	Years 2-4	CLA, private woodlot owners, KWD, MFS	CLA, KWD	$1,500
Address High Impact NPS Sites (20 sites)					
A4	Address NPS sites on residential properties ***Goal: 7 residential sites***	Years 1-3	CRLA, KCSWCD, private property owners	US EPA (319), Maine DEP, Commercial Property Owners	$25,000
A5	Address NPS sites on private roads***: 4 private road sites***	Years 1-3	CRLA, KCSWCD, private property owners	US EPA (319), Maine DEP, Landowners	$12,000
A6	Address NPS sites on town roads ***Goal: 3 town road sites***	Years 1-3	CRLA, KCSWCD, Town of China	US EPA (319), Maine DEP, Landowners	$5,000

Action Plan & Management Measures		Schedule	Who	Potential Funding Sources	Estimated Cost (10 years)
A7	Address NPS sites on driveways ***Goal: 2 driveway sites***	Years 1-3	CRLA, KCSWCD, landowners & road associations	US EPA (319), Maine DEP, landowners	$5,000
A8	Address NPS sites on other high impact sites ***Goal: 4 other sites***	Years 1-3	CRLA, KCSWCD, private property owners	US EPA (319), Maine DEP, Landowners	$500
Address Medium Impact NPS Sites (59 sites)					
A9	Address NPS sites on residential properties ***Goal: 35 residential sites***	Years 2-5	CRLA, KCSWCD, landowners	US EPA (319), Maine DEP, landowners	$105,000
A10	Address NPS sites on private gravel roads ***Goal: 9 sites***	Years 2-10	CRLA, KCSWCD, landowners	US EPA (319), Maine DEP, landowners, road associations	$90,000
A11	Address NPS sites on town roads ***Goal: 4 sites***	Years 2-10	CRLA, KCSWCD, Town of China	US EPA (319), Maine DEP, Town of China	$100,000
A12	Address NPS sites on beach access sites ***Goal: 4 sites***	Years 2-10	CRLA, KCSWCD, landowners	US EPA (319), Maine DEP, landowners	$40,000
A13	Address NPS sites on state roads ***Goal: 2 sites***	Years 2-10	CRLA, KCSWCD, DOT	US EPA (319), Maine DEP, Maine DOT	$40,000
A14	Address NPS sites on driveways ***Goal: 2 driveway sites***	Years 2-10	CRLA, KCSWCD, landowners	US EPA (319), Maine DEP, landowners	$5,000
A15	Address NPS sites on other sites (boat access, commercial) ***Goal: 3 sites***	Years 2-10	CRLA, KCSWCD, Commercial property owners	US EPA (319), Maine DEP, landowners	$6,000
Address Low Impact NPS Sites (50 sites)					
A16	Work with residential property owners to address low-impact residential NPS sites (including driveways, trails/paths, beach access, construction) ***Goal: Address 50% of low-impact residential related sites (38 sites)***	Years 5-10	CRLA, Landowners	Landowners	$74,000

Action Plan & Management Measures		Schedule	Who	Potential Funding Sources	Estimated Cost (10 years)
A17	Continue existing LakeSmart Program and encourage shorefront properties to become LakeSmart ***Goal: 25% (113 properties) of shorefront property owners participating by 2031***	Years 1-10	CRLA	CLA, Town of China, Landowners, US EPA (319), Maine DEP	$7,000
A18	Work with landowners to address low-impact driveway sites ***Goal: Address 5 driveway sites***	Years 5-10	CRLA, KCSWCD, landowners	Road Associations, Private Landowners	$40,000
A19	Address low-impact sites on town road and municipal/public sites ***Goal: Address 5 low-impact town road and municipal/public sites***	Years 5-10	CRLA, KCSWCD, Town of China	Town of China	$26,500
A20	Work with road associations and homeowners to address low-impact private road sites ***Goal: Address 2 low-impact road sites***	Years 5-10	CRLA, KCSWCD, Road Associations	Town of China, Road Associations, Private Landowners	$5,000
External Phosphorus Load (NPS Sites) Subtotal					**$1,088,000**

SEPTIC SYSTEMS

While P loading from septic systems appears to have a relatively small impact on the water quality of China Lake based on the watershed modeling (7% in the east basin and less than 1% in the west basin), there are still many unknowns about their impact. Just one or two failing septic systems leaching nutrient-rich wastewater into the lake could result in localized water quality problems. Proposed load reduction targets from septic systems are conservative estimates that can be further refined when more information is available regarding the state of septic systems in the watershed. The following actions are recommended for reducing the external load by upgrading septic systems in the watershed. A detailed planning schedule, potential funding sources, and estimated costs for eight related actions is provided below.

REDUCE NPS FROM SEPTIC SYSTEMS ACTION ITEMS & MANAGEMENT MEASURES				
Action Plan & Management Measures	**Schedule**	**Who**	**Potential Funding Sources**	**Estimated Cost** (10 years)
Reduce NPS from Septic Systems (Goal 10% of old systems replaced)				

Action Plan & Management Measures		Schedule	Who	Potential Funding Sources	Estimated Cost (10 years)
A21	Combine the pre-1998 Town of China Septic Database with 2021 update that utilized the State HHE 200 database and create a prioritized list of at-risk systems.	Ongoing	CLA, Town of China	Grants, CLA	$5,000
A22	Target property owners located on parcels with **at risk soils and offer technical assistance** (318 developed properties in the Town of China within the watershed including 134 developed shoreline properties). Cross reference with updated septic database to prioritize older systems.	Year 2-4	CLA, Town of China, Maine State Soil Scientist	Grants, CLA	$2,500
A23	Offer landowners free septic evaluations & septic designs for high priority systems ***Goal: 10 free evaluations, 5 system designs***	Years 4-6	CLA, KCSWCD, Site Evaluators	Grants	$12,500
A24	Provide cost-share grants to assist landowners with replacing problem septic systems **Goal: 5 systems (targeted outreach to landowners with systems >20 years old and/or failing or malfunctioning systems)**	Years 4-10	CLA, KCSWCD, DHHS, Watershed Towns	Grants	$50,000
A25	Conduct community outreach regarding **DEP Small Community Septic System grants** for malfunctioning systems to eligible landowners with high priority systems	Years 1-10	CLA, Towns of China & Vassalboro	n/a	$500
A26	Require **proof that septic systems have been installed to code** when properties change from seasonal to year-round status, and require replacement if proof is not available	Years 1-10	Towns of China & Vassalboro	Town of China	$1,500
A27	Create a system for adequately **tracking septic inspections** conducted for all real estate transactions in the shoreland zone; this may include an ordinance that requires new homeowners to submit	Years 1-2	Towns of China & Vassalboro	Town of China	$5,000

Action Plan & Management Measures		Schedule	Who	Potential Funding Sources	Estimated Cost (10 years)
	a copy of their inspection report to the town				
A28	Create a permitting system and **registration requirement for rental properties on the shoreline** to minimize impacts from undersized septic systems	Years 2-4	Towns of China & Vassalboro	Town of China	$10,000
External Phosphorus Load (Septic Systems) Subtotal					**$87,000**
External Phosphorus Load (NPS Sites & Septic) Total					**$1,175,000**

ADDRESSING THE INTERNAL LOAD

As described in the previous section, internal loading from sediments exposed to low oxygen is a major source of P to China Lake, and a key factor in the dynamics causing elevated P in the lake which fuel recurring nuisance algal blooms. *The internal load will need to be reduced to meet desired water quality targets and conditions in the lake*.

PRELIMINARY EVALUATION OF REMEDIATION OPTIONS

There are several ways to directly address algal blooms caused by internal P loading, but the focus of remediation should be on preventing blooms from occurring. There are three basic approaches known to work with an acceptable degree of reliability from past research and experience: dredging, oxygenation, and P inactivation. These are not mutually exclusive approaches, but rarely is more than one applied in a given lake. Several other approaches have been discussed for China Lake including: hypolimnetic withdrawal, lake drawdown and alewife reintroduction (Appendix J).

A large barge is used to add alum to lakes with chronic internal P loading. (Photo credit, Georges Pond Association)

Phosphorus inactivation can be used three ways: to treat incoming water high in phosphorus, to strip phosphorus from the water column in a lake, or to bind phosphorus in surficial sediments and make reserves less susceptible to release under anoxia. All are applicable, but the most advantageous approach would be a treatment of the sediment area subject to anoxia with a phosphorus binder such as aluminum. The track record for such treatments is favorable, including past efforts in Maine, and the empirical evidence that higher Al:Fe ratios in the sediment prevents phosphorus release also favors this approach. Previous assessments of China Lake's water quality concluded that an aluminum treatment would be an effective strategy for addressing internal P loading and meeting water quality goals for China Lake (MDEP, 2001; Kleinschmidt, 2012).

Successful P inactivation of sediment under water >7 m deep could reduce the average P concentration in the east basin by about 40% in each basin (Table 13) and result in a reduction of at least 90% of the internal load. If only the east basin was treated, the P concentration in the west basin would be reduced by about 20%.

Table 13. *Possible improvement in China Lake with a 90% reduction in internal loading (Source: WRS, 2021)*

90% Reduction	Current Model Prediction		EB internal reduced 90%		EB+WB internal reduced 90%	
	East Basin	*West Basin*	*East Basin*	*West Basin*	*East Basin*	*West Basin*
Avg In-lake TP (ppb)	18.3	15.0	10.8	12.9	10.8	7.5
Avg Secchi (m)	2.5	2.9	3.7	3.3	3.7	4.9
Avg chl-a	6.6	5.1	3.3	4.2	3.3	1.9
% of time Chl-a >8 ppb	26.7	12.7	2.2	6.1	2.2	0.10

For the east basin with a 90% reduction in internal P load, the probability of blooms[37] would decrease from 26.7 to 2.2%, equivalent to a decline in the period with poor conditions from over 3 months to about a week. For the west basin with only P inactivation in the east basin, the bloom probability decreases from 12.7 to 6.1%. With a 90% reduction in the west basin internal load, the bloom probability further declines to 0.1%.

The cost of P inactivation is a function of the necessary dose and area to be treated. Ten composite samples, seven of which were tested, is a good start toward estimating inactivation needs, but is hardly adequate for a lake of this size. Working with available data, however, sediment assays with aluminum addition were conducted at Colby College and had generally favorable results. Using these results and applying the most applicable ones to the areas for which sediment samples were not tested, estimates of dosing needs and related costs were developed (Appendix K). Dose determination is approximate, given the limited amount of data available, but a suggested dose is offered based on best professional judgement based on available data.

[37] Defined as Chl-a < 8 ppb.

Suggested doses range from 30 to 70 g/m^2 and the cost to treat the east basin is about $1.4 million, while the cost to treat the west basin is about $2.1 million, based on the best available information, but more sample collection and analysis is strongly advised before planning a P inactivation treatment. At the cost envisioned, the cost to better define dosing needs is minor by comparison and getting a better feel for how much to apply where to achieve target conditions is strongly advised.

Following review of the results of the sediment analysis and P inactivation summary by the project's technical advisory committee, a treatment for the east basin was recommended for this Plan. A preliminary treatment areas and aluminum dose map is presented in Appendix K which will be refined following additional sediment sampling and analysis expected to occur within the first year of plan implementation. Aluminum is used extensively in water treatments worldwide. When applied in a lake, it is buffered to remain pH neutral and will not harm fish when applied properly. Fish and aquatic life surveys will be conducted before, during and after the treatment, as well as in-plume monitoring of pH, and floc evaluation during treatment to ensure that pH remains neutral.

Watershed management by itself will not achieve desired water quality conditions in China Lake but will provide protection for the future and increase the efficacy of an in-lake treatment which is necessary to meet the objective of minimizing algal blooms in China Lake. The following actions are recommended for reducing the internal loading in China Lake. A detailed planning schedule, potential funding sources, and estimated costs for eight related actions is provided below.

REDUCE THE INTERNAL LOAD
ACTION ITEMS & MANAGEMENT MEASURES

Action Plan & Management Measures		Schedule	Who	Potential Funding Sources	Estimated Cost (10 years)
B. Internal Phosphorus Load in China Lake					
Conduct an Aluminum Treatment					
B1	Conduct **additional sediment sampling and analysis for the <u>east basin</u>** before finalizing an aluminum treatment plan	Year 1	CLA, DEP, Colby, KWD	CLA, KWD, Private Donors	$5,000
B2	Develop final **treatment options and a funding plan** for inactivating sediment in the east basin	Year 1 - 2	CLA, consultant	CLA, consultant	$1,500
B3	Complete required **permitting** for aluminum treatment(s)	Year 3			$6,500

	Action Plan & Management Measures	Schedule	Who	Potential Funding Sources	Estimated Cost (10 years)
			CLA, consultant, contractor	CLA, Consultant, Maine DEP	*(plus $793 annual permit fee)*
B4	Develop Request for Proposals (RFP) and **select contractor** for aluminum application(s)	Year 3	CLA, Consultant	CLA	$1,000
B5	Conduct **aluminum treatment**(s) in the east basin	Years 4 - 5	CLA, Colby, consultants	CLA, Town of China & Vassalboro, grants or low interest loans, Maine DEP, Donors, Landowners	$1,405,000
B6	Implement an **aluminum treatment monitoring plan** before and during treatment(s)	Years 4 - 5	CLA, LSM, Colby, KWD, consultants	CLA, KWD, Private Donors	$15,000
B7	**Continue fall drawdown** and revisit timing and volume following downstream dam removal to maximize P removal	Years 1 - 10	Town of Vassalboro	Town of Vassalboro	$2,500
B8	**Assess the need for an aluminum treatment in the <u>west basin</u>** following treatment of the east basin. If needed, collect additional sediment samples and develop a treatment plan.	Years 6 - 7	CLA, DEP, Colby, KWD	CLA, KWD, Private Donors	$5,000
				Internal Phosphorus Load Total	**$1,441,500**

PREVENT NEW SOURCES OF NPS POLLUTION

Preventing new sources of P from getting into the lake will be key to the success of the management strategies described above. As the water quality in the lake improves, China Lake will continue to be a desirable place to live and to visit, resulting in new development in the watershed. Prevention strategies will include ongoing public education, municipal planning, and land conservation.

FUTURE DEVELOPMENT, MUNICIPAL PLANNING & CONSERVATION

The Town of China has several ordinances that regulate P input, runoff, and development in the shoreland zone. The town's Resource Protection District, Shoreland District, and Stream Protection District include all waterbodies in the China Lake watershed and their shoreland zones, and they all include measures to prevent P loading from new development. However, it is likely that many older structures do not meet the current standards set by these ordinances. Along with new construction on the remaining undeveloped shoreline parcels, conversion of seasonal or second homes to year-round homes is the most likely shift in usage along the shoreline, thereby increasing the potential for additional stormwater runoff to the lake, and related impacts from septic systems. Ensuring that regulations are in place to address runoff from conversions of structures in the shoreland zone will be important for protecting water quality.

Roads and driveways built to access new development can deliver large quantities of sediment and attached P if not built correctly or maintained properly. (Photo Credit: CLA)

Any improvement in water quality is likely to increase the potential for additional development in the watershed and along the shoreline (including seasonal to year-round conversions). Protecting high-value riparian habitat through land conservation in order to safeguard small headwater streams and large areas of undeveloped forests should be a consideration over the next 10-year planning period.

Below are the major recommendations from the China Lake Steering Committee and Technical Advisory Committee related to reducing impacts from future development. A detailed planning schedule, potential funding sources, and estimated costs for seven related actions is provided below.

PREVENT NEW SOURCES OF NPS (FUTURE DEVELOPMENT) ACTION ITEMS & MANAGEMENT MEASURES					
Action Plan & Management Measures		**Schedule**	**Who**	**Potential Funding Sources**	**Estimated Cost** (10 years)
C. Prevent New Sources of NPS Pollution					
General Tasks					
C1	Attend regular town selectman's meetings to update the towns about watershed activities and needs ***Goal: Minimum 2 meetings/town/year***	Years 1-10	CLA	CLA	$500

Action Plan & Management Measures		Schedule	Who	Potential Funding Sources	Estimated Cost (10 years)
C2	Work with town officials to review and revise BMPs related to **cleaning up winter sand** and annual road maintenance	Years 1-10	CLA	CLA	$1,000
C3	Work with landowners/road associations to conduct **annual road maintenance on gravel roads and reduced salt application** where applicable	Years 2-10	CLA, KCSWCD	CLA	$1,000
Future Development & Conservation					
C4	Investigate and report on an opportunity to create a China Lake Watershed Land Trust to identify, acquire and preserve land parcels in the watershed, when undeveloped over time, benefits water quality in the lake	Years 1-3	CLA, local land trusts, watershed towns	CLA, KWD, watershed towns, grants	$2,500
Municipal Planning					
C5	Conduct a **review of current town ordinances** to determine what improvements can be made to be more protective of water quality in the watershed	Years 3-5	CLA, towns of China, Vassalboro & Albion, KVCOG	Towns, grants	$5,000
C6	Develop a **watershed-wide P control ordinance** for all new development (including single family residential units and roads and seasonal to year-round conversions)	Years 3-5	CLA, Watershed Towns	CLA, towns	$10,000
C7	Include provisions for **3rd party site review**, and long-term maintenance as a requirement for all new building permits	Years 3-5	Watershed Towns	Towns, grants	$25,000
Prevent New Sources of NS (Future Development) Total					**$45,000**

CLIMATE CHANGE

Watershed modeling estimates **an additional 56 – 118 kg P/yr from the watershed and 85 – 90 kg P/yr from increased internal loading with an increase in precipitation of 10% due to climate change.** Climate change adaptation planning, such as upgrading infrastructure on roads (i.e., undersized culverts), infiltrating stormwater runoff on commercial and residential properties, planting buffers, and conserving undeveloped land are a few ways to counteract the effects of the anticipated increase in precipitation.

The following climate change activities should be factored into the future watershed planning activities. A detailed planning schedule, potential funding sources, and estimated costs for the ten actions is provided below.

PREVENT NEW SOURCES OF NPS (CLIMATE CHANGE)					
Action Plan & Management Measures		**Schedule**	**Who**	**Potential Funding Sources**	**Estimated Cost** (10 years)
Climate Change					
C8	Host a **climate change workshop** or webinar to provide information about ways landowners can adapt to climate change and help protect water quality	Year 4	CLA, Maine Climate Council, Watershed Towns	Grants	$2,500
C9	Conduct a **stream-crossing survey** to assess whether culverts at road/stream crossings require upgrades	Years 3-4	CLA, KCSWCD, Consultant	Grants, CLA	$3,000
C10	Work with the watershed towns and Maine DOT to apply for grants to fund and implement **culvert upgrade projects**	Years 5-10	CRLA, KCSWCD, towns of China & Vassalboro, Maine DOT	Towns, Maine DOT, Maine DEP	$5,000
Prevent New Sources of NPS Pollution (Climate Change)Total					**$10,000**

INFORMATION, EDUCATION & OUTREACH

Public education and outreach is an important and necessary component of the China Lake watershed restoration strategy. Development of a comprehensive outreach strategy led by a steering committee consisting of watershed partners that are actively conducting outreach is needed in order to streamline outreach messaging and increase participation in watershed planning activities in order to meet water quality goals.

CLA is the primary entity conducting public outreach in the watershed. CLA currently hosts an annual meeting for all interested watershed residents, provides watershed updates on its website, and distributes an annual newsletter, as well as supporting CRLA programming. As of 2022, CRLA is heading up the China Lake CBI program, LakeSmart, YCC, and related watershed restoration work. KCSWCD has provided technical assistance to the CRLA and watershed landowners for past 319 grant projects.

A detailed planning schedule, potential funding sources, and estimated costs for each of the 18 education and outreach action is provided below.

INFORMATION, EDUCATION & OUTREACH ACTION ITEMS & MANAGEMENT MEASURES					
Action Plan & Management Measures		**Schedule**	**Who**	**Potential Funding Sources**	**Estimated Cost** (10 years)
D. Education, Outreach & Communications					
General Outreach					
D1	Develop an outreach strategy/**communications committee** to get the word out to the community; meet quarterly to discuss plan objectives	Year 1-2	CLA, interested stakeholders	CLA	$2,500
D2	Maintain the CRLA and CLA websites with a page dedicated to the China Lake WBMP for public to access information	Year 1-2	CRLA, CLA	CRLA, CLA	$5,000
D3	Keep partner **websites** updated regarding on-going monitoring efforts and NPS pollution projects	Years 1-10	KWD, Town of China, Town of Vassalboro	KWD, Towns	$5,000
D4	Provide **welcome packets** to new property owners with water quality educational materials	Years 1-10	CLA	CLA	$5,000
D5	Prepare and distribute **press releases** about watershed improvement activities, grant projects, and successful projects	Years 1-5	CLA/CRLA	CLA	$2,500
D6	Develop and install permanent informational signage at boat launch sites and picnic areas at N. and S. necks at the China Narrows	Years 3-6	CLA, KWD	KWD, CLA, Towns	$2,500
Aluminum Treatment Outreach					
D7	Develop a Frequently Asked Questions (FAQ) page about aluminum treatments and post on partner websites that describes the	Year 1	CLA, DEP, consultant	CLA	$250

Action Plan & Management Measures		Schedule	Who	Potential Funding Sources	Estimated Cost (10 years)
	process and addresses health and safety concerns				
D8	Develop an **online educational video** pertaining to the need for an aluminum treatment that can be viewed by the public and help with fundraising efforts	Year 1-2	CLA Outreach Committee	Grants, CLA	$5,000
Targeted Outreach					
D9	Follow-up with the Town of China regarding 2020 watershed survey sites for their annual budget planning (roads)	Year 1	CLA, CRLA	n/a	n/a
D10	Follow-up with **educational materials for landowners with high-impact sites** (8 sites) **and medium-impact sites** (24 sites) to gauge interest in cost-sharing opportunities for a future 319 grant	Year 1-2	CRLA, KCSWCD	CRLA, Grants	$1,600
D11	Design a **Buffer Campaign** with easy to follow guidance/recipes for installing effective shoreline buffers and canvas the watershed	Year 1-2	CRLA, CLA	Grants, Landowners	$5,000
D12	Send letters to and meet **road associations** with documented NPS problems to determine interest in future 319 grant cost-sharing opportunities	Year 1	CRLA, CLA, KCSWCD, Road Associations	CLA	$3,000
D13	Conduct outreach to landowners/road associations to **promote use of bluestone gravel surface material from local gravel pits** for use on driveways and roads	Years 2-4	CRLA, CLA, KCSWCD, Road Associations, Landowners	CLA, Maine DEP	$5,000
D14	**Increase participation in NRCS agricultural programs** through regular newspaper articles, NRCS sponsored workshops, and targeted outreach to small-scale	Years 1 - 3	NRCS, KCSWCD	NRCS	$1,500

Action Plan & Management Measures		Schedule	Who	Potential Funding Sources	Estimated Cost (10 years)
	hobby farms throughout the watershed				
Workshops					
D15	Host **gravel road workshops** in the watershed working directly with road associations	Years 3, 6 & 8	CRLA, KCSWCD, Maine DEP	CRLA, US EPA (319)	$6,000
D16	Host **LakeSmart workshops** in targeted neighborhoods	One every 2 years, different areas of the shoreline	CRLA	CRLA, CLA	$2,500
Other					
D17	Work with **local realtors and the** towns to **track property transfers and subdivisions**	Years 1-10	Town of China, Town of Vassalboro, CLA, Realtors	Town of China & Vassalboro	$10,000
			Education, Outreach & Communications Total		**$62,350**

BUILDING LOCAL CAPACITY

CLA, in cooperation with watershed partners, will oversee plan implementation, which will require funding the plan, meeting annually with project partners, and strengthening relationships within the community among other tasks described below. A detailed planning schedule, potential funding sources, and estimated costs for each of the nine capacity building actions is provided below.

BUILD LOCAL CAPACITY ACTION ITEMS & MANAGEMENT MEASURES					
Action Plan & Management Measures		**Schedule**	**Who**	**Potential Funding Sources**	**Estimated Cost** (10 years)
E. Build Local Capacity					
Fundraising					
E1	Develop and maintain a fundraising **committee** to help implement the plan	Year 1-2	CLA, interested stakeholders	n/a	$0

Action Plan & Management Measures		Schedule	Who	Potential Funding Sources	Estimated Cost (10 years)
E2	Create a sustainable funding plan to pay for the cost of an aluminum treatment for the east basin, watershed restoration projects, and long-term monitoring ***Goal: $2 million raised by 2031***	Years 1-3	CLA	CLA, private donors, TIF	$5,000
E3	Hire a part-time **watershed coordinator** to oversee plan implementation	Years 2-10	CLA, CRLA	CLA, CRLA, towns, grants, private donors	$150,000
E4	Apply for US EPA Clean Water Act Section 319 watershed implementation grants to address the external load in the east basin, and NPS sites ***Goal: 3 phases of 319 implementation projects***	Years 2, 5, 7	CLA, CRLA, Consultants	CLA, CRLA, towns, private donors	$9,000
E5	Fundraise for **septic system cost-sharing grants**	Years 1-3	CLA	CLA, grants, Town of China	n/a
E6	Apply for other state, federal or private foundation **grants** that support planning recommendations	Years 1-10	CLA, Consultants	CLA	$5,000
Steering Committee & Partnerships					
E7	Steering Committee to **meet quarterly years 1 - 3, and annually thereafter** to discuss action items and goals	Quarterly, Years 1 - 3 and Annually, Years 4 - 10	CLA, Steering Committee	n/a	n/a
E8	Reach out to **new potential SC members** including town officials, local businesses, realtors, and septic inspectors	Year 1, 5 & 8	CLA	n/a	n/a
E9	Continue working with the watershed towns to strengthen **stakeholder relationships** and bolster community support for restoration efforts	Years 1-10	CLA, CRLA, KWD	n/a	n/a
Education, Outreach & Communications Total					**$169,000**

8. Monitoring Activity, Frequency and Parameters

Maine water quality standards require China Lake to have a stable or improving trophic state and be free of culturally induced algal blooms. Measuring changes in water quality of the lake is a necessary component of successful watershed planning because it evaluates progress. When improvements in water clarity, P, or other positive changes in water quality are evident, then planning objectives are being met. Whereas, if water quality gets worse, additional management strategies may be needed.

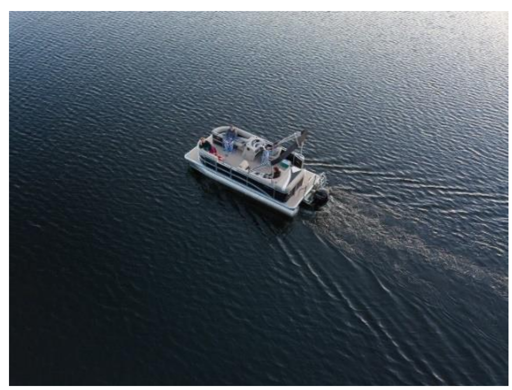
The monitoring program has been divided into six planning categories:

1) **Baseline Monitoring**
2) **Sediment Sampling & Analysis**
3) **Aluminum Treatment Monitoring**
4) **Alewife Monitoring**
5) **Stream Monitoring**
6) **Invasive Plants & Harmful Algal Blooms (HAB)**

A detailed planning schedule, potential funding sources, and estimated costs for each monitoring action is provided below.

FUTURE BASELINE MONITORING

An assessment of existing water quality monitoring data in China Lake was completed as part of the water quality analysis (1970 - 2020). Ongoing baseline monitoring should continue on China Lake indefinitely to assess and track annual changes in water quality, the effects of P inactivation in the east basin, alewife reintroduction, and to evaluate the success of NPS mitigation efforts. Future baseline monitoring should be conducted from mid-April through mid-October at all three stations including:



KWD maintains a boat and monitoring equipment for baseline sampling in China Lake. (Photo Credit: CLA)

1) **Water Clarity, Temperature, Dissolved Oxygen, Chlorophyll-*a*, and pH** collected bi-weekly.

2) **Phosphorus** collected twice monthly at 7m, 14m, and 21m at Station 1, and at 7 and 14m at Stations 2 and 3, using a Van Dorn sampler. Monthly samples will continue to be taken at the dam.

BASELINE MONITORING
ACTION ITEMS & MANAGEMENT MEASURES:

	Action Plan & Management Measures	Schedule	Who	Potential Funding Sources	Estimated Cost (10 years)
F. Conduct Long-Term Monitoring & Assessment					
Baseline Lake Monitoring					
F1	Continue collecting **baseline water quality data** to inform long-term management actions (see future monitoring plan)	Years 1-10	KWD, Maine DEP	KWD, Private Donors, Grants	$120,000
F2	Add nitrogen and iron testing to baseline monitoring to gain a better understanding of limiting nutrients and Fe:P ratios (especially at depth)	Years 2-3	CLA, LSM	n/a	$0
F3	Track and document the presence and duration of **metaphyton in the littoral zone**	Years 1-10	KWD, Volunteers	KWD	$0
F4	Add annual baseline monitoring results to long-term data set and **update long and short-term trends analysis** to document any changes	Years 1-10	KWD, DEP, Consultant	KWD	$3,750
F5	Continue collecting **monthly P samples at the outlet dam** at least monthly	Years 1 - 10	KWD, Town of Vassalboro	Town of Vassalboro, KWD	$8,400
				Baseline Monitoring Total	**$132,150**

SEDIMENT SAMPLING & ANALYSIS

Follow-up sediment testing and analysis is needed following the 2021-2022 sediment analysis conducted by Colby College in order to refine aluminum treatment area and dose for the east basin. Preliminary recommendations include an additional 6 core samples at three different depth ranges in the southeast basin, and 3 core samples across three depth ranges in the northeast basin. Should there be a need to inactivate P in the sediment in the west basin in the future, an additional 10 samples (at 30 locations across four depth ranges) is recommended but is not a high priority for this 10-year plan.

SEDIMENT SAMPLING & ANALYSIS ACTION ITEMS & MANAGEMENT MEASURES:					
Action Plan & Management Measures		**Schedule**	**Who**	**Potential Funding Sources**	**Estimated Cost** (10 years)
Sediment Sampling & Analysis					
F6	Collect additional sediment samples to inform the aluminum treatment in the east basin (see B1) and develop treatment plan based on the results	Year 1	CLA, DEP, Colby, KWD	CLA, KWD, Private Donors	Costs included in action item B1
F7	Collect additional sediment samples in the west basin as needed (see B8)	Years 5-6	CLA, DEP, Colby, KWD	CLA, KWD, Private Donors	$10,000
			Sediment Sampling & Analysis Total		**$ 10,000**

ALUMINUM TREATMENT MONITORING

An alum barge preparing for deployment (Photo Credit: John Eliasberg, GPA)

Baseline monitoring, detailed above, will provide an accurate assessment of the pre-treatment conditions in China Lake and measure changes in the long-term water quality trends. Additional monitoring performed during and after the aluminum treatment(s) will be required (a condition of the Maine DEP permit to apply the aluminum) to ensure water quality criteria are met for the protection of fish and aquatic life from aluminum toxicity and will allow for evaluation of short and long-term effects of the treatment(s). Short-term objectives include maintaining appropriate pH, alkalinity, and aluminum levels during the aluminum treatment, and long-term objectives include documenting reduced in-lake TP concentrations and the elimination of harmful algal blooms in China Lake. Pre (at least one week prior to treatment) and post aluminum treatment monitoring (within a week after treatment) and monitoring during the aluminum treatment, and monthly thereafter will be required as part of the permitting process.

A detailed aluminum treatment monitoring plan including monitoring schedule, frequency, and parameters before, during, and after the proposed aluminum treatment(s) will need to be developed prior to an aluminum treatment. The plan will include all parameters measured during baseline plus:

- **Alkalinity** samples will be collected from the epilimnion (epilimnetic core) as determined by the dissolved oxygen and temperature profile as well as a bottom grab sample.
- **Aluminum** samples (total and dissolved) will be collected monthly from an epilimnetic core and bottom grab following an aluminum treatment until concentrations return to pre-treatment levels.
- **Sediment** samples (composited) will be collected and analyzed using a modified Psenner Al/Fe/P speciation technique at 5-year intervals.
- **Fish and aquatic life surveys** will be ongoing during and after the aluminum treatment (see below).

The plan will also outline requirements for monitoring throughout the day during the aluminum treatment at specific monitoring locations including the treatment area, a control point, in plume monitoring and floc evaluation, and daily fish and aquatic life surveys of the shoreline during the aluminum treatment, and monthly thereafter. Surveyors will also observe shoreline areas for fish, shellfish, snail, amphibian, and bird fatalities, insect hatches and other signs of potential aluminum or pH toxicity.

ALUMINUM TREATMENT MONITORING
ACTION ITEMS & MANAGEMENT MEASURES

	Action Plan & Management Measures	Schedule	Who	Potential Funding Sources	Estimated Cost (10 years)
Aluminum Treatment Monitoring					
F8	Develop and **aluminum treatment monitoring plan**	Years 2-3	CLA, DEP, Colby, KWD	CLA	Costs associated with aluminum treatment
F9	Conduct **pre- and post-aluminum treatment monitoring** to include baseline monitoring data plus alkalinity, aluminum, plankton, sediment, fish and aquatic life surveys; **conduct monitoring during treatment(s)** (treatment area monitoring, control monitoring, in-plume monitoring & floc evaluation, and fish and aquatic life surveys)	Pre- and post within a week before treatment, during, within a week of completion, monthly thereafter	CLA, Consultant	Private Donors, Grants	

ALEWIFE MONITORING

Alewife were re-introduced to China Lake beginning in 2014 with about 25,000 fish brought over the dam each year. 2021 was the first year in which alewives were able to return to the outlet dam of China Lake due to the opening of two fish passages and removal of two dams on the outlet stream. These fish were netted over the dam for several days. Beginning in late 2021, the fish passage at the outlet dam was opened, allowing the alewives to return to China Lake freely in the spring of 2022. DMR will be monitoring the fish passage for several years after its opening and including using electronic fish counters, PIT tagging, and visual counts. Alewives main food source is zooplankton, and zooplankton's main food source is phytoplankton (algae). Currently no baseline data exists on the plankton community in the lake. An immediate need is to collect plankton samples while the alewife introduction and populations are relatively new to the lake to examine short- and long-term changes to the plankton community. Monitoring activities include:

ALEWIFE MONITORING ACTION ITEMS & MANAGEMENT MEASURES					
Action Plan & Management Measures		**Schedule**	**Who**	**Potential Funding Sources**	**Estimated Cost** (10 years)
Alewife Monitoring					
F10	Collect monthly **plankton data** (May-Sept) at all three stations to establish a baseline (phyto & zooplankton)	Years 1-3	KWD, CLA, DEP, Consultant	KWD, CLA, Town of Vassalboro, grants, donors	$11,250
F11	Set up an **alewife counting system (in and out)**, provide annual counts to project partners	Years 1-10	DMR, Town of Vassalboro	DMR, Town of Vassalboro	$20,000
F12	**Monitor water level at the dam** to ensure alewife can leave the lake	Years 1-10	Town of Vassalboro, DMR	Town of Vassalboro, DMR	$5,000
				Alewife Monitoring Total	**$36,250**

STREAM MONITORING

Both watershed modeling and the sediment analysis completed as part of the development of the 2022 WBMP provided insights about the areas of the watershed with the greatest P inputs to the lake.

The modeling provided information about sub-basins with the greatest estimated total P load as well as drainages with the highest P load per unit area such as smaller unnamed subdrainages with more intensive land uses. The sediment analysis recommended follow-up monitoring in tributaries on the north end of the lake (i.e., Hunter Brook, Muldoon Stream). While development of a stream monitoring program would be beneficial, priority should be given to addressing shoreline development and roads and internal loading. First steps for stream monitoring might include:

STREAM MONITORING ACTION ITEMS & MANAGEMENT MEASURES					
Action Plan & Management Measures		**Schedule**	**Who**	**Potential Funding Sources**	**Estimated Cost** (10 years)
Stream Monitoring					
F13	Develop a **stream monitoring plan** for tributaries with the greatest P loading in the watershed model	Years 1-3	CLA, DEP, KWD, Colby	Grants	$1,500
F14	Conduct **stream monitoring** to better understand the sediment dynamics in east basin (north)- see F13	Years 3 - 5	CLA, DEP, KWD, Colby, CLA	Grants, CLA, Town of China	$7,500
				Stream Monitoring Total	**$9,000**

NPS ASSESSMENTS

Additional NPS assessments following the 2020 Watershed Survey can be beneficial for preventing new sources of NPS from getting into the lake as well as protecting water quality and the significant monetary investment needed for an aluminum treatment. The actions below will track NPS pollution in the watershed over the next 10 years.

NPS ASSESSMENTS ACTION ITEMS & MANAGEMENT MEASURES:					
Action Plan & Management Measures		**Schedule**	**Who**	**Potential Funding Sources**	**Estimated Cost** (10 years)
NPS Pollution Assessments					
F15	Set up **NPS Site Tracker** & update annually	Ongoing (Years 1-10)	CLA	US EPA (319)	$5,000

Action Plan & Management Measures		Schedule	Who	Potential Funding Sources	Estimated Cost (10 years)
F16	Conduct **spring site visits to logging sites** that were not assessed in the 2020 Watershed Survey	Years 1-3	CLA	CLA	$0
F17	Conduct an informal watershed survey for **new NPS sites** 5 and 10 years after initial survey	Years 3 and 8	CLA, KCSWCD, Consultant	CLA, grants	$10,000
F18	Conduct a GIS-based **shoreline photo survey** and share with the Town of China to assist with compliance in the shoreland zone; include documentation of buffer quality.	Years 2 and 7	CLA, Consultant	CLA, grants	$10,000
				NPS Assessments Total	**$25,000**

INVASIVE PLANTS & HARMFUL ALGAL BLOOMS (HABs)

In a nutrient-rich lake with a large littoral zone like China Lake, keeping aquatic invasive plants (AIP) out of the lake is a high priority. The following actions should be taken to prevent the introduction of AIP and to monitor for HABs in the lake:

INVASIVE PLANTS & HABs
ACTION ITEMS & MANAGEMENT MEASURES:

Action Plan & Management Measures		Schedule	Who	Potential Funding Sources	Estimated Cost (10 years)
Invasive Plants and Harmful Algal Bloom Monitoring					
F19	Participate in fundraising activities to **support programs that prevent the spread of milfoil** and other invasive aquatic plants (e.g., CBI, invasive plant surveys)	Years 1-10	CLA, volunteers	CLA, State Funding, towns	$40,000
F20	Recruit and train volunteers to survey the littoral zone for invasive aquatic plants	Years 1-10	CLA, LSM, DEP	CLA, volunteers	n/a

Action Plan & Management Measures		Schedule	Who	Potential Funding Sources	Estimated Cost (10 years)
F21	Conduct toxin monitoring in the presence of a lakewide "nuisance algal bloom" (SDT < 2m)	Years 1 - 10	KWD	KWD	$6,000
Invasive Plants & HABs Monitoring Total					**$46,000**
All Long-Term Monitoring & Assessment Total					**$258,000**

KWD will continue to work with project partners including Maine DEP, Lake Stewards of Maine (LSM) volunteer water quality monitors, DMR, and the Town of China to conduct long-term water quality monitoring at China Lake, and to analyze the results of this data to inform future watershed management planning and assessment.

9. Measurable Milestones, Indicators & Benchmarks

The following section provides a list of interim, measurable milestones to document progress in implementing management strategies outlined in the action plan. These milestones are designed to help keep project partners on schedule. Additional criteria are outlined to measure the effectiveness of the plan by documenting P loading reductions and changes in water quality over time thus providing the means by which the steering committee can reflect on how well implementation efforts are working to reach established goals.

Taking a Secchi disk reading. (Photo Credit: LSM)

Environmental, social, and programmatic indicators, and proposed benchmarks represent short-term (1-2 years), mid-term (3-5 years), and long-term (6-10 years) targets for improving the water quality in China Lake. The steering committee will review the criteria for each milestone annually to determine if progress is being made, and then determine if the watershed plan needs to be revised if targets are not being met. This may include updating proposed management practices and the loading analysis, and/or reassessing the time it takes for P concentrations to respond to lake and watershed restoration efforts. An adaptive management approach will be needed to revise the action plan in the event that benchmarks and milestones are not being met. The Steering Committee will weigh in on revised actions should this approach be needed during the 10-year planning period.

Environmental Milestones are a direct measure of environmental conditions. They are measurable quantities used to evaluate the relationship between pollutant sources and environmental conditions. Water quality benchmarks and interim targets for improving water quality are presented in Table 14 for the east basin and Table 15 for the west basin.

Social Milestones measure changes in social or cultural practices and behavior that lead to implementation of management measures and water quality improvements. Table 16 outlines the social indicators, benchmarks, and interim targets for the China Lake WBMP.

Programmatic Milestones are indirect measures of watershed protection and restoration activities. Rather than indicating that water quality reductions are being met, these programmatic measurements list actions intended to meet the water quality goal. Table 17 outlines the programmatic indicators, benchmarks, and interim targets for the China Lake WBMP.

***Table 14**. Water quality benchmarks and interim targets for China Lake (East Basin).*

Environmental Milestones (East Basin)			
Water Quality & Phosphorus Load Reduction Benchmark[38]	***Interim Targets****		
	Years 1-2	*Years 3-5*	*Years 6-10*
a) Increase in average annual water clarity (SDT) **Current:** 2.5 m **Goal:** 3.9 m	2.5 m *(no change)*	3.7 m *(▲ 1.7 m)*	3.9 m *(▲ 1.9 m)*
b) Phosphorus loading reductions from external phosphorus sources. **Current:** 883 kg/yr **Goal:** 827 kg P/yr (reduce by 56 kg P/yr)	10 kg/yr *(▼ 10 kg/yr)*	20 kg/yr *(▼ 30 kg/yr)*	56 kg/yr *(▼ 56 kg/yr)*
c) Phosphorus loading reductions from internal sources. **Current:** 729 kg/yr **Goal:** 73 kg P/yr (reduce by 656 kg P/yr)	0 kg/yr *(no change)*	656 kg/yr *(▼ 656 kg/yr)*	656 kg/yr *(▼ 656 kg/yr)*
d) Decrease in average in-lake total phosphorus concentration. **Current:** 18 ppb **Goal:** 10 ppb	17.8 ppb *(▼ 0.2 ppb)*	10.5 ppb *(▼ 7.7 ppb)*	10 ppb *(▼ 8 ppb)*
e) Decrease in average Chl-a concentration. **Current:** 6.6 ppb **Goal:** 3 ppb	6.6 ppb *(no change)*	3.3 ppb *(▼ 3.3 ppb)*	3 ppb *(▼ 3.6 ppb)*

** Benchmarks are cumulative unless otherwise noted. Years 1-2 (2022-2023); Years 3-5 (2024-2026); Years 6-10 (2027-2032). Black arrows used for interim targets represent an increase (▲) or decrease (▼)from the previous period.*

***Table 15**. Water quality benchmarks and interim targets for China Lake (West Basin).*

Environmental Milestones (West Basin)			
Water Quality & Phosphorus Load Reduction Benchmark	***Interim Targets****		
	Years 1-2	*Years 3-5*	*Years 6-10*
a) Increase in average annual water clarity (SDT) **Current:** 2.9 m **Goal:** 3.3 m	3.0 m *(▲ 0.1 m)*	3.2 m *(▲ 0.3 m)*	3.3 m *(▲ 0.4 m)*

[38] In-lake reduction targets are based on model estimates for "current" SDT, TP, and Chl-a which may vary slightly from the 10-year average. However, the magnitude of change is valid for all parameters.

Environmental Milestones (West Basin)			
Water Quality & Phosphorus Load Reduction Benchmark	***Interim Targets****		
b) Phosphorus loading reductions from external phosphorus sources. **Current:** 309 kg/yr **Goal:** 288 kg P/yr (reduce by 21 kg P/yr)	5 kg/yr *(▼ 5 kg/yr)*	12 kg/yr *(▼ 17 kg/yr)*	21 kg/yr *(▼ 21 kg/yr)*
c) Phosphorus loading reductions from addressing east basin internal & external load **Goal:** Reduce by 249 kg P/yr (229 kg/yr east basin internal load; 20 kg/yr east basin external load)	0 kg/yr *(no change)*	229 kg/yr *(▼ 229 kg/yr)*	249 kg/yr *(▼ 249 kg/yr)*
d) Decrease in average in-lake total phosphorus concentration. **Current:** 15 ppb **Goal:** 12.5 ppb	15 ppb *(no change)*	12.9 ppb *(▼ 2.1 ppb)*	12.5 ppb *(▼ 2.5 ppb)*
e) Decrease in average Chl-a concentration. **Current:** 5.1 ppb **Goal:** 4.0 ppb	5.1 ppb *(no change)*	4.2 ppb *(▼ 0.9 ppb)*	4.0 ppb *(▼ 1.1 ppb)*

** Benchmarks are cumulative unless noted. Years 1-2 (2022-2023); Years 3-5 (2024-2027); Years 6-10 (2027-2032).* Black arrows used for interim targets represent an increase (▲) or decrease (▼)from the previous period.

Table 16. *Social indicators, benchmarks, and interim targets for China Lake.*

Social Milestones			
Indicators	***Benchmarks & Interim Targets****		
	Years 1-2	*Years 3-5*	*Years 6-10*
a) Number of LakeSmart site visits and new landowners participating **Goal:** 25% of landowners participating	7% of all properties	10% of all shoreline properties	25% of all shoreline properties
b) Number of new agricultural producers participating in NRCS programs. **Goal:** 5 new agricultural producers	2 landowners	3 landowners *(5 total)*	5 landowners *(10 total)*
c) Number of landowners participating in septic system incentive programs. **Goal:** 10 evaluations, 5 septic designs, 5 upgrades	n/a	4 evaluations, 3 designs, 2 upgrades	6 evaluations, 2 designs, 3 upgrades
d) Number of homeowners installing buffers through the Buffer Initiative. **Goal:** 20 new or expanded shoreline buffers	5 sites	15 sites *(20 sites total)*	25 sites *(45 sites total)*
e) Number of permanent educational signs at public locations. **Goal:** 3 permanent signs	1 site	2 sites	3 sites
f) Number of landowner meetings organized (residential property owners, commercial business owners, road associations, etc.) **Goal:** 2 meetings/year	4 meetings	6 meetings *(10 total)*	10 meetings (20 *total)*

Social Milestones				
Indicators		***Benchmarks & Interim Targets****		
		Years 1-2	*Years 3-5*	*Years 6-10*
g)	Number of educational workshops held (road associations, homeowner associations, gravel road workshop, buffer workshop, etc.) **Goal:** 1 – 2 workshops every other year	1 workshop	2 workshops *(3 total)*	3 workshops *(6 total)*
h)	Number of planning board and selectmen meetings attended to strengthen ordinances and relationships with town officials. **Goal:** 1 meeting/yr for each town	4 meetings *(4 total)*	6 meetings *(10 total)*	10 meetings *(20 total)*

** Benchmarks are cumulative unless noted. Years 1-2 (2022-2023); Years 3-5 (2024-2027); Years 6-10 (2027-2032)*

Table 17*. Programmatic indicators, benchmarks, and interim target for China Lake.*

Programmatic Milestones				
Indicators		***Benchmarks & Interim Targets****		
		(Years 1-2)	*(Years 3-5)*	*(Years 6-10)*
a)	Number of residential & driveway sites addressed. **Goal:** 80 residential and 9 driveway sites (20 sites/yr)	20 sites	30 sites *(50 total)*	50 sites *(80 total)*
b)	Number of road sites addressed. **Goal:** 28 road sites addressed	5 sites	10 sites *(15 total)*	13 sites *(28 total)*
c)	Number of Steering Committee Meetings **Goal:** 1 meeting/year	2 meetings *(2 total)*	3 meetings *(5 total)*	5 meetings *(10 total)*
d)	Amount of funding raised for lake and watershed restoration projects including external and internal load. **Goal:** $2,500,000	$500,000	$1,000,000 *($1.5M total)*	$1,000,000 *($2.5M total)*
e)	Amount of local financial contributions through in-kind donations and NPS work on private property **Goal:** $650,000	$130,000	$325,000	$650,000
f)	Number of new ordinances passed that help protect water quality and offset the effects of climate change	0 ordinances	1 ordinance	2 ordinances

** Benchmarks are cumulative unless noted. Years 1-2 (2022-2023); Years 3-5 (2024-2027); Years 6-10 (2027-2032).*

POLLUTANT LOAD REDUCTIONS & COST ESTIMATES

The following pollutant load reductions and costs were estimated for the next 10-year planning cycle based on six primary planning objectives outlined in the Action Plan (Table 18):

Table 18. *China Lake planning objectives, P load reduction targets, & cost.*

Planning Objective	Planning Action (2022-2032)	P Load Reduction Target	Cost
1	**Reduce the External (Watershed) P Load** (NPS sites, LakeSmart, agriculture, forestry)	56 kg/yr east basin 270 kg/yr west basin[39]	$1,175,000
2	**Reduce the Internal (Sediment) P Load** (Aluminum treatment, east basin only)	656 kg/yr east basin	$1,441,500
3	**Prevent New Sources of NPS Pollution** (Road maintenance, land conservation, municipal planning & enforcement, climate change adaptation)	n/a	$55,500
4	**Education & Outreach** (Outreach plan, welcome packets, signage, aluminum treatment education, buffer campaign, agricultural outreach, workshops)	n/a	$62,350
5	**Build Local Capacity** (Funding plan, steering committee, grant writing, relationship building & partnerships)	n/a	$169,000
6	**Long-Term Monitoring & Assessment** (Baseline monitoring, sediment sampling & analysis, aluminum treatment monitoring plan, alewife monitoring, stream monitoring, plankton monitoring, NPS and septic systems, invasive plants & Harmful Algal Blooms)	n/a	$258,400
	TOTAL	**982 kg/yr**	**$3,161,750**

Actual pollutant load reductions will be documented as work is completed as outlined in this plan. This includes reductions related to aluminum treatments and completed NPS sites to help demonstrate phosphorus and sediment load reductions as the result of BMP implementation. Pollutant loading reductions will be calculated using methods approved and recommended by Maine DEP and the US EPA and reported to Maine DEP for any work funded by Clean Water Act Section 319 grants.

[39] Estimated reductions in the west basin of China Lake equal 270 kg/yr. This includes 21 kg/yr in the direct watershed of the west basin, and 20 kg/yr from external load reductions in the east basin as well as an additional 229 kg/yr as a result of reducing the internal load in the east basin.

10. Plan Oversight, Partner Roles, and Funding

PLAN OVERSIGHT

Implementation of a ten-year watershed plan cannot be accomplished without the help of a central organization to oversee the plan, and a diverse and dedicated group of project partners and the public to support the various aspects of the plan. The following organizations will be critical to the plan's success and are excellent candidates for the watershed plan steering committee. The committee will need to meet at least annually to update the action plan, to evaluate the plan's success, and to determine if the water quality goal is being met.

PARTNER ROLES

China Lake Association (CLA) will serve as the designated entity for overseeing plan implementation and plan updates. CLA will serve on the watershed steering committee, be the primary entity for moving the internal load reduction recommendations forward, spearhead fundraising efforts, provide financial support for future watershed restoration projects, serve as the mechanism for public outreach and education in the watershed, and be the general liaison between all watershed partners and technical advisors.

China Region Lakes Alliance (CRLA) will serve as the primary organization overseeing watershed restoration activities through CRLA programs including LakeSmart, Youth Conservation Corps, and the Road Rehabilitation Program. CRLA is also responsible for coordinating the CBI program and will coordinate with watershed partners on education and outreach and fundraising efforts to address external P loading in the watershed.

Colby College will provide support to complete follow-up sediment analyses in the east basin to refine recommendations for an aluminum treatment in the east basin of China Lake and provide project partners with updates regarding research being conducted on China Lake.

Kennebec County Soil & Water Conservation District (KCSWCD) may provide technical assistance, assistance for road and residential NPS projects, and grant sponsorship and administration.

Kennebec Water District (KWD) will serve on the steering committee, lead ongoing in-lake water quality monitoring efforts, and assist with fundraising for source water protection activities.

Landowners & Road Associations will address NPS issues on their properties and provide a private source of matching funds by contributing to fundraising efforts and participating in watershed projects.

Maine Department of Environmental Protection (Maine DEP) will provide watershed partners with ongoing guidance, technical assistance and resources, and the opportunity for financial assistance through grants including the US EPA's 319 grant program, the Municipal Wastewater Grant Program, and Clean Water State Revolving Loan Fund. Maine DEP will also serve on the steering committee.

Maine Department of Marine Resources (Maine DMR) will provide watershed partners with ongoing guidance, monitoring, technical assistance, and resources related to alewife reintroduction and management in China Lake and serve on the steering committee.

Town of China will serve on the watershed steering committee, provide administrative support and available resources for future lake and watershed restoration projects, and support the CBI program. The town will also play a key role in addressing documented NPS sites on town roads and municipal/public property, provide training and education for municipal employees, and enforce ordinances that protect water quality.

Town of Vassalboro will serve on the watershed steering committee, provide ongoing monitoring of water level and phosphorus concentrations at the outlet, address documented NPS sites on town roads and municipal/public property, provide training and education for municipal employees, and enforce ordinances that protect water quality.

USDA/Natural Resources Conservation Service will provide education and outreach, technical and financial assistance to agricultural producers in the watershed.

US Environmental Protection Agency (US EPA) will provide guidance on grant programs particularly Clean Water Act Section 319, Clean Water State Revolving Fund (CWSRF) and Drinking

Water State Revolving Fund (DWSRF) programs, work plan guidance, and selected project funding, pending acceptability of grant proposals, final workplans and availability of federal funds.

ACTION PLAN IMPLEMENTATION & FUNDING

CLA will develop and coordinate a public-private fundraising plan and will coordinate and implement the proposed Action Plan. Expected partners are KWD, CRLA, the towns of China and Vassalboro, KCSWCD, Maine DEP, landowners, road associations, businesses, and private donors.

There is a long history of these partners working together to help improve water quality. Accomplishments include developing and implementing the 2008 China Lake Watershed-Based Management Plan, conducting three Clean Water Act section 319 nonpoint source pollution control implementation grants on China Lake between 2003 and 2016, conducting a watershed survey in 2020, and developing an updated China Lake Watershed-Based Management Plan in 2022.

There are a number of opportunities for acquiring funding to support implementation of the watershed management plan. The list below contains a few of the better-known State and Federal funding options. Additional support from private foundation grants, local fundraising efforts, monetary contributions by participating landowners, and financial support from municipal partners will be needed to adequately fund this plan.

- Maine DEP Courtesy Boat Inspection (CBI) Program Grants – A cost-share program to help fund locally-supported CBI programs. For more information: https://www.maine.gov/dep/water/grants/invasive/index.html
- Maine DEP Small Community Grant Program (SCG) – Administered by Maine DEP, this program provides grants to municipalities to help replace malfunctioning septic systems that are polluting a waterbody or causing a public nuisance. For more information: https://www.maine.gov/dep/water/grants/scgp.html
- Maine DEP Stream Crossing Upgrade Grant Program – A competitive grant program for the upgrade of municipal culverts and stream crossings that improve fish and wildlife habitats and improve community safety. For more information: https://www.maine.gov/dep/land/grants/stream-crossing-upgrade.html
- Maine DOT's Municipal Partnership Initiative (MPI) – This program funds projects of municipal interest on state infrastructure working with Maine DOT as a partner to develop, fund, and build the project. For more information: https://www.maine.gov/mdot/pga/

- Maine Drinking Water Program Source Water (Surface Water) Protection Grant – This is a competitive grant program for community and non-profit non-community public water systems up to $10,000/yr for planning or implementing projects that protect their surface water source. For more information: https://www.maine.gov/dhhs/mecdc/environmental-health/dwp/pws/financialResources.shtml
- Maine Natural Resource Conservation Program (MNRCP) – A cooperative program between Maine DEP and US Army Corps of Engineers, administered by The Nature Conservancy, funding the restoration, enhancement, preservation, and creation of wetland habitat. For more information: https://www.maine.gov/dep/land/nrpa/ILF_and_NRCP/index.html
- Town of China Tax Increment Financing (TIF) – The Town of China TIF funds are designed to improve the local economy, create jobs, and improve the local tax base. Funds have been used to improve public access to China Lake, conduct research related to water quality, and for trail development among other activities. For a copy of the TIF Application: https://china.govoffice.com/vertical/sites/%7B57BBD0A3-55D7-4C7C-8E42-8D085FC781A3%7D/uploads/Blank_TIF_Funds_App.pdf
- US EPA Clean Water Act (Section 319) Watershed Nonpoint Source (NPS) Grant Program – 319 grants assist communities implementing a watershed-based management plan for waters named on Maine DEP's NPS Priority Watershed List. For more information: https://www.maine.gov/dep/water/grants/319.html
- US EPA/Maine Clean Water State Revolving Fund (CWSRF) – Provides financial assistance for a wide range of water infrastructure projects including control of nonpoint sources of pollution, and other water quality projects. For more information: https://www.epa.gov/cwsrf/learn-about-clean-water-state-revolving-fund-cwsrf
- US EPA/Maine Drinking Water State Revolving Fund (DWSRF) – Provides financial assistance to water systems needing capitalization grants and/or technical assistance to improve the quality of drinking water and for delivery of safe drinking water to consumers: https://www.epa.gov/dwsrf
- USDA/NRCS Financial Assistance – NRCS offers voluntary programs to eligible landowners and agricultural producers to provide financial and technical assistance to help manage natural resources including financial assistance to help plan and implement conservation practices that address natural resource concerns or opportunities to help save energy, improve soil, water, plant, air, animal and related resources on agricultural lands and non-industrial private forest land: https://www.nrcs.usda.gov/wps/portal/nrcs/main/me/programs/financial/

11. References

Boyle, Kevin and Roy Bouchard (2003). *Water Quality Effects on Property Prices in Northern New England.* Lakeline 23(3), pp. 24-27.

CEAT (2005). Colby College Environmental Assessment Team, Problems in Environmental Science course (Biology 493), Colby College. *A Watershed Analysis of China Lake*. *Colby College Watershed Study: China Lake (2005, 1989)*. 1. https://digitalcommons.colby.edu/chinalake/1

Deeds, Amirbahman, Norton & Bacon (2020): *A hydrogeomorphic and condition classification for Maine, USA, lakes*, Lake and Reservoir Management. https://doi.org/10.1080/10402381.2020.1728597

Deeds, Amirbahman, Norton, Bacon & Hovel (2021): *Shifting baselines and cross-scale drivers of lake water clarity: Applications for lake assessment* , Limnol. Oceanogr. 9999, 2021, 1-14. https://aslopubs.onlinelibrary.wiley.com/doi/abs/10.1002/lno.11873

Ecological Instincts (2021a). *China Lake Water Quality Summary Memo.* Prepared for Dale Finseth, Kennebec County SWCD, October 13, 2021. 38 pp.

Ecological Instincts (2021b). *China Lake LLRM Modeling Memo.* Dale Finseth, Kennebec County SWCD, November 4, 2021. 35 pp.

Fernandez, I., S. Birkel, C. Schmitt, J. Simonson, B. Lyon, A. Pershing, E. Stancioff, G. Jacobson, and P. Mayewski. 2020. *Maine's Climate Future 2020 Update*. Orono, ME: Univ. of Maine.

Kennebec County Soil & Water Conservation District (2008). *Watershed Based Plan for China Lake, Maine.* Report prepared for the Maine Department of Environmental Protection. September 2008. 32 pp.

Kleinschmidt Associates. (2012). *Feasibility Study and Alternatives Analysis for Internal Phosphorus Reduction in China Lake*. Report submitted to the Kennebec Water District.

Kleinschmidt Associates. (2015). *Potential Effects of Alewife Restoration in China Lake*. Report submitted to the Kennebec Water District.

Lake Stewards of Maine (2020b). *Distribution of Trophic State Index in Maine Lakes from Transparency Data.* Accessed Online: https://www.lakestewardsofmaine.org/distribution-of-water-quality-data/

Maine Audubon, 2006. *Conserving Wildlife in Maine's Shoreland Habitats.* https://www.maine.gov/ifw/docs/MEAud-Conserving-Wildlife-Shoreland-Habitats.pdf

Maine Audubon, 2020. Audubon Loon Counts: Maine, 1983-2020. http://www.gulfofmaine.org/kb/2.0/record.html?recordid=9175

Maine Climate Council (MCC) Scientific and Technical Subcommittee (2020). *Scientific Assessment of Climate Change and Its Effects in Maine*. August 2020. 130pp. https://www.maine.gov/future/sites/maine.gov.future/files/inline-files/GOPIF_STS_REPORT_092320.pdf

Maine Department of Environmental Protection (2001). China Lake Total Maximum Daily Load Report. Maine DEPLW 2001-20

Maine DEP (2017). *Cyanobacteria (Blue-Green Algae).* Accessed online: http://www.maine.gov/dep/water/lakes/cyanobacteria.html

Maine Department of Inland Fisheries & Wildlife (1997). China Lake Survey and Map. Accessed online: https://www.maine.gov/ifw/docs/lake-survey-maps/kennebec/china_lake.pdf

Maine DMR (2004), Maine Rivers, & US Fish & Wildlife Service Gulf of Maine Program. *All about Maine Alewives.* Maine Department of Marine Resources. July 2004. Accessed online: https://www.fws.gov/gomcp/pdfs/alewife%20fact%20sheet.pdf

Maine Revised Statutes, §465-A. Standards for classification of lakes and ponds. Accessed online: http://legislature.maine.gov/statutes/38/title38sec465-A.html

Maine State Economist (2018a). *Maine State and County Population Projections 2038. Demographic Projections – Data Files.* Accessed online: https://www.maine.gov/dafs/economist/sites/maine.gov.dafs.economist/files/inline-files/MaineStateCountyPopulationProjections2038.pdf

Maine State Economist (2018b). *Maine City and Town Population Projection 2038. Demographic Projections – Data Files.* Accessed online: https://www.maine.gov/dafs/economist/sites/maine.gov.dafs.economist/files/inline-files/MaineCityTownPopulationProjections2038_0.pdf

MCC STS (2020). Scientific Assessment of Climate Change and Its Effects in Maine. A Report by the Scientific and Technical Subcommittee (STS) of the Maine Climate Council (MCC). Augusta, Maine. 370 pp. Accessed online: https://climatecouncil.maine.gov/future/sites/maine.gov.future/files/inline-files/GOPIF_STS_REPORT_092320.pdf

O'Hara, Frank. (2020). City of Augusta population estimate and projection. Memo to Matt Nazar, December 1, 2020.

Pershing, AJ, et al. (2021). Climate impacts on the Gulf of Maine ecosystem: A review of observed and expected changes in 2050 from rising temperatures. Elem Sci Anth, 9:1. Accessed online: https://doi.org/10.1525/elementa.2020.00076.

Shute & Wilson (2013), University of Southern Maine. *Metaphyton in Our Maine Lakes.* Accessed online: https://belgradelakesassociation.org/Portals/0/PDFs/Resources%20Water%20Quality/Metaphyton%20Algae/Metaphyton-by-Shute-2013.pdf

Sowles, J.W. (1983). *China Lake Water Quality Diagnostic Study*. Maine Department of Environmental Protection, Augusta, Maine. 32 pp.

Sykes, Abbey M., 2021. The Quantitative Assessment of Pond Scum: An examination of the biogeochemistry of phosphorus cycling in the Belgrade lakes. Senior Thesis, Colby College, May 2021.

Town of China (2019). Chapter 2: Land Use Ordinance. Accessed online: https://china.govoffice.com/index.asp?SEC=AAEC4736-39E1-49A9-AE9A-E57C794D90DF&Type=B_BASIC

Town of China (1993). Chapter 4: Phosphorus Control Ordinance. Accessed online: https://china.govoffice.com/index.asp?SEC=AAEC4736-39E1-49A9-AE9A-E57C794D90DF&Type=B_BASIC

US EPA (2019). Recommended Human Health Recreational Ambient Water Quality Criteria or Swimming Advisories for Microcystins and Cylindrospermopsin. EPA Document Number: 822-R-19-001. May 2019. Accessed online: https://www.epa.gov/sites/production/files/2019-05/documents/hh-rec-criteria-habs-document-2019.pdf

US EPA (2017). *Nutrient Policy and Data; Cyanobacteria/Cyanotoxins.* Accessed online: https://www.epa.gov/cyanohabs/learn-about-cyanobacteria-and-cyanotoxins

US EPA (2013). Nonpoint Source Program and Grants Guidelines for States and Territories. April 12, 2013. Accessed online: https://www.epa.gov/sites/default/files/2015-09/documents/319-guidelines-fy14.pdf

WRS, Inc. (2021). Internal Loading to China Lake and Related Implications. October 27, 2021.

Appendix A. China Lake Public Meeting Q&A

China Lake Watershed-Based Management Plan Public Meeting/Webinar
December 2, 2021 held via Zoom
Meeting recording: https://youtu.be/K1RCFlW0sFw

Q1: How might more data (say collected via citizen science) be helpful in understanding (and eventually addressing) the issues facing China Lake Watershed?

A1: Improving our understanding of the problems that face China Lake is an important part of determining what the best solutions might be. Long-term monitoring will be essential for determining how effective the 10-year plan is at restoring water quality.

Q2: Would oxygenation of the lake reduce internal phosphorus loading in the lake (as is in the Androscoggin River)? Is it feasible?

A2: Hypolimnetic oxygenation could increase oxygen in deep water by 75%, but the cost is prohibitive and permitting is difficult. Adding structures to the lake can affect recreation by catching anchors and fishing lines. The estimated cost of installing the necessary structures would be around $4 million, with annual operational costs around $450,000.

Q3: What are the downsides or risks to an aluminum treatment? Do the panelists have any thoughts on addressing the concerns of folks about the safety and possible side effects of "dumping chemicals in the lake"?

A3: One possible risk of an aluminum treatment is that we can't be completely certain about how successful it will be, given the complexity of the lake system. Another risk is the aluminum causing toxicity if the pH of the water changes too much during the aluminum treatment. This risk is mitigated by a second boat following the aluminum treatment barge and monitoring the water quality as aluminum is applied. There has not been a fish kill caused by an aluminum treatment in over 20 years as the methods used to plan and apply aluminum treatments have improved.

Q4: What is the source of the aluminum that is used for the aluminum treatment?

A4: The aluminum is manufactured by a few companies in New England, mostly for drinking water treatment.

Q5: Are there any possible negative effects on human health when treating the lake with aluminum?

A5: There have been some claims that aluminum has negative health effects, but they have largely been debunked. Aluminum is commonly used to treat drinking water supplies and is naturally found at some levels in all lake sediments. The aluminum also does not stay in the water column but settles quickly into the sediments and therefore would not affect swimmers.

Q6: What time of year is the aluminum applied?

A6: The aluminum treatment can be applied any time when the water is not frozen, but a spring application is ideal for locking phosphorus into the sediments before anoxia begins to occur at the lake bottom in summer.

Q7: Does the Kennebec Water District use aluminum as part of their water treatment process?

A7: Yes. Aluminum is used extensively by municipal water treatment plants to remove phosphorus and sediments to create potable water.

Q8: What caused the failure of the aluminum treatment at Threemile Pond?

A8: State biologists at Maine DEP believe that the lake was underdosed. At that time, the methods for completing an aluminum treatment were less developed than they are today and the amount of aluminum that could be applied was limited by how much the pH of the water changed. That problem was solved by adding a buffer as part of the aluminum treatment. Dosing determinations are more reliable today as a result of detailed sediment characterizations and aluminum assays as were completed for China Lake by Colby College.

Q9: Does treating the lake with aluminum limit the use of the lake for a period of time post-treatment? How long?

A9: Boating is discouraged within the treatment area so that there is no interference with the barge. Aluminum settles out of the water quickly so as soon as the treatment is complete recreation could resume. The treatment also occurs in deep water so it should not affect swimmers.

Q10: How will the alewife help improve water quality now that all the barriers to the fishery have been removed?

A10: Some models suggest that alewives could cause a net decrease in phosphorus in the lake while others suggest that they could increase phosphorus. The actual effect of alewife introductions on phosphorus levels is currently unknown, but it is likely that the fish will have little to no impact on water quality. There are concerns that more algae will grow as alewives eat zooplankton (which feed on algae). The extent of these interactions are not known. Kennebec Water District is working with Maine DMR to monitor the number of alewives entering and leaving the lake, while also collecting water quality data to monitor the effects of the reintroduction.

Q11: Who is responsible for seeking grant funding for the plan?

A11: The plan outlines which organizations are expected to lead each planning objective in the action plan. Most on-the-ground projects will be led by CRLA with support from CLA. There will also be potential for the watershed towns to apply for grants to help fund portions of the project.

Q12: Where can we find the recording of this presentation online?

A12: The recording will be posted on the CLA website.

Q13: What are some possible alternatives to aluminum treatments for reducing the internal load to China Lake? Should Hypolimnetic withdrawal or dredging be considered?

A13: In order for hypolimnetic withdrawal to be effective over the short term, water would need to be removed rapidly from the lake bottom at a rate that would cause destratification of the lake. If it was done more slowly to preserve lake stratification, it would take decades to see the desired results. Hypolimnetic withdrawal was examined as an alternative by a KWD consultant in 2012 and determined not to be a feasible option for several reasons. Dredging is an extremely effective way to remove pollution from and restore a lake, but it is extremely expensive ($50,000 per acre foot). It can also be difficult to find a place to dispose of dredged sediments and acquire the permits to do so.

Q14: Should there be increased focus on the Hunter Brook basin given its importance as a source of external loading?

A14: There is interest from the project partners, including KWD and Colby, for conducting stream monitoring at the outlet of Hunter Brook to evaluate loading from the brook. Hunter Brook is the largest sub-drainage in the watershed, and sediment results indicate the greatest release of P from sediments in the northeast basin near the Hunter Brook outlet. Based on the phosphorus loading model however, on a per acre basis, there are smaller drainages that are contributing high levels of P that may be targeted for watershed restoration. This includes the direct shoreline drainages for both basins, and some smaller unnamed drainages with more dense development in the watershed of the west basin.

Q15: Will the current abundance of aquatic plants in the lake be reduced by an aluminum treatment?

A15: The aluminum treatment is applied in deep water, where aquatic plants do not generally grow due to lack of sunlight. Adding aluminum to the sediments should not have any negative effects on plant health. The plant community in the lake may be affected by decreased phosphorus levels, however. Plants that get nutrients from the water column (e.g., American waterweed) may grow less densely as phosphorus is reduced, but increased water clarity that results from the treatment may also allow sunlight to penetrate deeper and allow plants to grow in areas where they previously could not.

Q16: Can you please expound upon the criticality of determining the right "formula" to dose the lake and the need for additional sediment sampling, specifically in the north end of the east basin?

A16: Sediment sampling helps to determine the amount of phosphorus in the sediment that will need to be inactivated. Eight composite samples of sediment were analyzed, but due to the size of the lake, additional sediment sampling and analysis is needed in order to finalize dosing recommendations for the east basin.

Q17: Are there any known techniques involving aluminum (or other filtering media) that could be installed in the streams or key watershed draining areas that would reduce external loading?

A17: This is a technique that has been used in urban areas in Massachusetts. Stormwater is treated as it is coming into the lake. This could be an option for China Lake, but it would require a long period of treatment each year due to the size of the lake. This technique is usually only recommended for urban watersheds because they generally cannot be improved very much through watershed work. China Lake on the other hand, has a fair amount of open land, meaning that there are opportunities to reduce external phosphorus loading through improvements in the watershed. It will be important to do this watershed work in conjunction with any treatment of the internal phosphorus load.

Appendix B. China Lake Watershed NRCS Soils & Soil Risk Factors

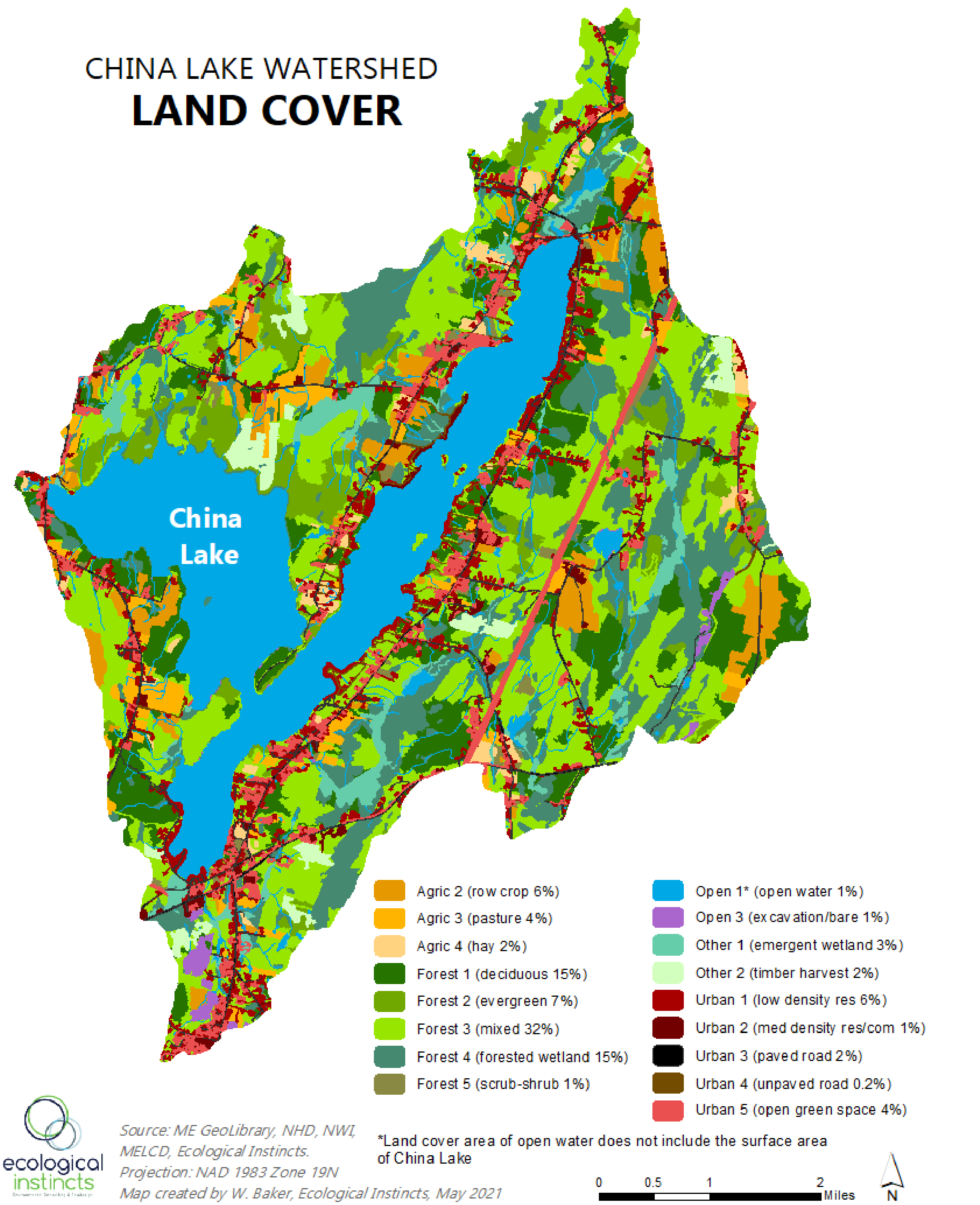
Sym	Soil Unit	Area (acres)	% Watershed		Hydro Soil Group	Parent Material Description
BhB	Berkshire fine sandy loam, 3 to 8 percent slopes	4	0.0%	0.0%	B	loamy supraglacial meltout till derived from phyllite and/or loamy supraglacial meltout till derived from granite and gneiss and/or loamy supraglacial meltout till derived from mica schist
Bo	Biddeford mucky peat, 0 to 3 percent slopes	619	3.5%	3.5%	D	organic material over glaciomarine deposits
BuB2	Lamoine silt loam, 3 to 8 percent slopes	365	2.1%	2.1%	C/D	fine glaciomarine deposits
BuC2	Buxton silt loam, 8 to 15 percent slopes	115	0.7%	0.7%	C/D	fine glaciomarine deposits
CF	Cut and fill land	5	0.0%	0.0%		
GP	Gravel pits	7	0.0%	0.0%		
HfC	Hartland very fine sandy loam, 8 to 15 percent slopes	427	2.4%	2.6%	B	coarse-silty glaciolacustrine deposits
HfD	Hartland very fine sandy loam, 15 to 25 percent slopes	36	0.2%		B	
HkB	**Hinckley gravelly sandy loam, 3 to 8 percent slopes**	**81**	**0.5%**	**1.8%**	**A**	**sandy-skeletal glaciofluvial deposits derived from granite and gneiss**
HkC	**Hinckley gravelly sandy loam, 8 to 15 percent slopes**	**175**	**1.0%**		**A**	
HkD	**Hinckley gravelly sandy loam, 15 to 30 percent slopes**	**62**	**0.4%**		**A**	
HrB	**Lyman-Tunbridge complex, 0 to 8 percent slopes, rocky**	**1024**	**5.8%**	**29.1%**	**D**	**loamy supraglacial till derived from granite and gneiss and/or loamy supraglacial till derived from phyllite and/or loamy supraglacial till derived from mica schist**
HrC	**Lyman-Tunbridge complex, 8 to 15 percent slopes, rocky**	**3936**	**22.5%**		**D**	
HrD	**Lyman-Tunbridge complex, 15 to 35 percent slopes, rocky**	**131**	**0.7%**		**D**	
HtB	**Lyman-Abram-Rock outcrop complex, 0 to 8 percent slopes**	**35**	**0.2%**	**6.4%**	**D**	**loamy supraglacial till derived from granite and gneiss and/or loamy supraglacial till derived from phyllite and/or loamy supraglacial till derived from mica schist**
HtC	**Lyman-Abram-Rock outcrop complex, 8 to 15 percent slopes**	**1007**	**5.7%**		**D**	

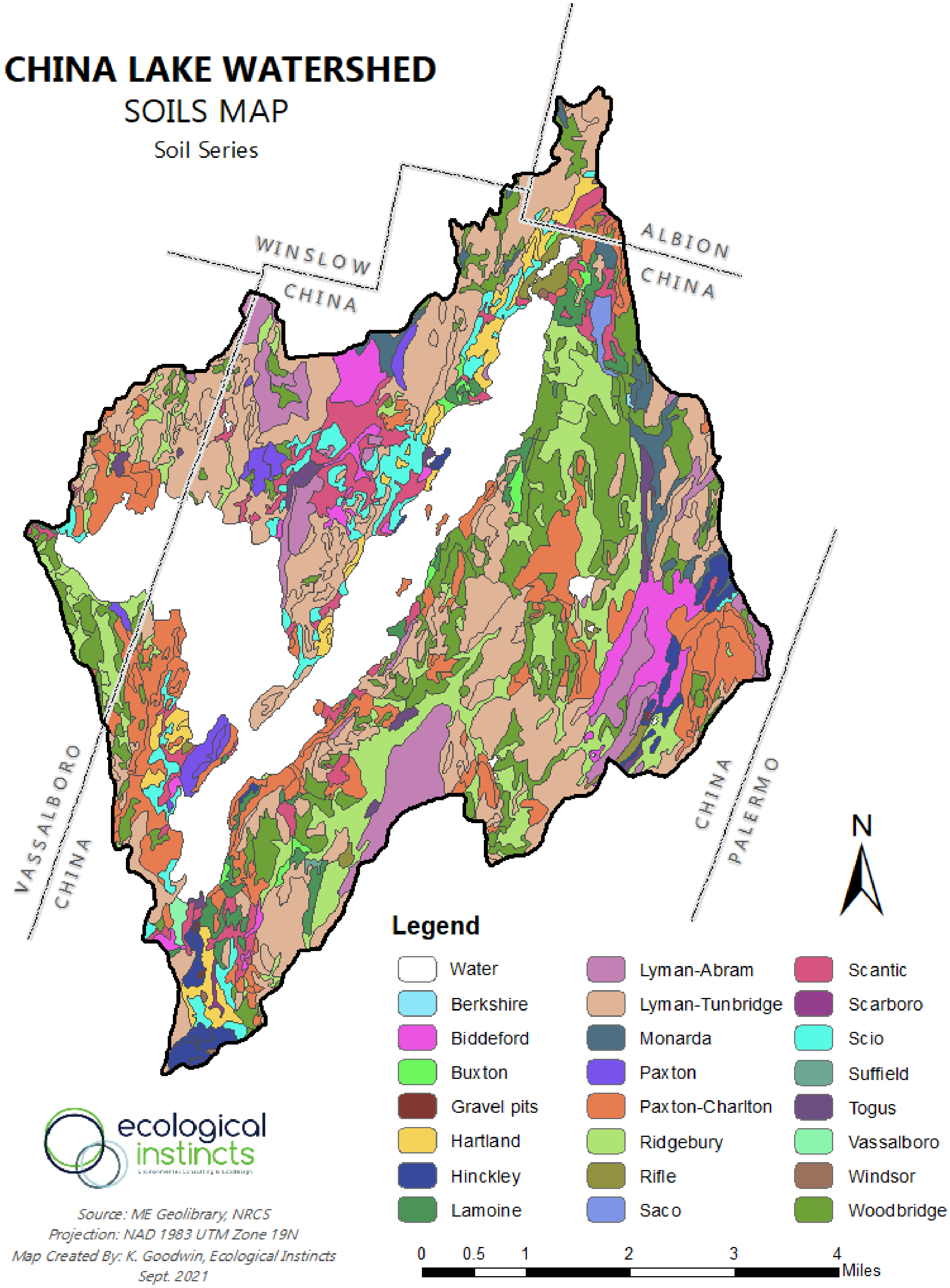
Sym	Soil Unit	Area (acres)	% Watershed		Hydro Soil Group	Parent Material Description
HtD	**Lyman-Abram-Rock outcrop complex, 15 to 35 percent slopes**	**71**	**0.4%**		**D**	
MoA	Monarda silt loam, 0 to 3 percent slopes	43	0.2%	1.9%	D	loamy lodgment till
MrA	Monarda silt loam, 0 to 3 percent slopes, very stony	297	1.7%		D	
PbB	Paxton fine sandy loam, 3 to 8 percent slopes	46	0.3%	1.3%	C/D	coarse-loamy lodgment till derived from mica schist
PbC	Paxton fine sandy loam, 8 to 15 percent slopes	68	0.4%		C/D	
PcB	Paxton very stony fine sandy loam, 3 to 8 percent slopes	20	0.1%		C/D	
PcC	Paxton very stony fine sandy loam, 8 to 15 percent slopes	96	0.5%		C/D	
PdB	Paxton-Charlton fine sandy loams, 3 to 8 percent slopes	443	2.5%	13.7%	C/D	coarse-loamy lodgment till derived from mica schist
PdC2	Paxton-Charlton fine sandy loams, 8 to 15 percent slopes, eroded	661	3.8%		C/D	
PdD2	Paxton-Charlton fine sandy loams, 15 to 25 percent slopes, eroded	38	0.2%		C/D	
PeB	Paxton-Charlton very stony fine sandy loams, 3 to 8 percent slopes	105	0.6%		C/D	
PeC	Paxton-Charlton very stony fine sandy loams, 8 to 15 percent slopes	905	5.2%		C/D	
PeD	Paxton-Charlton very stony fine sandy loams, 15 to 30 percent slopes	239	1.4%		C/D	
RcA	Ridgebury fine sandy loam	302	1.7%	11.8%	C/D	coarse-loamy lodgment till derived from mica schist
RdA	Ridgebury very stony fine sandy loam	1760	10.1%		C/D	
RF	Rifle mucky peat	153	0.9%	0.9%	A/D	organic material
SA	Saco soils	56	0.3%	0.3%	B/D	coarse-silty alluvium
ScA	Scantic silt loam, 0 to 3 percent slopes	813	4.6%	4.6%	D	glaciomarine deposits
Sd	**Scarboro mucky peat**	**13**	**0.1%**	**0.1%**	**A/D**	**sandy glaciofluvial deposits derived from granite and gneiss**
SkB	Scio very fine sandy loam, 3 to 8 percent slopes	626	3.6%	3.6%	C	very fine sand glaciolacustrine deposits

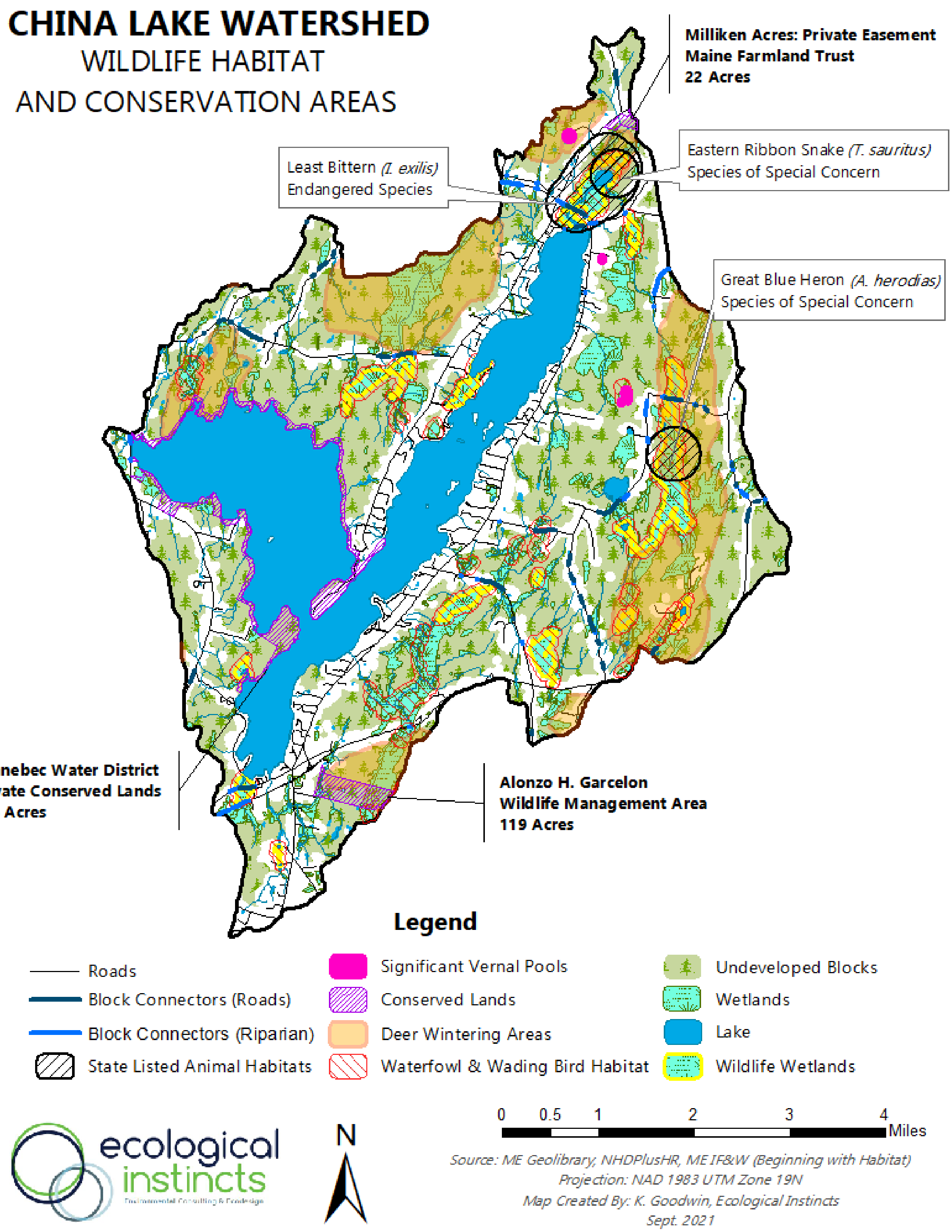
Sym	***Soil Unit***	***Area (acres)***	***% Watershed***		***Hydro Soil Group***	***Parent Material Description***
SkC2	Scio very fine sandy loam, 8 to 15 percent slopes, eroded	4	0.0%		C	
SuC2	Suffield silt loam, 8 to 15 percent slopes, eroded	9	0.0%	0.0%	C	fine glaciolacustrine deposits
TO	Togus fibrous peat	164	0.9%	0.9%	A/D	organic material
VA	Vassalboro fibrous peat	32	0.2%	0.2%	A/D	organic material
WmB	**Windsor loamy sand, 3 to 8 percent slopes**	**4**	**0.0%**	**0.1%**	**A**	**sandy glaciofluvial deposits derived from granite and gneiss**
WmC	**Windsor loamy sand, 8 to 15 percent slopes**	**10**	**0.1%**		**A**	
WrB	Woodbridge fine sandy loam, 3 to 8 percent slopes	765	4.4%	14.3%	C/D	coarse-loamy lodgment till derived from mica schist
WrC	Woodbridge fine sandy loam, 8 to 15 percent slopes	81	0.5%		C/D	
WsB	Woodbridge very stony fine sandy loam, 3 to 8 percent slopes	1594	9.1%		C/D	
WsC	Woodbridge very stony fine sandy loam, 8 to 15 percent slopes	59	0.3%		C/D	

Soil Series are grouped by common soil unit and parent material. Soils highlighted by **bold orange text** are considered at risk due to having a shallow depth to bedrock and a high potential for septic short-circuiting. Soils highlighted by **bold red text** are considered at risk due to having a coarse texture and a very high potential for septic short circuiting. Soils highlighted by **bold green text** are considered at risk due to having a coarse texture and a high potential for septic short circuiting.

Appendix C. Additional Watershed Maps




CHINA LAKE WATERSHED
SOILS MAP
Soil Series
WINSLOW
CHINA
ALBION
CHINA
VASSALBORO
CHINA
CHINA
PALERMO
N
Legend
Water
Berkshire
Biddeford
Buxton
Gravel pits
Hartland
Hinckley
Lamoine
Lyman-Abram
Lyman-Tunbridge
Monarda
Paxton
Paxton-Charlton
Ridgebury
Rifle
Saco
Scantic
Scarboro
Scio
Suffield
Togus
Vassalboro
Windsor
Woodbridge
0 0.5 1 2 3 4
Miles
Source: ME Geolibrary, NRCS
Projection: NAD 1983 UTM Zone 19N
Map Created By: K. Goodwin, Ecological Instincts
Sept. 2021


CHINA LAKE WATERSHED
WILDLIFE HABITAT
AND CONSERVATION AREAS
Milliken Acres: Private Easement
Maine Farmland Trust
22 Acres
Least Bittern (I. exilis)
Endangered Species
Eastern Ribbon Snake (T. sauritus)
Species of Special Concern
Great Blue Heron (A. herodias)
Species of Special Concern
Kennebec Water District
Private Conserved Lands
356 Acres
Alonzo H. Garcelon
Wildlife Management Area
119 Acres
Legend
Roads
Block Connectors (Roads)
Block Connectors (Riparian)
State Listed Animal Habitats
Significant Vernal Pools
Conserved Lands
Deer Wintering Areas
Waterfowl & Wading Bird Habitat
Undeveloped Blocks
Wetlands
Lake
Wildlife Wetlands
ecological instincts
N
0 0.5 1 2 3 4 Miles
Source: ME Geolibrary, NHDPlusHR, ME IF&W (Beginning with Habitat)
Projection: NAD 1983 UTM Zone 19N
Map Created By: K. Goodwin, Ecological Instincts
Sept. 2021

Appendix D. KENNEBEC WATER DISTRICT SOURCE WATER PROTECTION SUMMARY

To help preserve China Lake as the sole source of supply for over 22,000 customers, KWD has helped implement many programs and protections within the lake and watershed over its more than 100-year use of the lake. These programs and protections fucus on reduction of risks associated with contamination of drinking water and greater controls as proximity to the intake to the treatment process increases. Therefore, a muti tiered approach to protection of the drinking water supply with many layers has been implemented and adjusted over time.

The foremost among the protections implemented by KWD being the ownership and management of a 343.5-acre parcel of land that includes about 10 miles of shoreline surrounding most of the west basin. The primary goal of KWD's landownership in the China Lake watershed is to protect and enhance the water quality of China Lake. To this end, KWD is striving to take an active role in the management of the land and forest in ways that will protect and enhance water quality for generations to come. One objective to meet this primary goal is the establishment and perpetuation of an uneven aged, mixed species forest shown to provide a resilient ecosystem to environmental stressors, such as drought and pest infestation. Additionally, the mixed age and species forests allows for more sequestration of nutrients within plant growth and thus can serve as an extremely effective buffer preventing nutrients from entering the lake.

Three State of Maine laws, partitioned for by KWD, also help protect the drinking water supply. Chapter 67, Public laws of Maine, 1931 prohibits contact with the water in the West Basin and helps prevent the spread of diseases and other harmful bacteria, viruses, and parasites. Chapter 120, Public Laws of Maine, 1969 prohibits trespassing on lands owned by the Kennebec Water District around the lake. This helps protect the watershed as a whole and ensures the integrity if the buffer zone that is so vital to water quality. Title 22, Part 5, Chapter 601, Subchapter 4, Article 2 establishes a restricted zone around the intake pipe. This closed area zone in the west basin, approximately 200' in diameter and designated by floating buoys, is in place to protect vulnerable submerged infrastructure critical to KWD's operations and provides a final buffer from certain types of contamination.

Likewise, KWD partners with and supports many local community groups such as CLA, CRLA, and Lake Stewards of Maine to implement water quality focused project and provide education focused conservation techniques to property owners, recreationalists, and users of China Lake. KWD also provides financial and administrative support to water quality focused projects lead by these community partners such as the Courtesy Boat Inspection program lead by CRLA focused on stopping invasive species from entering China Lake, the Gravel Road Rehabilitation Program lead by CLA focused on repair of private roads in the watershed, and the LakeSmart Program lead by CLA focused on implementing best management practices of land ownership around the watershed.

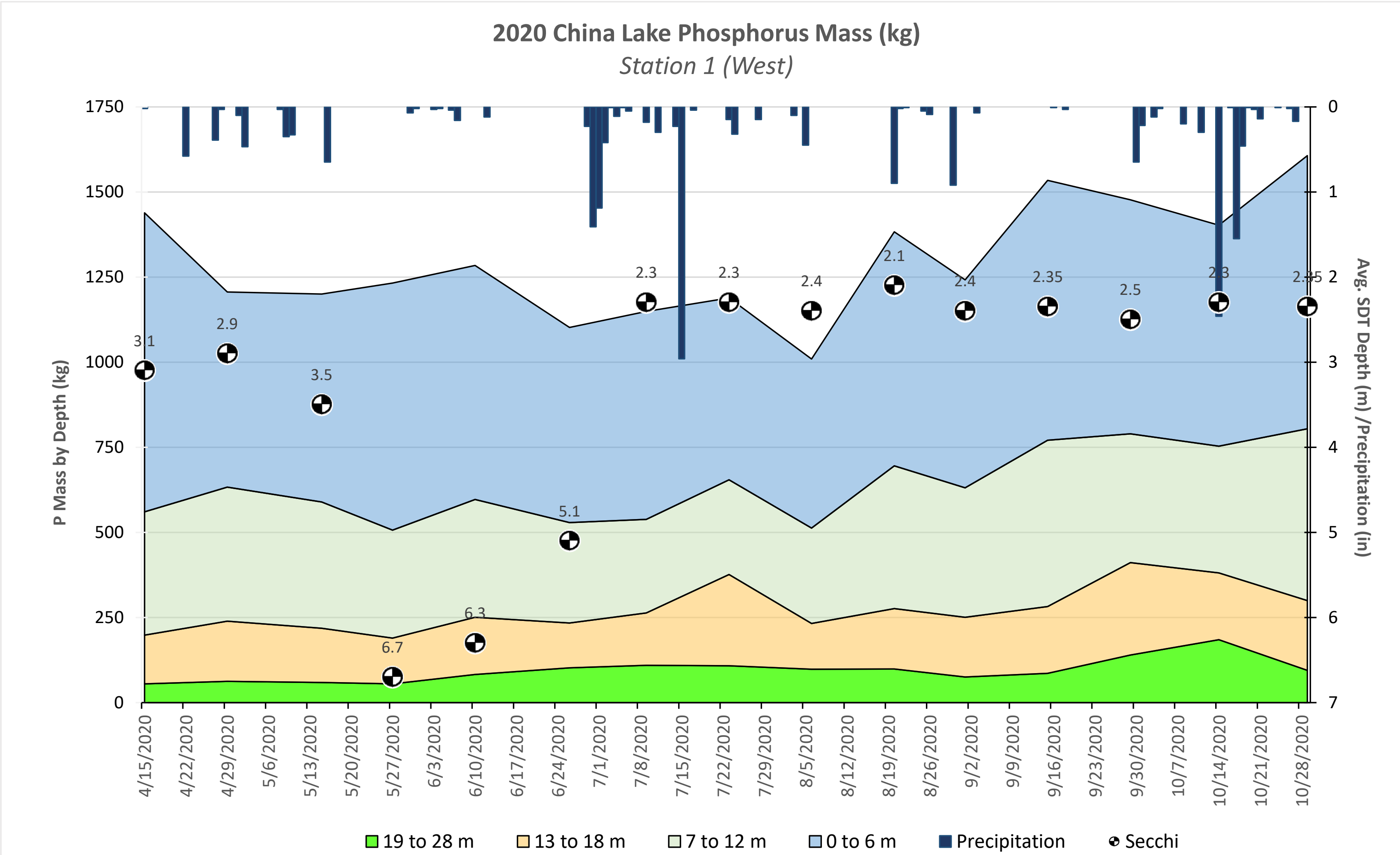
Another critical function KWD is conducting for source water protection is monitoring and reviewing long-term and short-term water quality trends in the lake. Many parameters are tested and reported every 2 weeks during the summer months to provide data that allows for valuable insights into the lake's overall health. The parameters that KWD is collecting and trending within all three basins of the lake, include Secchi Disk Transparency, Dissolved Oxygen, Total Phosphorus, and Chlorophyll-A. This data is reported to Lake Stewards of Maine and available on their website (www.lakestewardsofmaine.org/).

Appendix E. China Lake Water Quality Summary by Station and Parameter

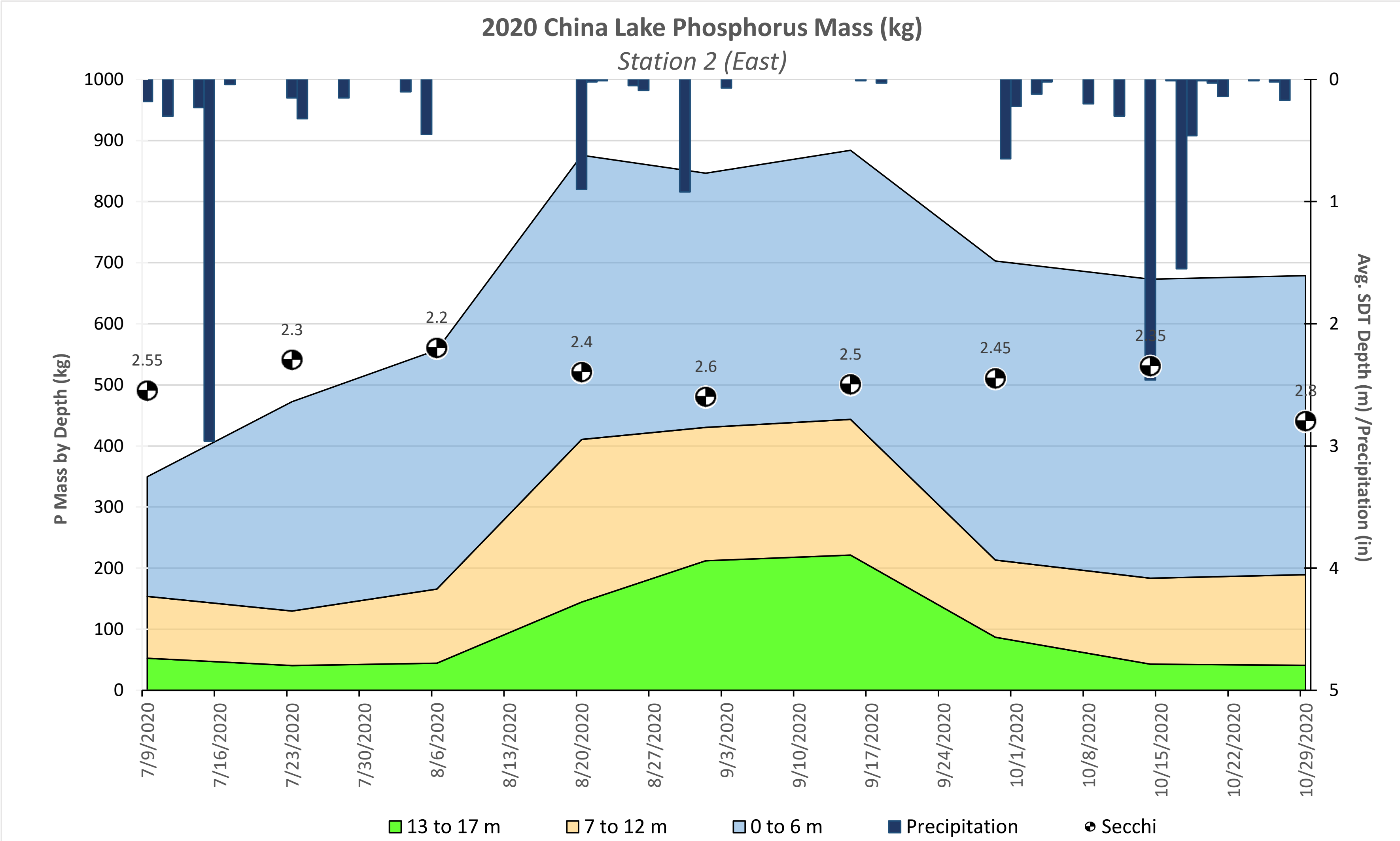
CHINA LAKE - HISTORICAL MONITORING DATA SUMMARY (1970 - 2020)

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
TP - Core (DEP)							x	x					x	x	x					x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x				
TP - Core (KWD)																																														x	x	x	x	x	x
TP - Profiles (DEP)										x				x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x			x				
TP - Profiles (KWD)																																														x	x	x	x	x	x
TP - Bottom Grab (DEP)													x	x											x	x			x	x	x	x	x				x		x	x	x		x	x	x	x	x				
Chlorophyll-a (DEP)							x		x				x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x				
Chlorophyll-a (KWD)																																														x	x	x	x	x	x
DO/Temp (DEP & KWD)									x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Station 2 (East)																																																			
SDT (DEP & KWD)	x	x	x	x				x	x		x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
TP - Core (DEP)											x		x	x	x					x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x						
TP - Core (KWD)																																																	x	x	x
TP - Profiles (DEP)														x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x		x																			
TP - Profiles (KWD)																																																	x	x	x
TP - Bottom Grab (DEP)										x			x	x						x		x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x						
Chlorophyll-a (DEP)											x		x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x						
Chlorophyll-a (KWD)																																																	x	x	x
DO/Temp (DEP and KWD)									x				x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Station 3 (North)																																																			
SDT (DEP & KWD)								x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x
TP - Core (DEP)											x									x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x						
TP - Core (KWD)																																																	x	x	x
TP - Profiles (DEP)																	x		x	x	x	x	x	x	x	x	x	x	x			x									x		x								
TP - Profiles (KWD)																																																	x	x	x
TP - Bottom Grab (DEP)										x										x				x	x	x			x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x						
Chlorophyll-a (DEP)											x						x		x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x						
Chlorophyll-a (KWD)																																																	x	x	x
DO/Temp (DEP & KWD)									x		x			x			x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x		x	x	x	x	x

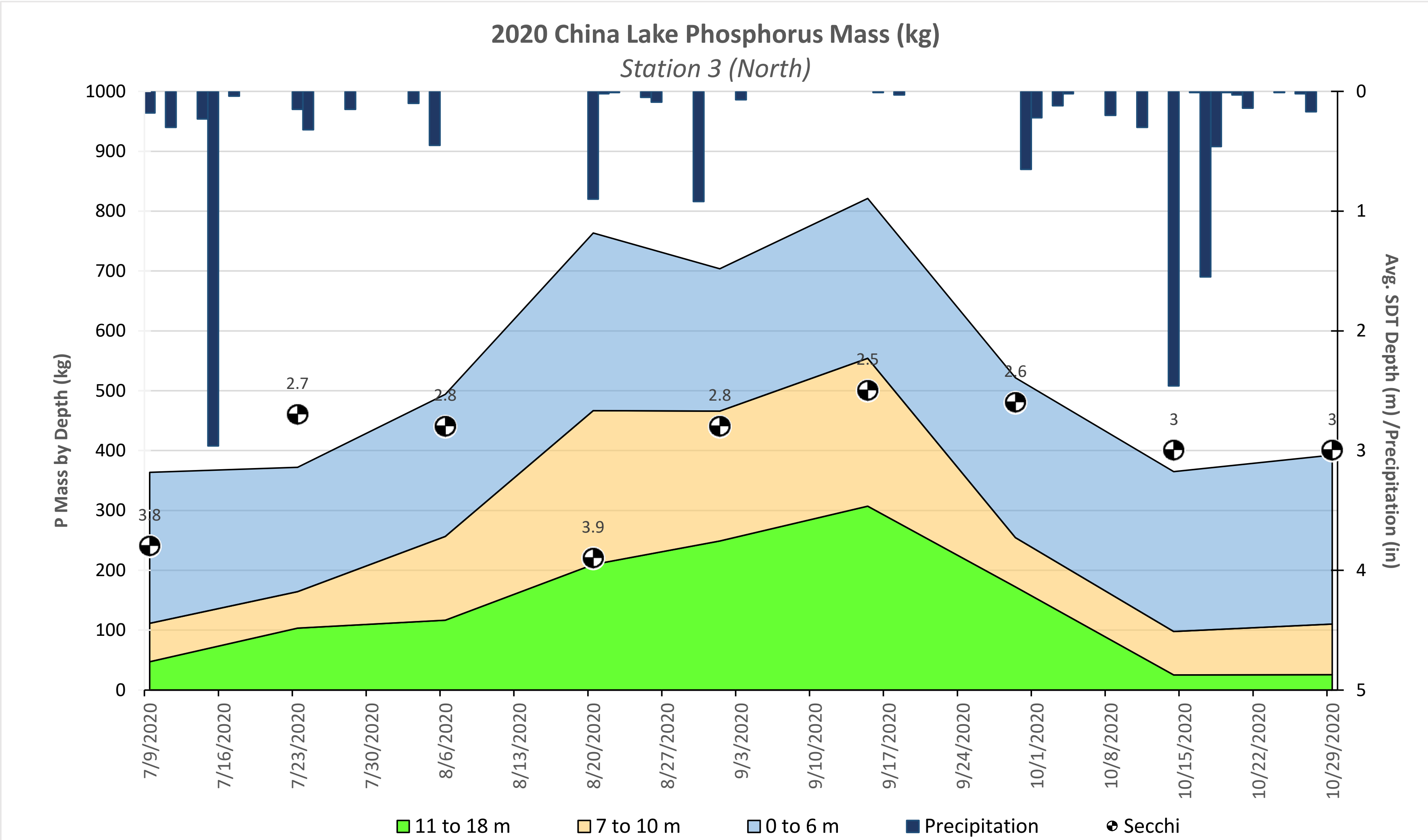
Appendix F. Mass of Phosphorus by Station in China Lake, 2020



Mass of phosphorus at Station 1 (west basin) of China Lake over *time.*



Mass of phosphorus at Station 2 (southeast basin) of China Lake over *time.*



Mass of phosphorus at Station 3 (northeast basin) of China Lake over *time.*

Appendix G. Model Calibration, Limitations & Assumptions

Calibration is the process by which model results are brought into agreement with observed data and is an essential part of environmental modeling. Usually, calibration focuses on the input data with the greatest uncertainty. Changes are made within a plausible range of values, and an effort is made to find a realistic explanation among environmental conditions for these changes. In the case of the China Lake LLRM model, the in-lake P concentration was used as a guide for reviewing and/or adjusting land cover export coefficients and attenuation factors. A review of the draft model was completed by members of the TAC in June 2021, which resulted in the overall separation of the east and west basins, so that they are considered as separate waterbodies with the east flowing to the west. The revised model was reviewed a second time by the TAC in October 2021 which led to the final modeling results.

LLRM generates load estimates for water and P using various assumptions with regard to export coefficients, basin attenuation factors, and specific loading details (for example, the number of people per household to calculate wastewater loading) that, if changed, result in changes to each loading component and ultimately the total load estimate to China Lake. LLRM is a "steady state" model that uses the annual averages for the selected or assumed input values. Major model limitations include:

- <u>Land cover was not ground-truthed</u>. Land cover was updated using recent aerial imagery without field verification of any questionable areas. However, the updated land cover layer received review by USDA/NRCS, KCSWCD and the Maine Forest Service whose comments were incorporated into the final land cover file prior to running the model.
- <u>Land cover export coefficients are estimates</u>. Literature values and best professional judgement were used in evaluating and selecting appropriate land cover export coefficients for China Lake. While these coefficients may be accurate on a larger scale, they are likely not representative on a site-by-site basis. Land cover export coefficients and other model assumptions were reviewed by a sub-group of the TAC and recommendations were incorporated into the current model.
- <u>Waterfowl counts are based on estimates</u>. In the future, a more precise bird census would help improve the model, but the method used here fell within the plausible range estimated by Water Resource Services (2016).
- <u>Tributary data were not available to aid overall model calibration</u>. Real measurements of phosphorus concentrations were not available for the tributaries. Comparing measured values to the modelled phosphorus concentration could aid in the selection of attenuation values and overall model calibration.

- P attenuation factors are estimates based on available P data for each sub-basin. Attenuation factors range from 0.35 (65% loss) to 0.75 (25% loss) and were estimated based on individual basin characteristics and available data.
- Water Attenuation is estimated. The final model opted for a standardized approach to estimating water attenuation within each sub-basin. It was assumed that 85-90% of the water falling on the land makes it to the lake as runoff, baseflow, or groundwater from direct drainages. Indirect drainage values (east basin to west basin) was set at 80%.
- The model has not been validated, a process whereby data not involved in calibration are used to check the accuracy of the model for a separate time period. This is a helpful step that improves reliability but requires data not currently available. Splitting the available data into part to be used in calibration and part for verification was an option but the quantity of data is not large enough to make such an exercise worthwhile. As such, there may be unquantified error in the model and sensitivity analyses can be applied to determine just how influential such error may be. For example, if the actual area in given land uses are off by 10%, what that may do to the model can be assessed by making changes to land use and observing the change in final values like the predicted in-lake phosphorus concentration. Ideally, data would be collected for selected tributaries, a weak point in the data set, allowing comparison of model predictions with actual data not available at the time of model construction. As it is, we believe the model represents reality for China Lake, but should not be considered an extremely accurate representation.
- Sub-basin conditions are not considered within the model. Work that has been completed by watershed partners to address NPS pollution has not been incorporated into the model. Alternatively, major problem spots that are unknown to the modeling team may be overlooked. The model could be improved with more detailed knowledge of each individual sub-basin.

Appendix H. External Load Reductions Using the Relational Method

CHINA LAKE (EAST BASIN)

Source Type	Sub-type	Fraction of total load	Fraction Addressed	Expected BMP Efficiency	Load Fraction Reduced
Agriculture					
	Row Crop	0.156	0.25	0.37	1.4%
	Hayland/Grassland/Hobby Farm	0.024	0.25	0.5	0.3%
	Grazing	0.055	0.25	0.35	0.5%
Urban Development					
	Low Density Development	0.129	0.3	0.42	1.6%
	Medium Density Development/Cc	0.034	0.3	0.40	0.4%
	Developed Open Space	0.071	0.15	0.40	0.4%
	Paved Roads	0.036	0.25	0.40	0.4%
	Gravel Roads	0.008	0.3	0.40	0.1%
	Excavation/Bare soil	0.020	0.2	0.25	0.1%
Non-Developed Land					
	Unmanaged Forest	0.142	0	0	0.0%
	Open Water	0.004	0	0	0.0%
	Scrub/Shrub	0.003	0	0	0.0%
	Emergent Wetlands	0.012	0	0	0.0%
	Forested Wetlands	0.048	0	0	0.0%
	Timber Harvesting	0.010	0.2	0.78	0.2%
Atmospheric		0.099	0	0	0.0%
Waterfowl		0.023	0	0	0.0%
Septics		0.126	0.1	0.75	0.9%
	Total	**1.00**			**6.3%**

Expected Load Reduction (EB)

TP Export Load kg TP	**883**
TP Export Loading Target	**827**
TP Reduction Needed	**56**
% Reduction Required	**n/a**
% Reduction Possible	**6.3%**

CHINA LAKE (WEST BASIN)

Source Type	Sub-type	Fraction of total load	Fraction Addressed	Expected BMP Efficiency	Load Fraction Reduced
Agriculture					
	Row Crop	0.113	0.25	0.37	1.0%
	Hayland/Grassland/Hobby Farm	0.005	0.25	0.5	0.1%
	Grazing	0.051	0.25	0.35	0.4%
Urban Development					
	Low Density Development	0.021	0.2	0.42	0.2%
	Medium Density Development/Con	0.004	0.2	0.4	0.0%
	Developed Open Space	0.013	0.2	0.4	0.1%
	Paved Roads	0.009	0.2	0.4	0.1%
	Gravel Roads	0.000	0.2	0.4	0.0%
	Excavation/Bare soil	0.000	0.2	0.25	0.0%
Non-Developed Land					
	Unmanaged Forest	0.063	0	0	0.0%
	Open Water	0.001	0	0	0.0%
	Scrub/Shrub	0.001	0	0	0.0%
	Emergent Wetlands	0.006	0	0	0.0%
	Forested Wetlands	0.015	0	0	0.0%
	Timber Harvesting	0.010	0.25	0.78	0.2%
E. to W. Basin		0.592	0.10	1	5.9%
Atmospheric		0.074	0	0	0.0%
Waterfowl		0.020	0	0	0.0%
Septics		0.001	0	0.75	0.0%
	Total	**1.00**			**8.0%**

Expected Load Reduction (WB)

TP Export Load kg TP	**968**
TP Export Loading Target	**890**
TP Reduction Needed	**41**
% Reduction Required	**n/a**
% Reduction Possible	**8.0%**

Appendix I. China Lake NPS Sites

Impact of NPS Sites: The impact rating is an indicator of how much soil and phosphorus erodes into the lake from a given site. Factors such as slope, soil type, amount and severity of eroding soil, and buffer size are considered. Generally, low impact sites are those with limited transport of soil off-site, medium impact sites exhibit sediment transportation off-site, but the erosion does not reach high magnitude, and high impact sites are those with large areas of significant erosion and direct flow to water. Estimated costs are ranked as high cost (greater than $2,500), medium cost ($500 - $2,500), and low cost (less than $500). Technical level to install refers to sites that require an engineered design (high technical level), sites in which a technical person should visit the site and make recommendations (medium technical level), or sites in which a property owner can accomplish the work on their own with some reference materials (low technical level).

Site	Flow path to lake	Land use	Problem	Recommendations	Impact Rating	Cost to Fix	Technical Level
1-01	Directly into lake	Municipal / Public	Surface Erosion-Sheet	Erosion Control Mulch, Stabilize Foot Path, Infiltration Steps, Add to Buffer, Reseed bare soil & thinning grass, Rip Rap, Remove Invasive Plants	Low	Low	Low
1-02	Directly into lake	Beach Access	Surface Erosion-Sheet	Define Foot Path, Infiltration Steps, Erosion Control Mulch, Establish Buffer, Reseed bare soil & thinning grass, Rip Rap, Mulch/Erosion Control Mix	Low	Low	Low
1-03	Stream	State Road	Culvert-Unstable inlet/outlet	Armor Inlet/Outlet	Medium	Medium	Low
1-04	Minimal Vegetation	Residential	Surface Erosion-Sheet, Roof Runoff Erosion	Define Foot Path, Add to Buffer, Rip Rap, Mulch/Erosion Control Mix, Rain Garden	Low	Low	Low
1-05	Directly into lake	Residential	Surface Erosion-Sheet	Erosion Control Mulch, Infiltration Trench @ roof dripline	Low	Low	Low
2-01	Directly into lake	Private Road	Surface Erosion-Gully, Ditch-Gully Erosion	Armor with Stone; Lower portion closer to lake has been armored, may need to be extended higher upstream	Medium	Medium	Medium
2-02	Directly into lake	Residential	Surface Erosion-Gully, Ditch-Gully Erosion	Armor with Stone	Medium	Medium	High
2-03	Directly into lake	Residential	Surface Erosion-Sheet, Soil-Bare, Shoreline-Inadequate Shoreline Vegetation	Add to Buffer, Mulch/Erosion Control Mix	Low	Low	Low

Site	Flow path to lake	Land use	Problem	Recommendations	Impact Rating	Cost to Fix	Technical Level
2-04	Directly into lake	Residential	Surface Erosion-Sheet, Soil-Bare	Add to Buffer, Reseed bare soil & thinning grass, No Raking; House side gardens along drip line could use veg and mulch	Low	Low	Low
2-05	Directly into lake	Residential	Surface Erosion-Sheet, Soil-Bare	Reseed bare soil & thinning grass, Mulch/Erosion Control Mix; Tough spot for veg so erosion control mulch maybe	Low	Low	Low
2-06	Directly into lake	Residential	Surface Erosion-Sheet, Shoreline-Lack of Shoreline Vegetation, Shoreline-Inadequate Shoreline Vegetation, Shoreline-Erosion	Establish Buffer, Remove Invasive Plants	Low	Low	Low
2-07	Directly into lake	Residential	Surface Erosion-Gully, Ditch-Gully Erosion, Ditch-Bank Failure, Shoreline-Inadequate Shoreline Vegetation, Shoreline-Erosion	Add to Buffer, Rip Rap	Medium	Medium	Medium
2-08	Directly into lake	Residential	Shoreline-Undercut, Shoreline-Lack of Shoreline Vegetation, Shoreline-Inadequate Shoreline Vegetation, Shoreline-Erosion	Establish Buffer, Rip Rap	Medium	Medium	Low
2-09	Minimal Vegetation	Residential	Surface Erosion-Sheet, Surface Erosion-Rill, Soil-Bare	Add gravel, Install Runoff Diverters-Waterbar, Large parking area for campers most likely.	Medium	Medium	Medium
2-10	Ditch	Private Road	Surface Erosion-Gully, Surface Erosion-Rill, Surface Erosion-Sheet	Road is flagged by road survey and on the CRLA radar	High	High	High
2-11	Minimal Vegetation	Residential	Surface Erosion-Sheet, Soil-Bare, Shoreline-Lack of Shoreline Vegetation	Infiltration Trench @ roof dripline, Establish Buffer, Reseed bare soil & thinning grass, No Raking	Low	Low	Low
2-12	Directly into lake	Residential	Surface Erosion-Sheet, Soil-Bare	No Recommendations Given	Low	Medium	Medium
2-13	Stream	Residential	Surface Erosion-Sheet, Soil-Bare, Shoreline-Lack of Shoreline Vegetation	Establish Buffer, Add to Buffer; Multiple spots along stream frontage need same care	Low	Low	Low

Site	Flow path to lake	Land use	Problem	Recommendations	Impact Rating	Cost to Fix	Technical Level
2-14	Directly into lake	Residential	Surface Erosion-Sheet, Surface Erosion-Rill, Soil-Bare, Shoreline-Erosion	No Recommendations Given	Medium	Medium	Medium
2-15	Directly into lake	Residential	Surface Erosion-Gully, Shoreline-Inadequate Shoreline Vegetation, Shoreline-Erosion	No Recommendations Given	Low	Low	Low
2-16	Directly into lake	Residential	Surface Erosion-Gully, Surface Erosion-Rill, Shoreline-Unstable Access, Shoreline-Erosion, Shoreline-Inadequate Shoreline Vegetation	Erosion Control Mulch, Infiltration Steps, Define Foot Path	Medium	Low	Low
2-17	Directly into lake	Commercial	Surface Erosion-Rill, Shoreline-Unstable Access, Shoreline-Erosion, Shoreline-Inadequate Shoreline Vegetation	Infiltration Steps, Stabilize Foot Path, Add to Buffer, Rip Rap	Medium	Low	Low
2-18	Directly into lake	Residential	Surface Erosion-Rill	Erosion Control Mulch, Install Runoff Diverter (waterbar); Extend buffer closer to dock edges	Low	Low	Low
2-19	Minimal Vegetation	Residential	Shoreline-Inadequate Shoreline Vegetation, Shoreline-Erosion	Rip Rap	Medium	Medium	Medium
2-20	Minimal Vegetation	Residential	Surface Erosion-Rill, Shoreline-Lack of Shoreline Vegetation, Shoreline-Inadequate Shoreline Vegetation	Build Up, Reshape (Crown), Install Runoff Diverters-Rubber Razor; Establish Buffer	Medium	Medium	Medium
2-21	Directly into lake	Residential	Surface Erosion-Gully, Shoreline-Inadequate Shoreline Vegetation	Add to Buffer, Mulch/Erosion Control Mix, ECM or rip rap	Medium	Low	Low
2-22	Directly into lake	Residential	Surface Erosion-Rill, Soil-Bare, Shoreline-Unstable Access, Shoreline-Erosion, Shoreline-Inadequate Shoreline Vegetation	Establish Buffer, Rip Rap, Mulch/Erosion Control Mix	Medium	Medium	Medium

Site	Flow path to lake	Land use	Problem	Recommendations	Impact Rating	Cost to Fix	Technical Level
2-23	Minimal Vegetation	Residential	Surface Erosion-Sheet, Soil-Bare, Shoreline-Lack of Shoreline Vegetation	Define Foot Path, Erosion Control Mulch, Establish Buffer, No Raking	Low	Low	Low
2-24	Minimal Vegetation	Residential	Surface Erosion-Sheet, Soil-Bare, Shoreline-Lack of Shoreline Vegetation, Shoreline-Erosion	Define Foot Path, Erosion Control Mulch, Establish Buffer, Mulch/Erosion Control Mix	Low	Low	Low
2-25	Minimal Vegetation	Residential	Surface Erosion-Sheet, Soil-Bare, Shoreline-Inadequate Shoreline Vegetation	Define Foot Path, Add to Buffer, Mulch/Erosion Control Mix	Low	Medium	Low
2-26	Minimal Vegetation	Residential	Surface Erosion-Sheet, Soil-Bare, Shoreline-Inadequate Shoreline Vegetation	Define Foot Path, Erosion Control Mulch, Add to Buffer, Mulch/Erosion Control Mix	Low	Low	Low
2-27	Minimal Vegetation	Private Road	Surface Erosion-Rill, Road Shoulder Erosion-Rill	Build Up Road, Add gravel, Reshape (Crown); Entire road needs new surface, crowned	Medium	High	Medium
3-01	Ditch	Trail or Path	Surface Erosion-Rill, Soil-Bare	Erosion Control Mulch	Low	Low	Low
3-02	Directly into lake	Residential	Surface Erosion-Sheet, Soil-Bare	Reseed bare soil & thinning grass, Mulch/Erosion Control Mix	Low	Low	Low
3-03	Directly into lake	Beach Access	Surface Erosion-Gully, Shoreline-Erosion, Shoreline-Unstable Access	Rip Rap	Medium	Medium	Low
3-04	Ditch	Private Road	Ditch-Gully Erosion, Ditch-Bank Failure	Reshape Ditch, Install Check Dams, Reshape (Crown) Road	High	High	Medium
3-05	Directly into lake	Residential	Ditch-Gully Erosion, Ditch-Bank Failure	Install Check Dams	High	High	Medium
3-06	Directly into lake	Boat Access	Shoreline-Erosion, Shoreline-Unstable Access	Rip Rap	High	Medium	Low
3-07	Directly into lake	Beach Access	Shoreline-Erosion, Shoreline-Unstable Access	Rip Rap	High	Low	Low
3-08	Directly into lake	Residential	Ditch-Gully Erosion, Ditch-Bank Failure	Install Check Dams	High	High	Medium

Site	Flow path to lake	Land use	Problem	Recommendations	Impact Rating	Cost to Fix	Technical Level
3-09	Minimal Vegetation	Residential	Surface Erosion-Sheet	Establish Buffer, Mulch/Erosion Control Mix	Low	Low	Low
3-10	Ditch	Private Road	Surface Erosion-Rill, Surface Erosion-Gully	Reshape (Crown) Road ,Install Runoff Diverters-Broad-based Dip	High	High	High
3-11	Directly into lake	Beach Access	Shoreline-Erosion, Shoreline-Unstable Access	Install Runoff Diverter (waterbar), Rip Rap	Medium	Low	Low
3-12	Directly into lake	Beach Access	Shoreline-Erosion, Shoreline-Unstable Access	Rip Rap	Medium	Low	Low
3-13	Minimal Vegetation	Residential	Surface Erosion-Sheet, Soil-Bare	Mulch/Erosion Control Mix	Low	Low	Low
3-14	Minimal Vegetation	Beach Access	Surface Erosion-Sheet, Soil-Bare	Establish Buffer, Mulch/Erosion Control Mix	Low	Low	Low
3-15	Ditch	Driveway	Surface Erosion-Gully	Install Runoff Diverters-Broad-based Dip or Waterbar	High	Medium	Medium
3-16	Ditch	Private Road	Ditch-Gully Erosion, Ditch-Undersized	Install Check Dams, Reshape (Crown) Road, Install Runoff Diverters-Broad-based Dip/Open Top Culvert/Rubber Razor/Waterbar	High	High	High
3-17	Directly into lake	Boat Access	Surface Erosion-Rill, Soil-Bare, Shoreline-Unstable Access	Build Up Road, Reshape (Crown) Road, Install Runoff Diverters-Rubber Razor or Waterbar	Medium	Medium	Medium
3-18	Minimal Vegetation	Residential	Surface Erosion-Sheet, Soil-Bare, Shoreline-Inadequate Shoreline Vegetation	Define Foot Path, Erosion Control Mulch, Add to Buffer, Mulch/Erosion Control Mix	Low	Low	Low
3-19	Minimal Vegetation	Residential	Surface Erosion-Sheet, Soil-Bare, Shoreline-Inadequate Shoreline Vegetation	Define Foot Path, Erosion Control Mulch, Add to Buffer, Mulch/Erosion Control Mix	Low	Low	Low
3-20	Minimal Vegetation	Residential	Surface Erosion-Sheet, Soil-Bare, Shoreline-Erosion, Shoreline-Inadequate Shoreline Vegetation	Mulch, Seed/Hay, Erosion Control Mulch, Add to Buffer, Mulch/Erosion Control Mix; ECM all bare soil areas	Medium	Medium	Low
3-21	Minimal Vegetation	Residential	Surface Erosion-Sheet, Soil-Bare, Shoreline-Inadequate Shoreline Vegetation, Roof Runoff Erosion	Define Foot Path, Erosion Control Mulch, Infiltration Trench @ roof dripline, Add to Buffer, Mulch/Erosion Control Mix	Medium	Medium	Low

Site	Flow path to lake	Land use	Problem	Recommendations	Impact Rating	Cost to Fix	Technical Level
3-22	Minimal Vegetation	Residential	Surface Erosion-Sheet, Soil-Bare, Shoreline-Inadequate Shoreline Vegetation, Roof Runoff Erosion	Install Runoff Diverters-Rubber Razor or Waterbar, Define Foot Path, Erosion Control Mulch, Infiltration Trench @ roof dripline, Add to Buffer, Establish Buffer, Mulch/Erosion Control Mix; ECM berm/layer below driveway	Low	Low	Low
3-23	Minimal Vegetation	Beach Access	Surface Erosion-Sheet, Surface Erosion-Rill, Soil-Bare, Shoreline-Inadequate Shoreline Vegetation, Shoreline-Unstable Access	Define Foot Path, Erosion Control Mulch, Add to Buffer, Mulch/Erosion Control Mix, Remove Invasive Plants	Medium	Low	Low
4-01	Minimal Vegetation	Residential	Surface Erosion-Gully, Shoreline-Inadequate Shoreline Vegetation	Replace Culvert, Establish Buffer, Rain Garden	Medium	Medium	Medium
4-02	Minimal Vegetation	Private Road	Surface Erosion-Rill	Build Up Road, Add gravel, Install Runoff Diverters-Rubber Razor or Waterbar	Medium	High	Medium
4-03	Minimal Vegetation	Driveway	Surface Erosion-Rill	Build Up Road, Add gravel, Install Runoff Diverters-Rubber Razor, Reshape (Crown) Road	Medium	Medium	Medium
4-04	Directly into lake	Residential	Surface Erosion-Gully, Shoreline-Erosion, Roof Runoff Erosion	Infiltration Trench @ roof dripline, Stabilize bank with riprap	Medium	Low	Low
4-05	Minimal Vegetation	Residential	Surface Erosion-Rill	Build Up Road, Reshape (Crown) Road, Install Runoff Diverters-Rubber Razor, Mulch/Erosion Control Mix	Low	Medium	Medium
4-06	Stream	Town Road	Surface Erosion-Gully, Culvert-Unstable inlet/outlet, Ditch-Bank Failure	Armor Inlet/Outlet, Armor with Stone	High	High	Medium
4-07	Stream	Private Road	Surface Erosion-Gully, Ditch-Bank Failure, Ditch-Gully Erosion; Stream bank erosion	Armor with Stone	Medium	Low	Medium
4-08	Stream	Town Road	Surface Erosion-Gully, Culvert-Crushed/Broken, Ditch-Bank Failure, Ditch-Gully Erosion	Replace Culvert; Armor with Stone	High	High	High

Site	Flow path to lake	Land use	Problem	Recommendations	Impact Rating	Cost to Fix	Technical Level
5-01	Directly into lake	Residential	Surface Erosion-Sheet, Soil-Bare, Shoreline-Inadequate Shoreline Vegetation, Roof Runoff Erosion	Drywell @ gutter downspout, Infiltration Trench @ roof dripline, Add to Buffer, Mulch/Erosion Control Mix; Retrofit upper steps for infiltration	Low	Low	Low
5-02	Directly into lake	Private Road	Surface Erosion-Gully	Build Up Road, Add gravel, Install Runoff Diverters-Rubber Razor	Medium	Medium	Medium
5-03	Minimal Vegetation	Residential	Surface Erosion-Sheet, Soil-Bare	Stabilize Foot Path, Erosion Control Mulch, Install Runoff Diverter (waterbar), Infiltration Trench @ roof dripline	Low	Low	Low
5-04	Directly into lake	Residential	Surface Erosion-Sheet, Soil-Bare, Shoreline-Inadequate Shoreline Vegetation, Shoreline-Lack of Shoreline Vegetation, Roof Runoff Erosion	Define Foot Path, Stabilize Foot Path, Drywell @ gutter downspout, Add to Buffer, Reseed bare soil & thinning grass	Low	Low	Low
5-05	Minimal Vegetation	Residential	Surface Erosion-Rill	Install Check Dams, Rain Garden	Low	Low	Medium
5-06	Minimal Vegetation	Residential	Surface Erosion-Rill, Shoreline-Lack of Shoreline Vegetation	Install Runoff Diverter (waterbar), Infiltration Steps, Establish Buffer, Mulch/Erosion Control Mix	Low	Low	Low
5-07	Directly into lake	Residential	Surface Erosion-Sheet, Soil-Bare, Shoreline-Inadequate Shoreline Vegetation, Roof Runoff Erosion	No Raking, Add to Buffer, Mulch/Erosion Control Mix; Add timber to top of slope on south side of camp	Low	Low	Low
5-08	Directly into lake	Residential	Surface Erosion-Sheet, Soil-Bare, Shoreline-Lack of Shoreline Vegetation	Mulch/Erosion Control Mix; Add stone to stabilize vehicle access to dock. ECM bank.	Low	Low	Low
5-09	Directly into lake	Residential	Surface Erosion-Sheet, Soil-Bare, Shoreline-Lack of Shoreline Vegetation, Shoreline-Unstable Access	Stabilize Foot Path, Erosion Control Mulch, Install Runoff Diverter (waterbar), Define Foot Path, No Raking; Timbers and planting terraces to break up slope	Low	Low	Low
5-10	Stream	Driveway	Surface Erosion-Gully, Surface Erosion-Rill, Culvert-Clogged, Culvert-Unstable inlet/outlet, Culvert-Undersized	Armor Inlet/Outlet, Enlarge Culvert, Replace Culvert, Build Up Road, Add gravel, Reshape (Crown) Road, Install Runoff Diverters-Rubber Razor. Install new culvert so not under house. Reshape upper driveway to send runoff to turnout.	High	High	High

Site	Flow path to lake	Land use	Problem	Recommendations	Impact Rating	Cost to Fix	Technical Level
5-11	Directly into lake	Residential	Surface Erosion-Rill	Install Runoff Diverter (waterbar), Infiltration Steps, Stabilize Foot Path, Erosion Control Mulch, Add to Buffer, No Raking, Mulch/Erosion Control Mix.	Medium	Low	Medium
5-12	Stream	Private Road	Surface Erosion-Rill, Roadside Plow/Grader Berm	Armor Inlet/Outlet, Build Up Road, Reshape (Crown) Road, Remove Grader/Plow Berms	Medium	Medium	Medium
5-13	Directly into lake	Residential	Surface Erosion-Sheet, Soil-Bare, Shoreline-Unstable Access	EC blankets or rolls on bare areas.	Medium	Medium	Medium
5-14	Minimal Vegetation	Residential	Surface Erosion-Sheet, Roof Runoff Erosion	Infiltration Steps, Stabilize Foot Path, Erosion Control Mulch, Add to Buffer	Low	Low	Low
5-15	Directly into lake	Driveway	Surface Erosion-Rill	Build Up Road, Add gravel, Install Runoff Diverters-Rubber Razor; Define parking and enclose edge with timber for runoff	Medium	Medium	Medium
5-16	Directly into lake	Residential	Surface Erosion-Sheet, Roof Runoff Erosion	Infiltration Trench @ roof dripline, Mulch/Erosion Control Mix	Low	Low	Low
5-17	Directly into lake	Residential	Surface Erosion-Sheet, Soil-Bare, Roof Runoff Erosion	Infiltration Trench @ roof dripline, Add to Buffer, Mulch/Erosion Control Mix	Low	Low	Low
5-18	Minimal Vegetation	Residential	Surface Erosion-Sheet, Soil-Bare, Shoreline-Unstable Access, Roof Runoff Erosion	Stabilize Foot Path, Erosion Control Mulch, Infiltration Steps, Establish Buffer, Reseed bare soil & thinning grass	Low	Medium	Low
5-19	Directly into lake	Residential	Surface Erosion-Sheet, Soil-Bare	Define Foot Path, Stabilize Foot Path, Erosion Control Mulch, Install Runoff Diverter (waterbar), Establish Buffer	Low	Low	Low
5-20	Directly into lake	Residential	Surface Erosion-Sheet, Surface Erosion-Rill, Soil-Bare, Shoreline-Unstable Access, Shoreline-Lack of Shoreline Vegetation	Define Foot Path, Erosion Control Mulch, Install Runoff Diverter (waterbar), Stabilize Foot Path, Establish Buffer, No Raking; Plantings on slope	Medium	Medium	Medium

Site	Flow path to lake	Land use	Problem	Recommendations	Impact Rating	Cost to Fix	Technical Level
6-01	Stream	Commercial	Surface Erosion-Gully, Culvert-Unstable inlet/outlet, Ditch-Gully Erosion, Road Shoulder Erosion-Gully, Soil-Bare, Soil-Uncovered Pile	Armor Culvert Inlet/Outlet, Vegetate, Armor with Stone, Install Turnouts, Vegetate Shoulder, Silt Fence/EC Berms, Seed/Hay, Mulch/Erosion Control Mix	High	High	High
6-02	Stream	Town Road	Culvert-Unstable inlet/outlet, Soil-Uncovered Pile, Soil-Bare	Armor Inlet/Outlet, Vegetate Shoulder; remove pile of road material above culvert	Low	Medium	Low
6-03	Stream	State Road	Culvert-Crushed Broken, Culvert-Unstable inlet/outlet	Armor Culvert Inlet/Outlet, Replace Culvert	Medium	High	High
6-04	Directly into lake	Residential	Surface Erosion-Sheet, Soil-Bare, Shoreline-Inadequate Shoreline Vegetation, Shoreline-Erosion	Add to Buffer, Establish Buffer, No Raking, Mulch/Erosion Control Mix	Medium	Medium	Low
6-05	Minimal Vegetation	Residential	Surface Erosion-Sheet, Soil-Bare, Roof Runoff Erosion	Drywell @ gutter downspout, Rain Barrel, Reseed bare soil & thinning grass, No Raking, Mulch/Erosion Control Mix, rain garden would be great to capture roof and driveway runoff	Low	Medium	Low
6-06	Directly into lake	Residential	Ditch-Gully Erosion	Reshape Ditch, Armor with Stone, Vegetate, Install Check Dams	High	Medium	Medium
6-07	Ditch	Residential	Culvert-Unstable inlet/outlet, Culvert-Crushed Broken, Culvert-Undersized	Replace Culvert, Armor Culvert Inlet/Outlet, Enlarge Culvert, Install Plunge Pool	Medium	Medium	Medium
6-08	Minimal Vegetation	Construction Site	Surface Erosion-Sheet, Soil-Bare	Silt Fence/EC Berms, Mulch, Seed/Hay, Reseed bare soil & thinning grass, Mulch/Erosion Control Mix	Low	Medium	Medium
6-09	Directly into lake	Boat Access	Surface Erosion-Sheet, Surface Erosion-Rill, Soil-Bare, Shoreline-Unstable Access	Pave, Add gravel, Install Runoff Diverters-Waterbar, Infiltration Trench, boat launch pavers/crushed stone	High	High	Medium
6-10	Directly into lake	Town Road	Surface Erosion-Gully	Build Up Road, Reshape (Crown) Road, Install Runoff Diverters-Waterbar or Rubber Razor	High	High	High
6-11	Stream	Driveway	Culvert-Crushed Broken, Culvert-Unstable inlet/outlet	Armor Culvert Inlet/Outlet, Replace Culvert, Lengthen Culvert	Medium	Medium	Medium

Site	Flow path to lake	Land use	Problem	Recommendations	Impact Rating	Cost to Fix	Technical Level
6-12	Stream	Town Road	Culvert-Unstable inlet/outlet	Armor Culvert Inlet/Outlet, Replace Culvert, replace rip rap or regrade so it doesn't fall into the stream	Medium	High	High
6-13	Minimal Vegetation	Residential	Surface Erosion-Sheet, Soil-Bare	Reseed bare soil & thinning grass, Establish Buffer, cover patch of bare soil, plant vegetation	Low	Low	Low
6-14	Directly into lake	Residential	Surface Erosion-Sheet, Soil-Bare, Shoreline-Lack of Shoreline Vegetation	Establish Buffer	Low	Low	Low
6-15	Directly into lake	Residential	Surface Erosion-Sheet, Soil-Bare, Shoreline-Lack of Shoreline Vegetation	Establish Buffer, Mulch/Erosion Control Mix, more crushed stone, cover bare soil	Low	Low	Low
6-16	Directly into lake	Residential	Surface Erosion-Rill, Soil-Bare, Shoreline-Erosion, Shoreline-Unstable Access	Erosion Control Mulch, Stabilize Foot Path, Define Foot Path, Add to Buffer, No Raking, Mulch/Erosion Control Mix, Install Runoff Diverter (waterbar), vegetation	Medium	Medium	Medium
6-17	Directly into lake	Residential	Surface Erosion-Rill, Soil-Bare, Shoreline-Inadequate Shoreline Vegetation, Shoreline-Unstable Access, Shoreline-Erosion	Define Foot Path, Stabilize Foot Path, Erosion Control Mulch, Establish Buffer, cover steep area	Medium	Low	Low
6-18	Directly into lake	Residential	Surface Erosion-Sheet, Soil-Bare, Shoreline-Inadequate Shoreline Vegetation	Add to Buffer, cover bare soil on steep slope	Low	Low	Low
6-19	Directly into lake	Residential	Surface Erosion-Rill, Soil-Bare, Shoreline-Inadequate Shoreline Vegetation	Erosion Control Mulch, Add to Buffer, No Raking, Install Runoff Diverter (waterbar), Mulch/Erosion Control Mix	High	Medium	Low
6-20	Directly into lake	Residential	Surface Erosion-Sheet, Soil-Bare, Shoreline-Erosion, Shoreline-Unstable Access	Stabilize Foot Path, Define Foot Path, Install Runoff Diverter (waterbar), Erosion Control Mulch, Add to Buffer, No Raking, Mulch/Erosion Control Mix	Medium	Low	Low
6-21	Stream	Town Road	Surface Erosion-Rill, Culvert-Unstable inlet/outlet	Armor Culvert Inlet/Outlet	Medium	Medium	Low

Site	Flow path to lake	Land use	Problem	Recommendations	Impact Rating	Cost to Fix	Technical Level
7-01	Ditch	Driveway	Surface Erosion-Sheet, Roadside Plow/Grader Berm	Add gravel, Reshape (Crown) Road, Install Runoff Diverters-Rubber Razor	Low	Low	Medium
7-02	Minimal Vegetation	Residential	Surface Erosion-Sheet, Shoreline-Inadequate Shoreline Vegetation, Roof Runoff Erosion	Drywell @ gutter downspout, Infiltration Trench @ roof dripline, Reseed bare soil & thinning grass, Add to Buffer, Mulch/Erosion Control Mix	Low	Low	Low
7-03	Minimal Vegetation	Residential	Surface Erosion-Sheet, Shoreline-Inadequate Shoreline Vegetation	Add to Buffer, Mulch/Erosion Control Mix	Low	Low	Low
7-04	Directly into lake	Residential	Surface Erosion-Sheet, Shoreline-Erosion, Shoreline-Inadequate Shoreline Vegetation	Add to Buffer, Rip Rap	Low	Low	Low
7-05	Directly into lake	Residential	Surface Erosion-Sheet, Shoreline-Erosion	Stabilize Foot Path, Erosion Control Mulch, Mulch/Erosion Control Mix, Rain Garden; Replace paved path with rock or mulch, add mulch and maybe rain garden to yard to the left of the path.	Medium	Low	Low
7-06	Directly into lake	Residential	Surface Erosion-Sheet, Shoreline-Lack of Shoreline Vegetation, Shoreline-Erosion	Establish Buffer, Add to Buffer, Rip Rap	Medium	Low	Low
7-07	Minimal Vegetation	Residential	Surface Erosion-Sheet, Shoreline-Erosion, Shoreline-Lack of Shoreline Vegetation	Add to Buffer	Low	Low	Low
7-08	Directly into lake	Residential	Soil-Uncovered Pile	Seed/Hay, Mulch, Establish Buffer	High	Medium	Medium
7-09	Directly into lake	Boat Access	Surface Erosion-Gully, Shoreline-Unstable Access	Add gravel, Install Runoff Diverters-Broad-based Dip	Medium	Low	Low
7-10	Stream	Private Road	Surface Erosion-Sheet, Culvert-Clogged, Culvert-Undersized, Culvert-Unstable inlet/outlet	Enlarge Culvert, Armor Culvert Inlet/Outlet	Low	Medium	Medium
7-11	Ditch	Private Road	Surface Erosion-Rill	Build Up Road, Add gravel, Reshape (Crown) Road, Install Runoff Diverters-Waterbar or Rubber Razor	Medium	Medium	Medium
9-01	Directly into lake	Trail or Path	Surface Erosion-Sheet, Soil-Bare	Stabilize Foot Path, Infiltration Steps	Low	Low	Low

Site	Flow path to lake	Land use	Problem	Recommendations	Impact Rating	Cost to Fix	Technical Level
9-02	Directly into lake	Residential	Surface Erosion-Sheet, Soil-Bare, Shoreline-Inadequate Shoreline Vegetation	Infiltration Steps, Erosion Control Mulch, Establish Buffer	Low	Low	Low
9-03	Directly into lake	Residential	Surface Erosion-Sheet, Soil-Bare	Add to Buffer, Reseed bare soil & thinning grass, Mulch/Erosion Control Mix, Rebuild failing wall, eliminate boat ramp	Medium	Medium	Medium
9-04	Directly into lake	Residential	Surface Erosion-Sheet, Soil-Bare	Define Foot Path, Erosion Control Mulch, Infiltration Steps, Establish Buffer	Low	Medium	Medium
9-05	Directly into lake	Residential	Surface Erosion-Sheet, Soil-Bare	Erosion Control Mulch, Define Foot Path, Reseed bare soil & thinning grass	Low	Low	Low
9-06	Minimal Vegetation	Residential	Surface Erosion-Sheet, Soil-Bare	Define Foot Path, Erosion Control Mulch, Reseed bare soil & thinning grass	Low	Low	Low
9-07	Directly into lake	Residential	Surface Erosion-Sheet, Soil-Bare	Erosion Control Mulch	Low	Low	Low
9-08	Directly into lake	Residential	Surface Erosion-Gully, Shoreline-Erosion, Shoreline-Unstable Access	Stabilize Foot Path, Infiltration Steps	Medium	Low	Medium
9-09	Directly into lake	Residential	Surface Erosion-Sheet, Soil-Bare	Define Foot Path, Stabilize Foot Path, Infiltration Steps	Medium	Low	Medium
9-10	Directly into lake	Residential	Surface Erosion-Sheet, Soil-Bare	Define Foot Path, Stabilize Foot Path, Infiltration Steps	Low	Low	Medium
9-11	Directly into lake	Residential	Surface Erosion-Sheet, Soil-Bare	Erosion Control Mulch, Stabilize Foot Path, Define Foot Path	Low	Low	Low
10-01	Directly into lake	Residential	Surface Erosion-Sheet, Soil-Bare, Shoreline-Erosion, Shoreline-Lack of Shoreline Vegetation	Add to Buffer, Coir log with vegetative stakes plantings and ECM	Low	Low	Low
10-02	Minimal Vegetation	Residential	Surface Erosion-Rill, Soil-Bare, Shoreline-Erosion, Roof Runoff Erosion, Other-Invasive Plants	Erosion Control Mulch, Infiltration Trench @ roof dripline, Add to Buffer, No Raking, Mulch/Erosion Control Mix, Coir logs for terracing and revegetate and mulch	Medium	Medium	Medium
10-03	Minimal Vegetation	Driveway	Surface Erosion-Rill, Road Shoulder Erosion-Rill	Build Up Road, Add gravel, Install Runoff Diverters-Waterbar	Medium	Medium	Medium

Site	Flow path to lake	Land use	Problem	Recommendations	Impact Rating	Cost to Fix	Technical Level
10-04	Minimal Vegetation	Residential	Surface Erosion-Sheet, Soil-Bare, Shoreline-Lack of Shoreline Vegetation, Shoreline-Erosion, Shoreline-Inadequate Shoreline Vegetation, Shoreline-Unstable Access, Roof Runoff Erosion	Infiltration Trench @ roof dripline, Establish Buffer, Add to Buffer, Mulch/Erosion Control Mix, Add mulch to steep banks, Cover bare soil	Low	Low	Low
10-05	Minimal Vegetation	Residential	Surface Erosion-Sheet, Shoreline-Lack of Shoreline Vegetation, Shoreline-Inadequate Shoreline Vegetation, Roof Runoff Erosion	Infiltration Trench @ roof dripline, Establish Buffer, Reseed bare soil & thinning grass, No Raking, Replace invasive plants with natives.	Low	Low	Low
10-06	Minimal Vegetation	Residential	Soil-Bare, Shoreline-Erosion, Shoreline-Lack of Shoreline Vegetation, Shoreline-Undercut, Shoreline-Inadequate Shoreline Vegetation, Shoreline-Unstable Access, Roof Runoff Erosion, Other - Black pipe coming out of hill creating channel. Connected to gutter.	Infiltration Trench @ roof dripline, Drywell @ gutter downspout, Add to Buffer, Reseed bare soil & thinning grass, Mulch/Erosion Control Mix, Terrace and vegetate and mulch, crushed stone under steps. Disconnect gutter and install drywell	Low	Medium	Medium
10-07	Minimal Vegetation	Residential	Surface Erosion-Rill, Soil-Bare, Shoreline-Undercut, Shoreline-Inadequate Shoreline Vegetation, Roof Runoff Erosion, Other-Invasive Plants	Infiltration Trench @ roof dripline, Add to Buffer, Establish vegetation at top of slope to mitigate erosion	Low	Low	Medium
10-08	Minimal Vegetation	Residential	Surface Erosion-Sheet, Soil-Bare, Shoreline-Erosion, Shoreline-Inadequate Shoreline Vegetation	Add to Buffer, Mulch/Erosion Control Mix, Stabilize soil at top of slope by stairs. Add crushed stone under stairs to cover bare soil	Low	Low	Low
10-09	Directly into lake	Residential	Surface Erosion-Gully, Shoreline-Erosion, Shoreline-Undercut, Shoreline-Lack of Shoreline Vegetation	Establish Buffer, Reseed bare soil & thinning grass, remove failing retaining wall. Reestablish natural shoreline with rock and native vegetation	High	High	High
10-10	Minimal Vegetation	Driveway	Surface Erosion-Rill, Other-Eroding driveway	Add gravel, Build Up Road, Reshape (Crown) Road, Install Runoff Diverters-Rubber Razor, Define parking area within existing gravel are with parking bollards or timber to prevent compaction on grass	Medium	Medium	Medium

Site	Flow path to lake	Land use	Problem	Recommendations	Impact Rating	Cost to Fix	Technical Level
10-11	Minimal Vegetation	Residential	Surface Erosion-Sheet, Soil-Bare, Shoreline-Inadequate Shoreline Vegetation, Other-Major cut bank on backside of property, outdoor shower drains to ground, possible sand additions at shoreline. Dog impacts have created large bare area near beach. Bare soil on secondary berm.	Add to Buffer, Reseed bare soil & thinning grass, Mulch/Erosion Control Mix, Minimize beach area to natural shoreline. Stabilize cut bank behind shower. Vegetate bare areas on berm. Do not wash with soaps in or near lake	Low	Low	Medium
10-12	Directly into lake	Residential	Surface Erosion-Sheet, Soil-Bare, Shoreline-Inadequate Shoreline Vegetation, Shoreline-Unstable Access, Roof Runoff Erosion	Infiltration Steps, Infiltration Trench @ roof dripline, Add to Buffer, Mulch/Erosion Control Mix, Coir logs and native vegetation on hill slope	Low	Medium	Medium
10-13	Minimal Vegetation	Residential	Surface Erosion-Rill, Soil-Bare, Shoreline-Lack of Shoreline Vegetation, Shoreline-Erosion, Roof Runoff Erosion, Other-Paved path to stairs conduit for water. Steep eroding bank above lake.	Infiltration Steps, Infiltration Trench @ roof dripline, Add to Buffer, Mulch/Erosion Control Mix, Terrace with staked coir logs, install vegetation and ECM to cover all bare soil	Medium	Medium	Medium
10-14	Directly into lake	Residential	Surface Erosion-Sheet, Soil-Bare, Shoreline-Inadequate Shoreline Vegetation, Shoreline-Unstable Access, Shoreline-Lack of Shoreline Vegetation, Shoreline-Erosion, Roof Runoff Erosion, Other-Ice berm at shoreline.	Infiltration Trench @ roof dripline, Add to Buffer, Establish Buffer, Mulch/Erosion Control Mix, Rip Rap, Terracing needed on slopes with vegetation and ECM	Medium	Medium	Medium
10-15	Directly into lake	Residential	Surface Erosion-Rill, Soil-Bare, Shoreline-Undercut, Shoreline-Erosion, Shoreline-Lack of Shoreline Vegetation	Add to Buffer, Rip Rap, Contact DEP - need PBR / site visit to mix riprap and veg at shoreline	Medium	Medium	Medium
10-16	Directly into lake	Residential	Surface Erosion-Rill, Shoreline-Undercut, Shoreline-Lack of Shoreline Vegetation, Shoreline-Erosion	Establish Buffer	Medium	Medium	Medium

Site	Flow path to lake	Land use	Problem	Recommendations	Impact Rating	Cost to Fix	Technical Level
10-17	Stream	Private Road	Culvert-Unstable inlet/outlet, Culvert-Undersized, Other-Beaver activity	Armor Culvert Inlet/Outlet, Rip Rap	Low	Low	Medium
10-18	Directly into lake	Residential	Surface Erosion-Sheet, Surface Erosion-Rill, Soil-Bare, Shoreline-Inadequate Shoreline Vegetation, Shoreline-Lack of Shoreline Vegetation	Install Runoff Diverter (waterbar), Stabilize Foot Path, Infiltration Trench @ roof dripline, Establish Buffer, Reseed bare soil & thinning grass, Mulch/Erosion Control Mix, Infiltration below deck edge	Low	Low	Low
10-19	Directly into lake	Residential	Surface Erosion-Rill, Soil-Bare, Shoreline-Lack of Shoreline Vegetation	Establish Buffer, Mulch/Erosion Control Mix, Don't cut or weed whack understory	Medium	Medium	Low
10-20	Directly into lake	Residential	Surface Erosion-Sheet, Soil-Bare, Shoreline-Lack of Shoreline Vegetation	Establish Buffer, Mulch/Erosion Control Mix	Low	Medium	Low
10-21	Directly into lake	Residential	Surface Erosion-Sheet, Soil-Bare, Shoreline-Unstable Access, Roof Runoff Erosion	Stabilize Foot Path, Infiltration Trench @ roof dripline, Add to Buffer, Add stone from steps to dock	Low	Low	Low
10-22	Stream	Private Road	Surface Erosion-Rill, Culvert-Unstable inlet/outlet, Road Shoulder Erosion-Rill	Armor Culvert Inlet/Outlet, Build Up Road, Reshape (Crown) Road, Add gravel, Reshape shoulder and seed or armor; turnouts on road.	Medium	Medium	Medium
10-23	Minimal Vegetation	Residential	Surface Erosion-Rill	Add gravel, Build Up Road, Reshape (Crown) Road, Install Runoff Diverters-Waterbar	Low	Medium	Low
10-24	Directly into lake	Residential	Surface Erosion-Sheet, Soil-Bare	No Recommendations Given	Medium	Medium	High
10-25	Directly into lake	Residential	Surface Erosion-Sheet, Soil-Bare, Shoreline-Inadequate Shoreline Vegetation	Install Runoff Diverters-Rubber Razor, Define Foot Path, Stabilize Foot Path, Drywell @ gutter downspout, Add to Buffer, Mulch/Erosion Control Mix.	Medium	Medium	Low
10-26	Stream	Town Road	Culvert-Unstable inlet/outlet, Ditch-Rill Erosion	Armor Culvert Inlet/Outlet, Armor with Stone	Medium	Low	Low
10-27	Directly into lake	Residential	Surface Erosion-Sheet, Soil-Bare, Shoreline-Unstable Access	Mulch/Erosion Control Mix	Low	Low	Low

Site	Flow path to lake	Land use	Problem	Recommendations	Impact Rating	Cost to Fix	Technical Level
10-28	Directly into lake	Residential	Surface Erosion-Sheet, Soil-Bare, Shoreline-Lack of Shoreline Vegetation, Shoreline-Unstable Access	Erosion Control Mulch, Establish Buffer, Reseed bare soil & thinning grass	Low	Low	Low
10-29	Directly into lake	Residential	Surface Erosion-Rill, Soil-Bare	Erosion Control Mulch, Establish Buffer, Add brush and vegetation to stabilize severe bank erosion	High	Medium	High
11-01	Stream	Town Road	Culvert-Unstable inlet/outlet, Culvert-Undersized	Armor Culvert Inlet/Outlet, Enlarge Culvert	Low	Medium	Medium
11-02	Stream	Private Road	Road Shoulder Erosion-Rill	Reshape (Crown) Road, Install some type of runoff diverter	Medium	Medium	Low
11-03	Stream	Driveway	Culvert-Undersized, Culvert-Unstable inlet/outlet, Road Shoulder Erosion-Rill	Armor Culvert Inlet/Outlet, Enlarge Culvert, Reshape (Crown) Road, Add gravel, Mulch/Erosion Control Mix	Medium	Medium	Medium
11-04	Ditch	Town Road	Ditch-Rill Erosion	Install Check Dams, Vegetate, Remove debris/sediment	Low	Medium	Medium
11-05	Stream	Town Road	Surface Erosion-Sheet, Culvert-Unstable inlet/outlet, Road Shoulder Erosion-Rill	Armor Culvert Inlet/Outlet, Install Turnouts, Vegetate, Riprap bank around culvert outlet	Medium	Medium	Medium
11-06	Stream	Town Road	Culvert-Unstable inlet/outlet, Road Shoulder Erosion-Sheet	Armor Culvert Inlet/Outlet, Potentially pave shoulder or add runoff diverter	Low	Medium	Medium

Appendix J. Evaluation of Remediation Options for Addressing the Internal Load

While there are multiple ways by which internal loading of P can occur, the dominant one in New England is for P bound by iron (Fe) to be released under low oxygen conditions. Redox reactions result in both Fe and P being released into the overlying water. If a lake is stratified, as is the case for both basins of China Lake, most of the released P is trapped in the lower water layer (hypolimnion). If the distance between the point of anoxia (defined as DO<2 mg/L, not 0 mg/L, as oxygen is likely to be 0 mg/L in the surficial sediment when oxygen in the water is <2 mg/L) and the point of light penetration into the lake is far enough apart (at least 3 m), available P may not move upward and be used by algae. However, mixing events, algae that move in the water column, and algae that grow at the sediment-water interface with just enough light to grow can all result in some internally loaded P reaching the upper waters. And if the anoxic boundary extends upward to the point where light is available, mid-depth (metalimnetic, in the vicinity of the boundary or thermocline) algae blooms may occur. Further, if the anoxic interface reaches the thermocline, diffusion and mixing of P into upper waters is expected. Weather patterns can create substantial variation among years, so the portion of internally loaded P that becomes part of the "effective" P load to the lake will also vary. Below is an overview of the various methods for addressing internal loading in lakes.

Dredging is true lake restoration, removing accumulated sediment and setting the lake back in time. While dredging does not affect ongoing watershed inputs, it can control internal loading and minimize oxygen demand. Dredging is very expensive, however, with a cost of $50,000 per acre-foot of sediment removed offered as a low-end estimate. Unless restoring lost depth is a major goal, dredging is rarely implemented to manage internal P loading, and dredging would be cost-prohibitive in China Lake.

Hypolimnetic oxygenation would increase oxygen in deep waters, limiting the release of phosphorus from associated sediment while enhancing coldwater fish habitat. There are limited examples of this approach being applied to lower phosphorus levels; most often oxygenation is conducted to enhance water quality for potable supply or fish habitat. But the theory is sound and where internal loading is a dominant component of phosphorus loading, oxygenating the hypolimnion should provide desirable results. Not all internal loading would be eliminated, and the extra oxygen would allow releases from decay to increase somewhat, but a 75% reduction in internal P loading is achievable and the benefits are clear. At the current/m^2/day over about 4.4 million m^2, and 1.2 g/m^2/day over 2.9 million m^2, a daily oxygen input of about 13,600 kg would be needed to counter the lakewide demand. As oxygen demand tends to rise in response to the movement of water that accompanies oxygen input, this estimate should be raised by at least 50% if pure oxygen is used, so a minimum oxygen supply of about 20,000 kg/day should be planned. The need could be several times larger if air is used as the oxygen source.

There are multiple means to oxygenate a lake without destratifying it, and with a vertical run of at least 6 m for the release of pure oxygen bubbles is the most efficient approach. The capital cost from other projects is at least $200 per kg/day, or about $4 million as a minimum for China Lake. The operational cost would be on the order of $0.50 per kg/day, or about $10,000 per day. Just how long the system would have to run is a matter of adjustment to prevent oxygen depletion; low oxygen needs to be prevented but saturation level oxygen does not need to be achieved. It would be likely that an oxygenation system would have to be turned on in early July and run into mid-August, about 45 days, which suggests an annual operational cost of $450,000.

Hypolimnetic withdrawal is designed to remove P from the lake by withdrawing nutrient-rich bottom water through a pipe system to control the lake outflow from the hypolimnion. This has been an effective restoration technique to reduce summer P concentrations for stratified lakes with a flushing rate >0.2 flushes/yr. This method was examined as a management strategy for China Lake (Kleinschmidt, 2012) and determined to have too many limitations to make it a preferred alternative to an aluminum treatment so was not revisited as part of the current plan. Limitations of this method include the inconsistency and magnitude of sedimentary P release in the west basin, the hydraulic limitations and cost of retrofitting the existing eight miles of cast iron pipe that would act as a siphon to move water from the lake to the treatment facility in Waterville, the cost of the operation and maintenance of a pump to produce an effective flow rate through the pipe, and the possible need for a NPDES permit to discharge the nutrient-rich water into a receiving waterbody.

Lake Drawdown in China Lake was modified in 2014 following recommendations from the 2012 feasibility study. The current drawdown was designed to remove water with high P and replace it with low P water. Under the current management of the Outlet Dam, the 2.5 ft. drawdown in the fall is estimated to result in a P reduction of approximately 54 kg/yr.[40] At this rate it would take 125 years to flush the internal load out of China Lake and is therefore not a primary strategy for addressing the internal load but does provide some benefits by contributing to the efforts to reduce P in the lake, and therefore should remain in place as a current management practice for China Lake.

Alewife. The potential effects of alewife restoration in China Lake were examined and it was determined that reintroduction should not negatively affect water quality in China Lake as long as

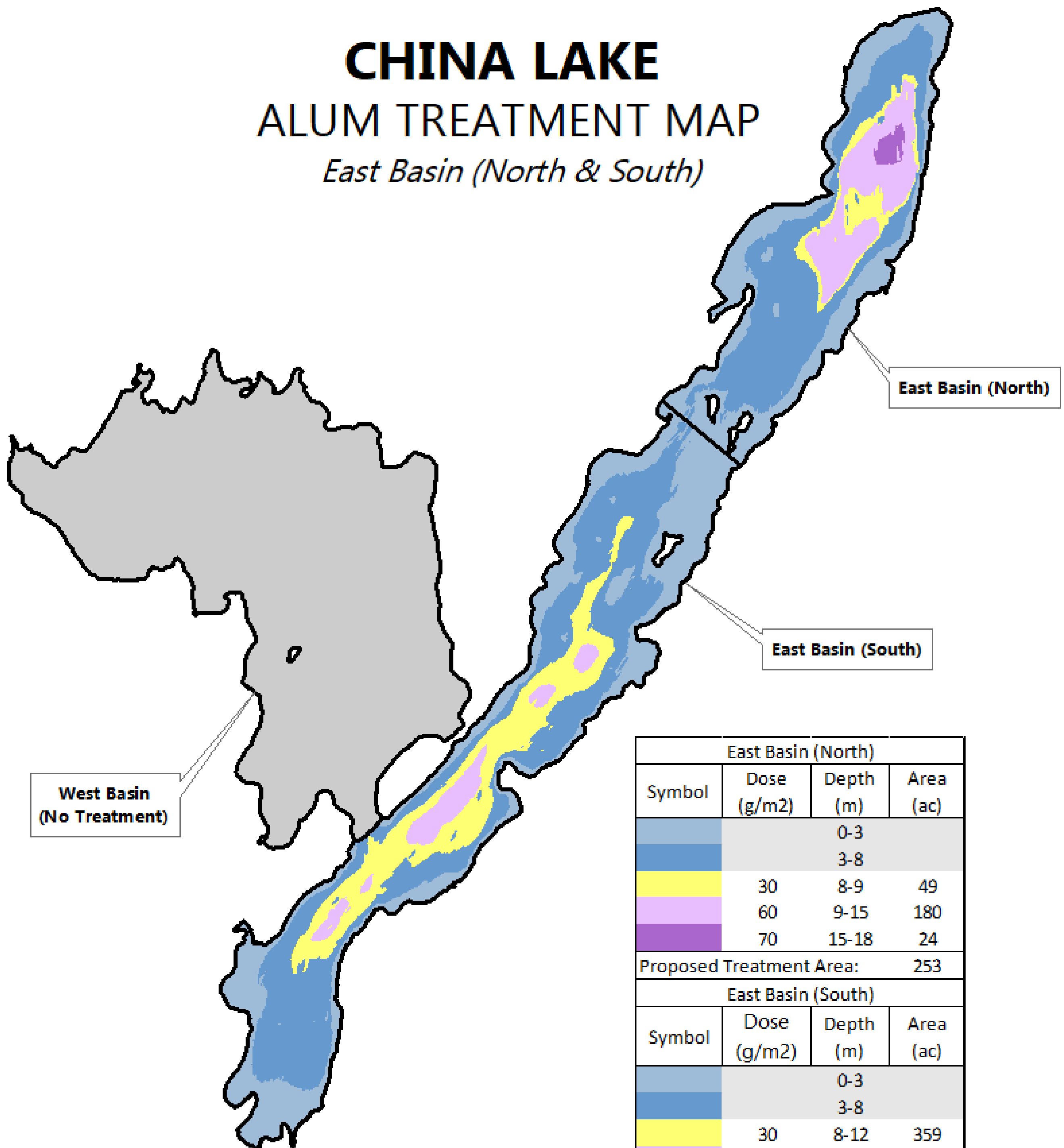
[40] P reductions for the current drawdown were recalculated based on the recent water quality analysis and bathymetric update. Estimated P reductions are lower than the 2012 estimates.

there is an outlet through which fish can emigrate (leave the lake) freely; nutrient models suggest that nutrient levels may increase in the lake when escapement (fish entering the lake) is high (Kleinschmidt, 2015). A literature review that indicated that alewife re-introductions have not been observed to be directly linked to water quality improvements or declines. In any given year, there could be more or less P in the lake after the alewife run, so reintroduction is not expected to result in a major net loss of P from the system.

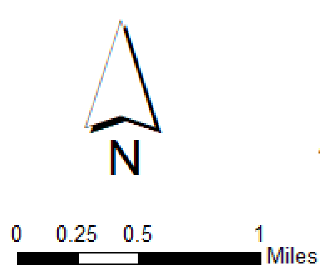
Appendix K. Preliminary Dose and Cost Estimates for P Inactivation in China Lake & Aluminum Treatment Map

Feature	East Basin - North			East Basin - South		West Basin		
Depth range	8-9 m	9-15 m	15-18 m	8-12 m	12-18 m	8-12 m	12-18 m	18-27 m
Mean Available Sediment P (mg/kg DW)	116	438	561	123	500	120	300	530
Target Depth of Sediment to be Treated (cm)	10	10	10	10	10	10	10	10
Volume of Sediment to be Treated per m2 (m3)	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
Specific Gravity of Sediment	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10
Percent Solids (as a fraction)	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080
Mass of Sediment to be Treated (kg/m2)	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8
Mass of P to be Treated (g/m2)	1.02	3.85	4.94	1.08	4.40	1.06	2.64	4.66
Target Area (ac)	49	180	24	359	108	504	357	238
Target Area (m2)	198,864	729,294	98,671	1,451,696	440,958	2,040,921	1,444,449	963,430
P mass in area (kg)	203	2,811	487	1,571	1,940	2,155	3,813	4,493
Aluminum sulfate (alum) @ 11.1 lb/gal and 4.4% aluminum (lb/gal)	0.4884	0.4884	0.4884	0.4884	0.4884	0.4884	0.4884	0.4884
Sodium aluminate (aluminate) @ 12.1 lb/gal and 10.38% aluminum (lb/gal)	1.256	1.256	1.256	1.256	1.256	1.256	1.256	1.256
Stoich. Ratio (ratio of Al to P in treatment)	20	20	20	20	20	20	20	20
Suggested areal dose (g Al/m2)	30	60	70	30	60	30	40	70
Dose at Al:P = 20	20	77	99	22	88	21	53	93
Dose at Al:P = 10	10	39	49	11	44	11	26	47
Assay result that yields 90% Fe-P reduction	15 to 28	58	58	28 to 58			7 to 15	15 to 28
Ratio of alum to aluminate during treatment (volumetric)	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Aluminum Load								
Dose (kg/area)	4060	56220	9742	31426	38804	43104	76267	89869
Dose (lb/area)	8932	123684	21433	69138	85369	94829	167787	197711
Dose (gal alum) @ specified ratio of Alum to Aluminate	8001	110788	19199	61929	76469	84942	150293	177097
Dose (gal aluminate) @ specified ratio of Alum to Aluminate	4000	55394	9599	30965	38234	42471	75147	88549
Application (gal/ac) for Alum in Alum+Aluminate Trtmt	163	615	788	173	708	168	421	744
Application (gal/ac) for Aluminate in Alum+Aluminate Trtmt	81	307	394	86	354	84	211	372
Estimated cost for suggested areal dose ($)	$66,316	$486,400	$76,777	$484,650	$291,600	$680,593	$642,247	$749,649
Area cost ($)	$629,493			$776,250		$2,072,489		
Basin cost ($)	$1,405,743					$2,072,489		

CHINA LAKE
ALUM TREATMENT MAP
East Basin (North & South)



East Basin (North)			
Symbol	Dose (g/m2)	Depth (m)	Area (ac)
		0-3	
		3-8	
	30	8-9	49
	60	9-15	180
	70	15-18	24
Proposed Treatment Area:			253
East Basin (South)			
Symbol	Dose (g/m2)	Depth (m)	Area (ac)
		0-3	
		3-8	
	30	8-12	359
	60	12-18	106
Proposed Treatment Area:			465



Data Source: original bathymetric data from Dan Buckley (Retired, University of Maine Farmington) collected in 2002 as part of the Lake Water Monitoring and Bathymetric Mapping Project, processed by Tara King (USDA-NRCS) in 2021 to create contours lines at 1 m intervals. Map Projection: NAD 1983 UTM Zone 19N, Created by: K. Goodwin, Ecological Instincts, November 2021

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