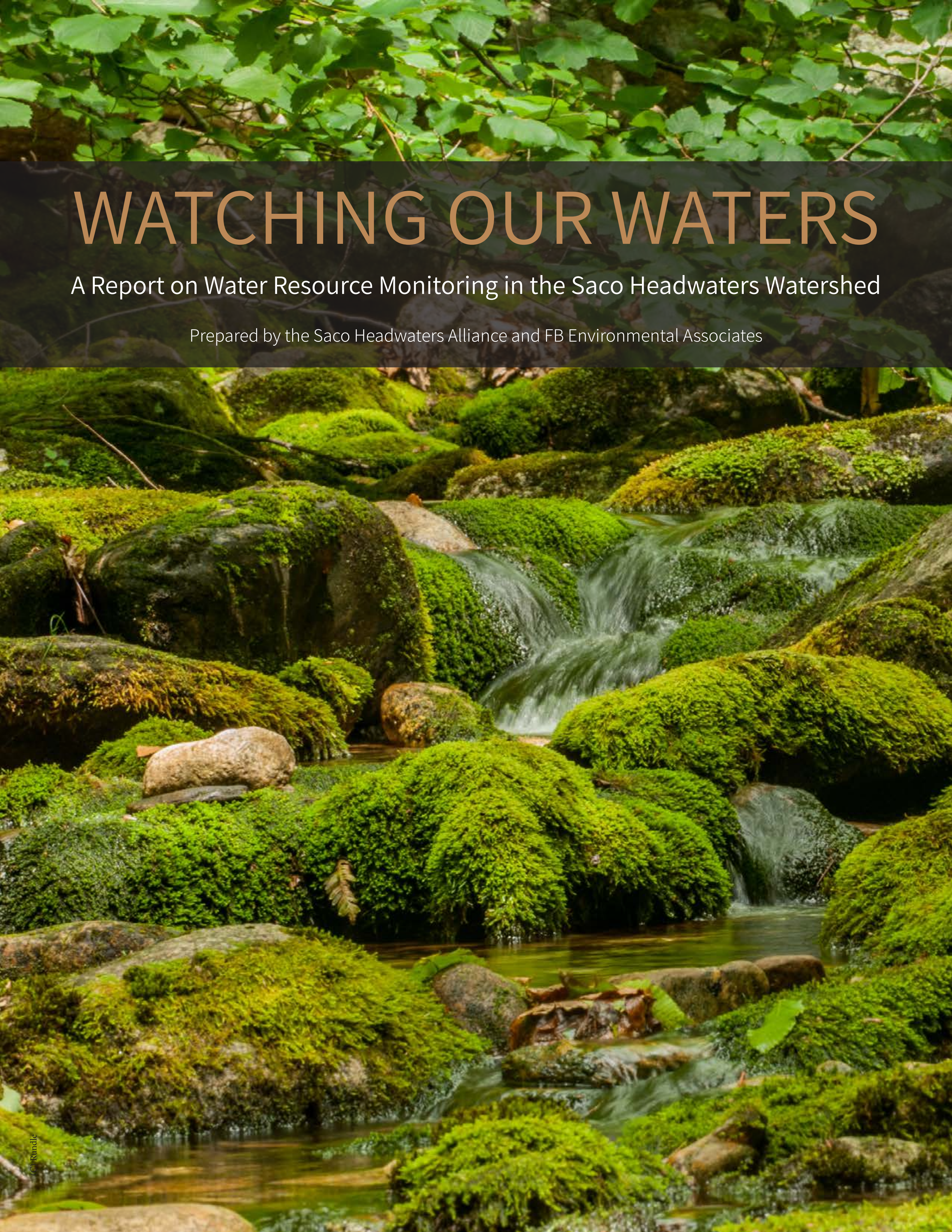
WATCHING OUR WATERS

A Report on Water Resource Monitoring in the Saco Headwaters Watershed

Prepared by the Saco Headwaters Alliance and FB Environmental Associates



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Special thanks to the Upper Saco Valley Land Trust (usvlt.org) and Joe Klementovich Photography (klementovichphoto.com).

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August 2020

Watching Our Waters represents the first completed project of the Saco Headwaters Alliance (SHA). a non-profit organization based in Conway, NH, and composed of representatives from many segments of our community – municipal leaders, conservationists, land trusts, and professionals – dedicated to protecting and conserving water quality and promoting sustainability and resilience in the Saco headwaters watershed.

All of the waterways of our Saco Headwaters Watershed – streams, rivers, ponds, lakes, and aquifers – are interconnected as one ecosystem. Consequently, pollution, floods, and drought know no municipal or state boundaries. This report is intended to serve as a resource to all stakeholders, both public and private, who share the Saco Headwaters Alliance vision for the future of this region: a resilient watershed, a prosperous economy, a vibrant coalition of communities, and a healthy natural environment for all, with inclusive access to clean, abundant surface and ground water resources for drinking and recreation.

We would like to express our gratitude to Mr. Brendan Fitzgerald and his colleagues at the Virginia Wellington Cabot Foundation (VWCF) for supporting our vision and our mission to protect and conserve abundant, clean ground and surface waters for a resilient Saco Headwaters Watershed for many years to come. Mr. Fitzgerald's personal goal was for the VWCF grant to not only underwrite a strategic study of water resource monitoring across the Saco Headwaters Watershed, but to catalyze the launch of the important work of the Saco Headwaters Alliance.

As we publish this report, Mr. Fitzgerald's goal is already being fulfilled. We have had the good fortune to facilitate funding from various sources including the New Hampshire Department of Environmental Services (NHDES) for projects created with various partners across the watershed, including municipalities and other stakeholders. We have also developed a pipeline of proposals for outstanding new projects awaiting decisions from funders, plus a robust "wish list" of future priorities. We would also like to thank the Upper Saco Valley Land Trust (USVLT) for serving as our fiscal agent and for providing the encouraging environment in which SHA was conceived by several of us who were USVLT Board members and then became among the first Board members of SHA.

This report represents a strategic building block for SHA's Mission and Urgent Vision. It is grounded in our guiding principles (collaboration, resiliency and ecosystem thinking) and is the result of our expertise in both the natural and social sciences. It describes a work in progress and concludes with a robust action plan.

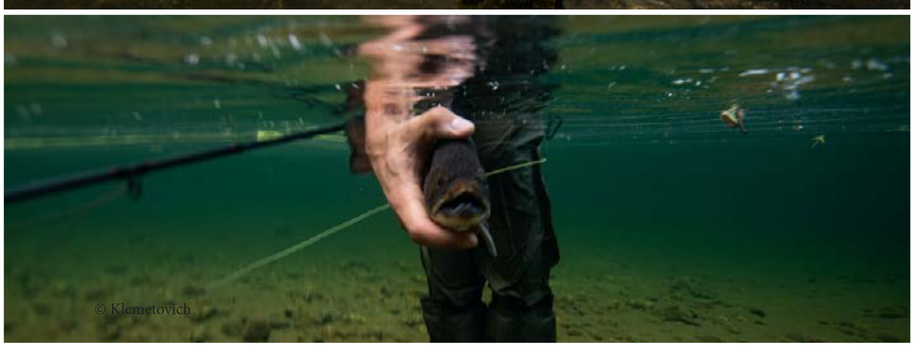
We invite your feedback and your participation as we continue to work to protect the waters and resources of the Saco Headwaters Watershed today and as a legacy for the future.

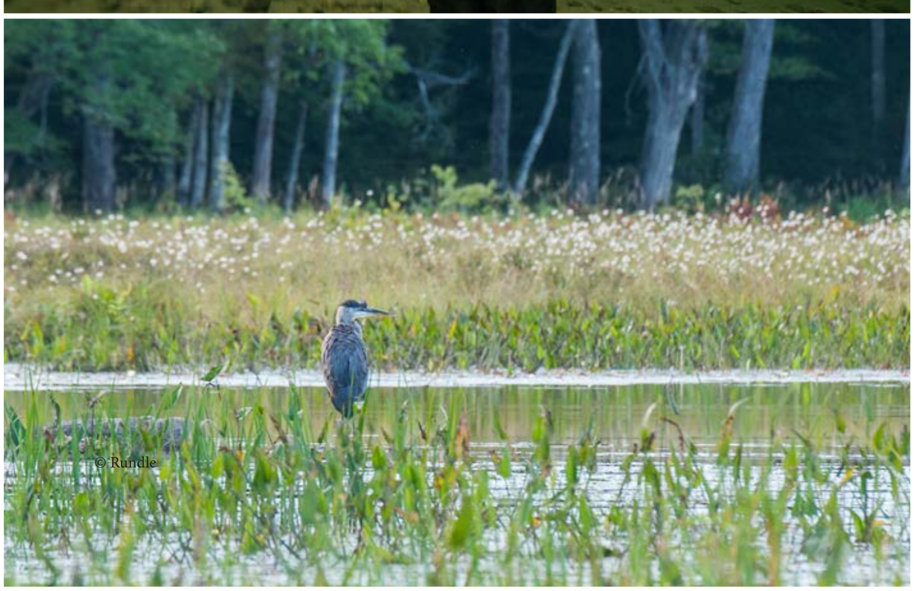
Sincerely,

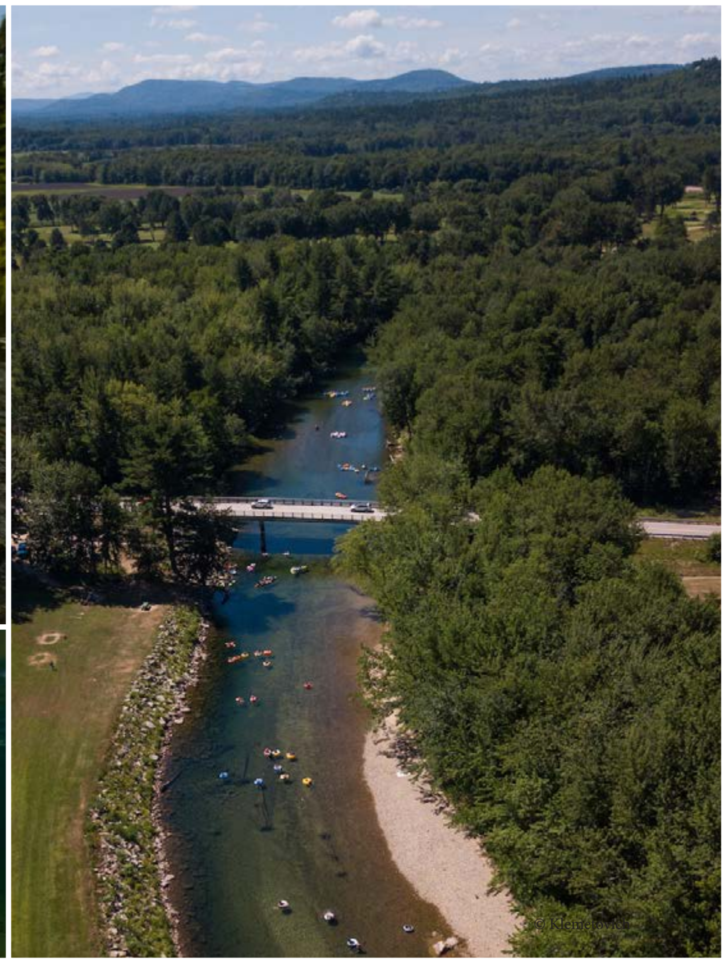
Thomas F. Gross
President, Saco Headwaters Alliance

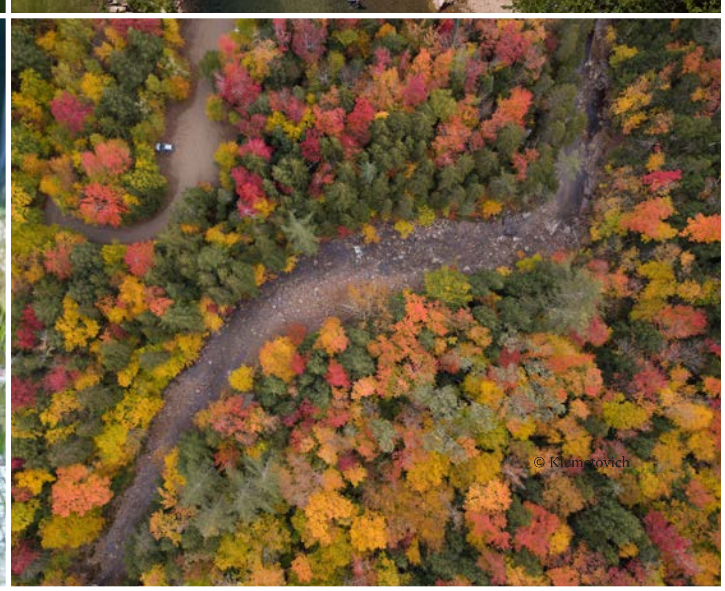
WHAT IS
A STRATIFIED DRIFT AQUIFER?

As glacial ice retreated in New England, layers of sand and gravel were deposited by meltwater streams in valleys and broad plains. Today, these deposits are important aquifers that hold abundant groundwater with a relatively short residence time - that is, groundwater is able to travel quickly through the large pore spaces between the sand grains and gravel fragments. These aquifers are primarily recharged quickly from the surface by precipitation and infiltration. They often yield large amounts of water to wells and public water supplies, making them crucial to protect.









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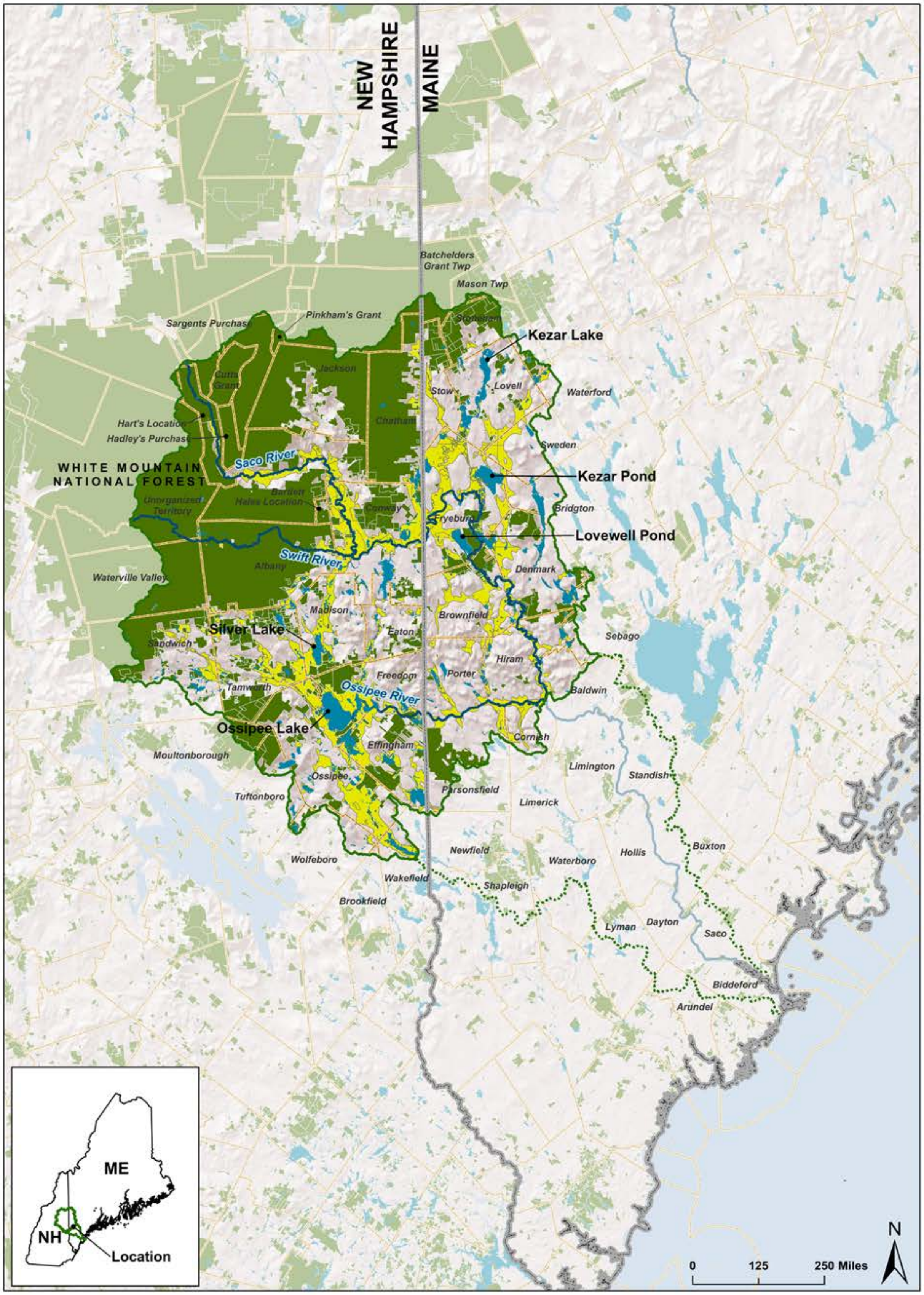

HUC8 Saco Watershed

HUC12 Upper Saco Watershed

Conserved Land (559 sq. mi.; 43.2%)

Waterbody

Aquifer*

River

Town Border

State Border

*Aquifers in New Hampshire represent "Stratified Drift Aquifers". Aquifers in Maine represent "Significant Sand and Gravel" and can further be represented by their production capacity.

SACO HEADWATERS WATERSHED

Overview Map

Data Source: ESRI DigitalGlobe, Maine Office of GIS and NH GRANIT
Projection: NH State Plane
Created By: Margaret Mills, FB Environmental
Date Created: June 2020

FB environmental

EXECUTIVE SUMMARY

The Saco Headwaters Watershed is a region of abundant water resources in eastern New Hampshire and western Maine. The watershed is defined by the drainage of the Saco River and its major tributary the Ossipee River at their confluence, an area slightly larger than the size of Rhode Island, and includes mountains, broad glacial valleys, vital stratified drift aquifers, and scenic lakes and rivers. Unspoiled natural resources support the recreational tourism economy and provide a high quality of life for residents.

A large portion of the Saco Headwaters Watershed − 43% − is protected as public and private conservation land. The region contains abundant high-quality streams, rivers, lakes, ponds, and aquifers that face mostly dispersed threats to water resources in the form of nonpoint source pollution. This form of pollution derives from contaminants produced by activities on the landscape that can be carried by stormwater to streams or ponds or infiltrated into groundwater. Some notable examples include nutrients from underground wastewater disposal, soil or sediment particles eroded and carried by storms, and road salt from winter deicing.

A robust water quality monitoring system is a key component of the Saco Headwaters Alliance's Urgent Vision for a more resilient watershed. The core purpose of this report is to assess the state of water resource monitoring with respect to known threats, as well as the ability to respond to newly developing threats, which is essential to building and maintaining resilience. To do this, we comprehensively reviewed the existing monitoring programs and data sources, analyzed gaps, and created recommendations for specific actions.

The **Programs & Data** section inventories monitoring programs, organizations, and data sources relevant to water protection in the Saco Headwaters Watershed. A diverse network of state and federal agencies and nonprofit organizations collects water data for many purposes and under many separate programs. We also take a close look at the available spatial data for the watershed – geographic information system data that maps locations and boundaries of natural resources and human infrastructure.

The **Gap Analysis** section critically appraises the available data and the existing monitoring programs for their ability to detect and understand water resource threats. Threats and their causes are given detailed discussion, and key gaps are identified.

The **Strategic Action Plan** section puts forth recommendations for specific actions to address gaps in data and scientific understanding. Details are provided on each action, including the responsible entity, the timeframe, and the estimated cost.

This report combines a number of components – each of which would be an important undertaking on its own – in pursuit of one goal: to strengthen water resource monitoring in the Saco Headwaters watershed so that key data gaps can be closed and water protection efforts can be based on the best science possible. A core assumption underlying all of this work is that investments in monitoring now will inform effective actions that will in turn prevent harm to our water resources that would be much more costly to restore, or worse, irreversible.

INTRODUCTION

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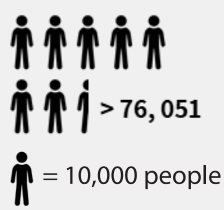
The Saco Headwaters Watershed in eastern New Hampshire and western Maine provides water resources that are vital to local communities.

The Saco Headwaters Watershed, defined as all lands and waterbodies that drain into the Saco River and its major tributary the Ossipee River, is a region covering 1,294 square miles in eastern New Hampshire and western Maine. The watershed includes parts of Carroll, Coos, and Grafton counties in New Hampshire and parts of Cumberland, Oxford, and York counties in Maine. Counting towns and unincorporated areas, there are 19 communities (13 in New Hampshire, 6 in Maine) and an additional 31 communities partially within the watershed (19 in New Hampshire, 12 in Maine). According to the 2010 US census, the region is home to 76,051 residents. Water resources within the Saco Headwaters watershed include over 1,591 miles of rivers and streams, 140 named lakes and ponds plus another 1,648 unnamed lakes and ponds, an unknown number of intermittent headwater streams, springs, and seeps, and two important stratified drift aquifers (the Ossipee and Upper Saco aquifers). These stratified drift aquifers are important sources of water for many municipalities, homes, and businesses in the region and receive their recharge waters from precipitation, infiltration, and stream seepage.

THE SACO HEADWATERS WATERSHED
AT A GLANCE

The watershed is home to **1,591** miles of named rivers and streams, **140** named lakes and ponds, and **2** major stratified drift aquifers.

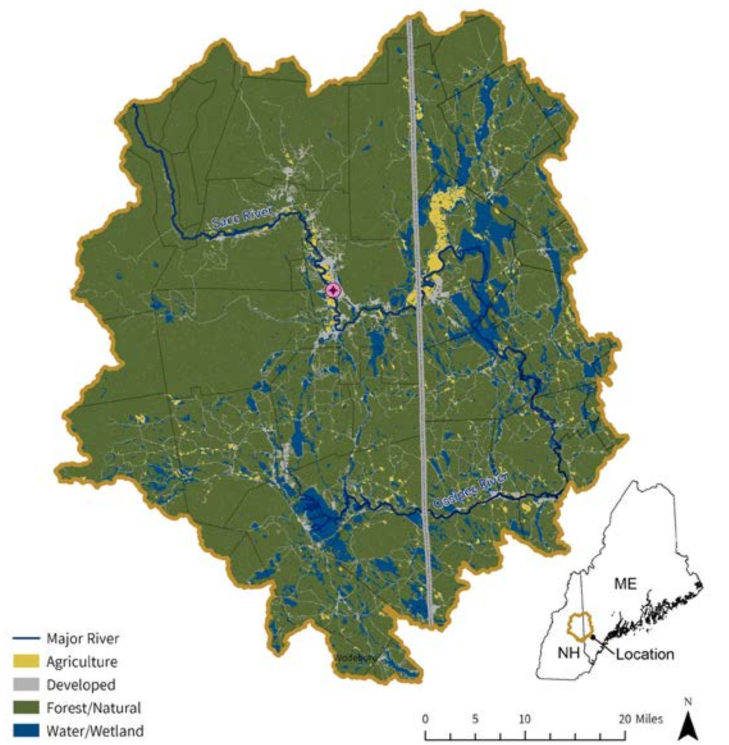


According to the 2010 US census, 38 of the 50 towns are home to **76,051** residents (the census does not include grant locations, purchases, or territories.)

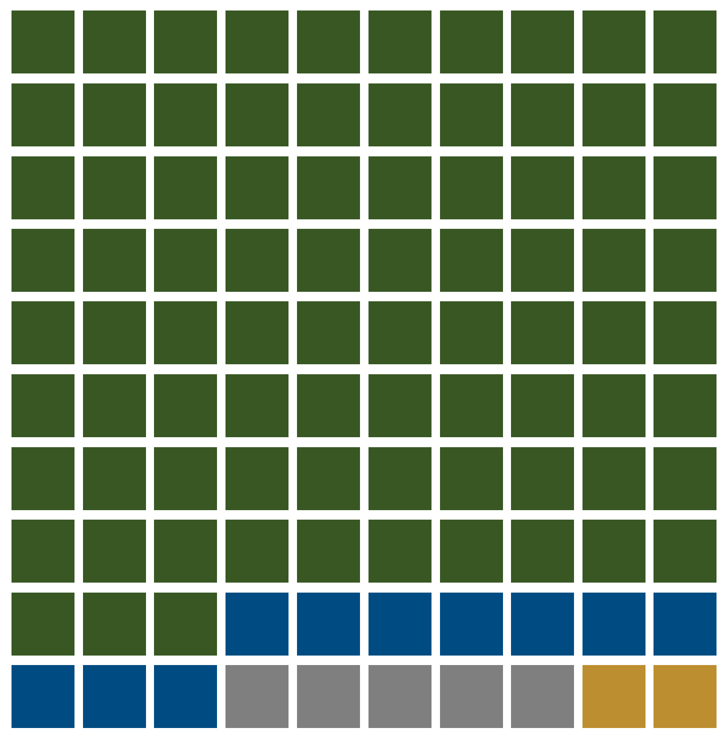
More than **43%** of the watershed is held as conserved land, with 385 sq. mi. in the White Mountain National Forest.

There are **50** communities either completely or partially within the watershed, **32** in NH and **18** in ME.

A large portion of the Saco Headwaters watershed, 43%, is protected conservation land. The region contains abundant high-quality streams, rivers, lakes, ponds, and aquifers. Where water quality threats do exist, they are mostly specific to land uses occurring nearby. Nonpoint source pollution – pollution that reaches surface waters or groundwater via contaminated stormwater runoff from developed land uses and not through a pipe or other conveyance – is estimated to be responsible or partially responsible for 90% of water pollution problems in New Hampshire (NHDES 2019). In Maine, nonpoint source pollution accounts for virtually all lake water quality impairments and is a leading cause of river and stream impairments (MEDEP 2019). Development pressure can exacerbate water quality problems in a number of ways. Replacing native vegetation with impervious surfaces (paved and gravel roads, parking lots, rooftops, shopping centers, logistics and distribution centers, etc.) decreases the fraction of stormwater that infiltrates the soil surface, percolates belowground, and recharges aquifers, with less groundwater eventually emerging as surface flow in a different location. In dry periods between storms, impervious surfaces collect a wide variety of contaminants such as nutrients, pathogenic microorganisms (e.g., fecal pathogens), and road salt. When it rains, these pollutants are carried away, and the pathway by which pollutants flow – whether through an untreated storm drain or ditch or a treated infiltration system – determines how much impact they have on water resources.



Land cover by general category for the Saco Headwaters watershed. See Appendix 1 for full-size maps.



One block represents 1% of land area within the Saco Headwaters watershed. ***Green*** *blocks represent forest cover,* ***blue*** *blocks represent water and wetlands,* ***grey*** *blocks represent developed land, and* ***yellow*** *blocks represent agriculture.*

Nonpoint source pollution may be to blame for most water quality problems in New Hampshire and Maine and within the Saco Headwaters watershed, but there are several notable exceptions that begin as air quality problems. First, the northeastern US is in a decades-long recovery from acid deposition (a.k.a., acid rain), which was first identified in the 1970s by scientists working at Hubbard Brook Experimental Forest in the Upper Pemigewasset watershed in New Hampshire. Industry and power generation by coal burning plants were the source of acidic nitrate and sulfate compounds in air masses traveling from the Midwest and depositing as acid rain in the northeastern US. Due to environmental laws (principally the Clean Air Act Amendments of 1990) and regulations, levels of acid deposition have decreased greatly in recent decades and waterbodies are becoming less acidic, but nitrogen deposition remains a persistent problem due to the difficulty of removing it from industrial smokestack and auto emissions. Second, mercury deposition is ubiquitous in the northeastern US and is also caused by atmospheric deposition tied to coal burning in the industrial plants of the Midwest. Mercury deposition is responsible for fish consumption advisories in all Maine and New Hampshire inland surface waters. Lastly, and perhaps most importantly for a forward-thinking assessment of monitoring, are the myriad climate change impacts that the northeastern US, one of the world's fastest warming regions, is already experiencing and will continue to experience in all future anthropogenic greenhouse gas emissions scenarios (National Climate Assessment 2018). As one highly visible example of climate change impacts to the region's recreational tourism economy, increases in surface water temperature brought on by climate warming are projected to significantly reduce coldwater habitat and the aquatic organisms it supports, such as the northeast's signature recreational fishery for native brook trout (National Climate Assessment 2018). Non-native species and the effects of decades of fish stocking are also key concerns to the active recreational fishing community that uses and stewards the region's streams, lakes, and ponds (Saco Valley Trout Unlimited 2019), but climate change adds additional pressure to these ecosystems in a variety of ways.

In ecology, resilience means the capacity of an ecosystem, including its human occupants, to respond to damage or disturbance by resisting harm, or by recovering fully and quickly. Communities become resilient by gathering information and preparing for the threats they face so that damage is minimized and recovery is as robust as possible. A resilient Saco Headwaters Watershed depends on the integrity of its water resources and the ability and willingness of the community to respond to threats. Water resource monitoring is fundamental to both.

Many groups and individual stakeholders have been hard at work for years protecting and monitoring the waters of the Saco River (Feurt et al. 2015), including the Saco Headwaters watershed. Water quality monitoring of both surface water and groundwater is an essential component to ensure that the region's water resources remain abundant and of high quality. Collecting water quality and quantity data regularly can serve as an early warning system when a new threat arises or a chronic problem becomes acute. Long-term water quality monitoring can also demonstrate whether or not management actions are achieving their desired effect. Protecting our waters requires us to be adaptive, responsive, and proactive and to constantly ask how we can improve.

This report serves multiple purposes in pursuit of one goal – to strengthen water resource monitoring in the Saco Headwaters Watershed so that key data gaps can be closed and water protection efforts can be based on the best science possible. The section on Programs & Data reviews and summarizes available water quality, hydrologic, and spatial data from state and federal agencies, regional institutions, nonprofit organizations, online data repositories, and scientific reports. The section on Gap Analysis takes a critical look at what is missing from the existing data and monitoring programs. The section on the Strategic Action Plan lays out a list of strategic actions recommended by the Saco Headwaters Alliance to close the key gaps identified and create a model for better informed water resource management in the region.

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PROGRAMS & DATA

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Regional monitoring programs have been collecting data for several decades in the Saco Headwaters. Stakeholders regularly use these data to guide efforts in management, outreach, education, regulation, and enforcement.

FBE compiled a water quality database for the Saco Headwaters watershed that combines all the water quality data records available from each of the data repositories and sources described below. This database is included as an electronic companion volume to this report under the filename FBE_WaterQualityDatabase_UpperSaco.xlsx. Please note that an extensive data quality assurance review, including screening for completeness, duplication, and outliers (as would be required for initiating any new water quality analysis project) will be completed in a future project phase.

Water resource data in the Saco Headwaters watershed comes from a wide variety of sources and is collected for many purposes. FBE compiled data from federal agencies such as the US Geological Survey (USGS) and the National Oceanic and Atmospheric Administration (NOAA); state agencies such as the New Hampshire Department of Environmental Services (NHDES) and the Maine Department of Environmental Protection; and regional or local institutions such as the Saco River Conservation Commission (SRCC), the Green Mountain Conservation Group (GMCG), and the Kezar Lake Watershed Association (KLWA). This section introduces the monitoring programs and other data collection efforts overseen by these organizations and discusses data sources accessed for this compilation, including online data repositories such as the NHDES Environmental Monitoring Database (EMD), the New Hampshire Hydro Server Mapper, the MEDEP Environmental and Geographic Analysis Database (EGAD), and the Gulf of Maine Knowledge Base.

Although not every sampling station contains data for every parameter, the most common parameters include pH, water temperature, turbidity, conductivity, dissolved oxygen concentration and percent saturation, and total phosphorus. Far and away the most commonly available groundwater parameter is depth to water table, but water quality parameter data are also available from several sources.

Active Water Resource Monitoring Programs

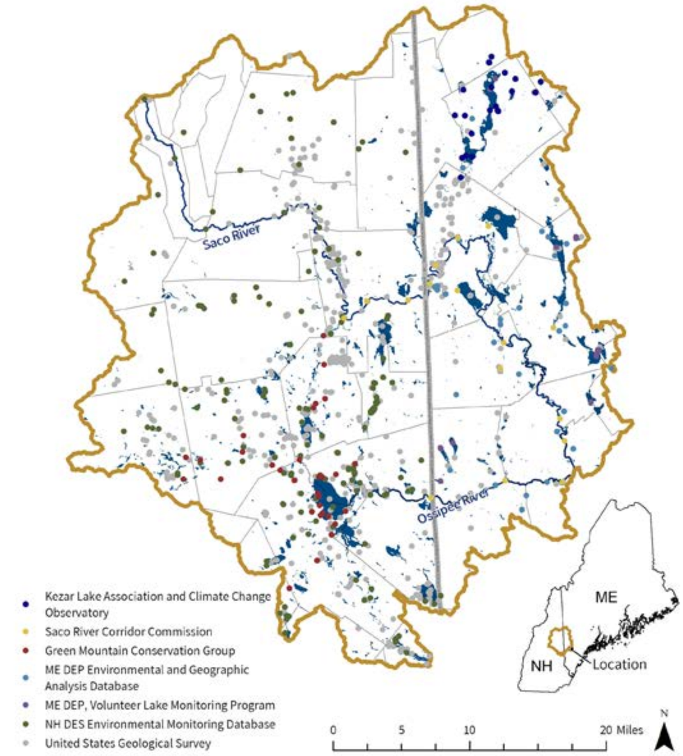
This section provides information on each organization with an active water resource monitoring program within the Saco Headwaters watershed.

New Hampshire Department of Environmental Services

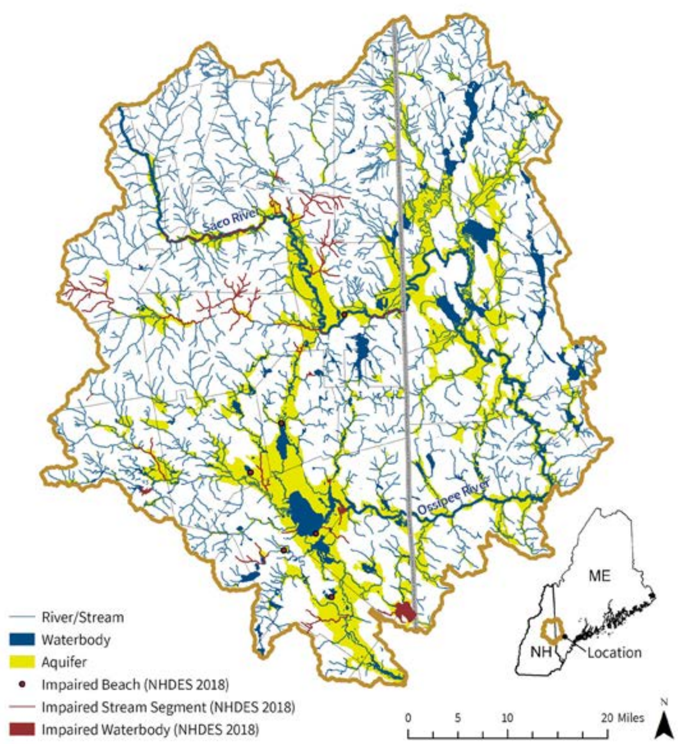
The core purpose of NHDES with regards to water quality monitoring is to conduct the surface water quality assessments required under the Clean Water Act. These assessments are intended to measure how well all waterbodies are attaining their designated uses based on water quality standards set by state law. The results are reported to the United States Environmental Protection Agency (USEPA) every two years in the state's Section 303(d)/305(b) Integrated Report. This reporting work is carried out by the NHDES Surface Water Quality Assessment Program with support from a wide variety of NHDES bureaus and programs, in addition to other organizations and programs funded by state grants and loans. The NHDES Biomonitoring Program and Volunteer Lakes and Volunteer Rivers Assessment Programs (VLAP and VRAP) provide support to the assessment efforts.

Whenever a waterbody is not attaining its designated uses, it is considered impaired by the Clean Water Act, which requires that the state agency – i.e. NHDES in New Hampshire and MEDEP in Maine – prepare a plan for steering the waterbody back into attainment. Two main categories of plans are used. Total Maximum Daily Loads (TMDLs) are cleanup plans that typically focus on tightening restrictions on point source pollution via National Pollution Discharge Elimination System (NPDES) permits required for emitters such as wastewater treatment plants or industrial facilities.

Watershed-based management plans typically focus on nonpoint source pollution and implementation of best management practices to reduce stormwater, agricultural, and other nonpoint pollutant loads. Federal funding for these activities is available through Clean Water Act Section 319 grants, which are administered by the state agencies. The Watershed Management Bureau administers Clean Water Act Section 319 grant funds to watershed planning efforts and nonpoint source pollution reduction projects. As part of this



Monitoring stations in the Saco Headwaters watershed. See Appendix 1 for full-size maps.



State-listed impaired waterbodies in the Saco Headwaters watershed. See Appendix 1 for full-size maps.

function, the Watershed Management Bureau oversees collection of nonpoint source pollution site information and pollutant reduction estimate data. It is important to note that watersheds and waterbodies can be eligible for funding for watershed-based management plans, even when designated uses are being attained, in order to ensure that degradation does not occur.

Several other NHDES bureaus and programs collect or maintain data relevant to water resource monitoring and protection:

- The Subsurface Systems Bureau is charged with reviewing septic system applications and keeps records of approvals across the state.
- The Drinking Water and Groundwater Bureau administers the Safe Drinking Water Act and reviews self-monitoring data provided by public water systems to ensure that clean public drinking water is provided in a manner compliant with the law. Though they carry out some groundwater and drinking water monitoring, they do not have a core monitoring mission.
- The Dam Bureau provides Ossipee River streamflow data in real time at a gauging station located between the Ossipee Dam and the NH-153 bridge, as well as streamflow for the Bearcamp River (a major tributary to Ossipee Lake) at a gauging station at NH-25.

Maine Department of Environmental Protection

MEDEP's core water quality monitoring role is to conduct water quality assessments for all surface waters in the state and is very similar to NHDES in this respect. In the biannual 303(d)/305(b) Integrated Report submitted to the USEPA, the State of Maine reports the results of these assessments and the attainment status of each waterbody's applicable designated uses according to water quality standards defined by the state's water classification system. The MEDEP Bureau of Water Quality's Division of Environmental Assessment is responsible for producing this report, with support from several MEDEP programs such as the Water Classification Program, the Biological Monitoring Program, and the Surface Water Ambient Toxics Program. Lake water quality monitoring data in Maine is handled primarily by Lake Stewards of Maine, a nonprofit organization that serves as the data management and quality assurance provider for the state's lakes data, much of which is collected by over 1,000 local volunteers at lakes across the state. MEDEP's water quality assessment of Maine lakes thus relies on data provided by Lake Stewards of Maine.

The MEDEP Bureau of Waste Management is responsible for operation of monitoring wells in proximity to remediation sites, closed landfills, and other sites where contamination of groundwater is a concern. MEDEP also coordinates closely with the Maine Drinking Water Program on water supply protection, jointly maintaining a database of potential and actual sources of contamination that may pose a risk to drinking water supplies.

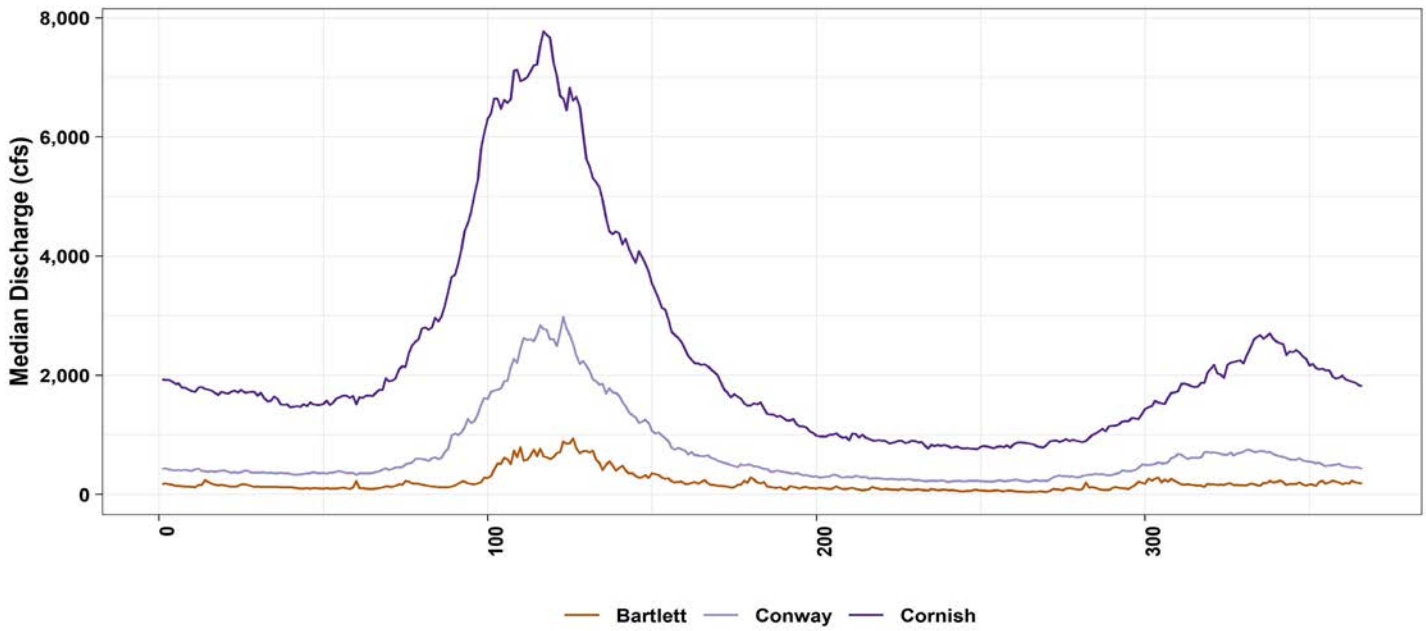
Maine Drinking Water Program

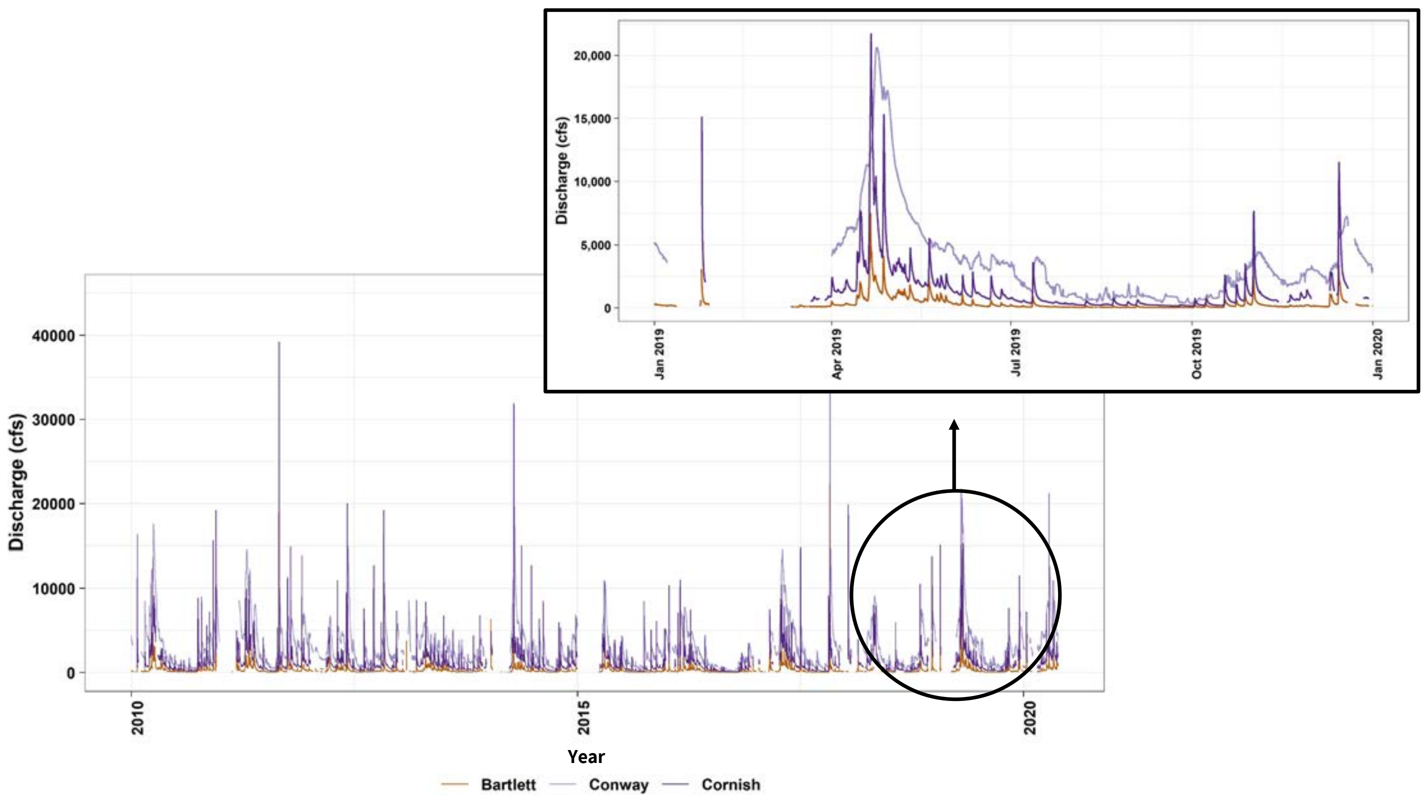
The Maine Drinking Water Program administers the Safe Drinking Water Act in Maine and ensures that public water systems self-monitor and provide clean water in compliance with the law and regulations. This program is housed in the Maine Department of Health and Human Services, whereas in New Hampshire this responsibility falls under the purview of NHDES. The Drinking Water Program also administers source water protection programs where grant funds assist with protection of groundwater at public water systems that supply water from their own wells (e.g. schools, hospitals, resorts, mobile home parks). In cooperation with MEDEP, the Drinking Water Program maintains the Public Water Resources Information System, a mapping tool available for download as a Google Earth file (a .kmz file) that displays locations of public water systems and potential and actual contamination sources.

United States Geological Survey (USGS)

The leading federal agency providing geological and hydrological science in the US, USGS studies the landscape of the US, its natural resources, and natural hazards such as earthquakes and flooding. USGS monitoring programs and scientific studies provide key data on the nation's water resources to the public. Their mission is scientific only and they have no regulatory duties. The data USGS scientists collect is often used to inform lawmaking, the regulatory process, and emergency management, and fills many other scientific needs at all levels of government.

The core monitoring programs operated by USGS are its nationwide network of over 7,400 stream gages collecting real-time streamflow data, and more than 1,800 wells outfitted with continuous data loggers that





Median daily discharge (cubic feet per second or cfs) for each day in the calendar year (1=Jan 1, 366=Dec 31) summarized from decades of data [TOP] and 15-min discharge (cfs) from 2010 to 2020 with a zoomed-in inset of a large 2019 storm event [BOTTOM] at three USGS gauging stations in Bartlett, Conway, and Cornish. Median daily discharge statistics based on the following time periods: Bartlett 9/18/2009-2/4/2020 (n=3,792); Conway 10/1/1903-2/9/2020 (n=35,487); and Cornish 6/4/1916-3/4/2020 (n=37,895).

record depth (and sometimes temperature and conductivity) every five to 15 minutes. In the Saco Headwaters watershed, USGS operates three stream gauges on the Saco River where real time streamflow is measured: Bartlett at River Street, Center Conway at Bryant Drive, and Cornish below the confluence of the Saco and Ossipee just upstream of the ME-5/ME-117 bridge. There are 18 monitoring wells in Maine and four in New Hampshire, but none of these continuous logger wells lie within the Saco Headwaters watershed.

Other Federal Agencies

The US Forest Service Northern Research Station conducts research on the ecology of northern hardwood forests at the Bartlett Experimental Forest, located south of Bartlett Village on the slopes north and west of Bear Notch Road. Study at this location includes streamflow measurement and water quality sampling. The data is not publicly available but an upcoming Forest Service publication that summarizes research on nutrients in streams is currently in press.

The National Atmospheric Deposition Program is a nationwide network of stations that monitor airborne contaminants carried in rain, snow, dust, and aerosols. This network began as a collaborative effort by US Department of Agriculture Experimental Stations in response to acid rain, and has grown to study all aspects of atmospheric deposition. The NADP interactive map shows one site in Bridgton, Maine, just west of the watershed boundary but provides data that can be applied to the Saco Headwaters watershed.

Saco River Corridor Commission (SRCC)

Created by an act of the Maine Legislature in 1979, SRCC is a regional planning board that regulates the use of land and water within the Saco River corridor in Maine. Headquartered in Cornish, ME, SRCC has land use authority over the river corridor extending 500 feet from the river channel in Maine municipalities from Fryeburg to Biddeford. A board of SRCC commissioners includes representatives from each of the corridor municipalities in Maine, and these commissioners serve as liaisons to help inform town water resource protection efforts.

SRCC also provides an important service to the entire Saco River watershed with its grab sampling program, which has been collecting grab samples at over 50 stations between Conway, NH and Biddeford, ME since 2001. SRCC makes these data available to municipalities and MEDEP for use in water quality management. Within the Saco Headwaters watershed, the SRCC monitoring program collects surface water quality data from May to October with field meters and grab samples at 18 sites along the Saco River, the Ossipee River, and several smaller tributaries and ponds. The farthest upstream site is in Conway, NH at Davis Park just downstream of the Saco/Swift River confluence, and the farthest downstream site is at the ME-5/ME-117 bridge between Cornish, ME and Baldwin, ME, just downstream of the Saco/Ossipee River confluence.

Green Mountain Conservation Group (GMCG)

Headquartered in the Ossipee River watershed in Effingham, NH, GMCG is a community-based environmental nonprofit with a mission to protect natural resources within the Ossipee watershed. GMCG facilitates citizen science through which members of the community participate in research, educational outreach and advocacy, and land conservation. From April to October, GMCG monitors 19 river sites for the Regional Interstate Volunteers for the Ecosystems and Rivers of the Saco (RIVERS) monitoring program. During the winter, monthly monitoring occurs at 9 sites. In addition to water chemistry data, aquatic habitat and biologic data are gathered by local schools and volunteers along with NHDES at ten sites through the Volunteer Biologic Assessment Program (VBAP). These data collected by the GMCG are compiled into a monitoring program and data final report at the end of each year, resulting in a yearly record of water quality data. Their growing database has established a robust baseline showing preliminary trends within the region.

Kezar Lake Watershed Association (KLWA)

Based in Lovell, ME, KLWA is a local non-profit organization with a mission to protect Kezar Lake and the surrounding watershed. KLWA maintains an active monitoring program that collects a wide array of continuous hydrologic data to study how Kezar Lake is changing over time and how it is reacting to changes in climate (e.g., temperature, precipitation, frequency and intensity of extreme climate events such as drought and powerful storms). The Kezar Lake watershed is situated within the northern part of the Saco Headwaters watershed. Pending approval from KLWA and the KLWA Climate Change Observatory (CCO), accessible data will include water level and temperature data from streams within the Kezar lake watershed. Beginning in 2014 as part of the CCO mission, FB Environmental Associates (FBE) has been assisting the KLWA CCO with water level and/or temperature monitoring at seven major Kezar Lake tributary streams throughout the watershed (Great Brook, Beaver Brook, Coffin Brook, Boulder Brook, Sucker Brook, Bradley Brook, Long Meadow Brook) using continuous loggers. In 2015, two additional water level and temperature monitoring sites were added at the Lower Bay and the Kezar Outlet Stream, which drains the Kezar Lake watershed into the Old Course Saco River.

Monitoring Data Sources

This section provides information on the data sources that were accessed to retrieve hydrologic and water quality data.

National Water Quality Monitoring Council Water Quality Portal

Water quality monitoring data from USGS and USEPA is available online through the Water Quality Portal, a federal service sponsored by USEPA, USGS, and the National Water Quality Monitoring Council that hosts data collected by more than 400 state, federal, tribal, and local agencies. A query for water quality data available within the Saco Headwaters watershed returned results from both groundwater (10,121 samples) and surface water samples (4,222 samples) at a total of 337 sites. Sample station information containing site IDs, site types, locations, and additional information) are available for download. These 337 sample stations represent the locations designated for lake, reservoir, river/stream, spring, well, wetlands, and other surface water sampling. This dataset includes data from October of 1954 through September of 2019. Surface and groundwater samples were collected for analysis of up to 356 parameters. Key parameters included alkalinity, chloride, chlorophyll-a, depth of water, dissolved oxygen, enterococci, E. coli, nitrate, pH, phosphate, temperature, and an array of metals.

National Oceanic and Atmospheric Administration (NOAA)

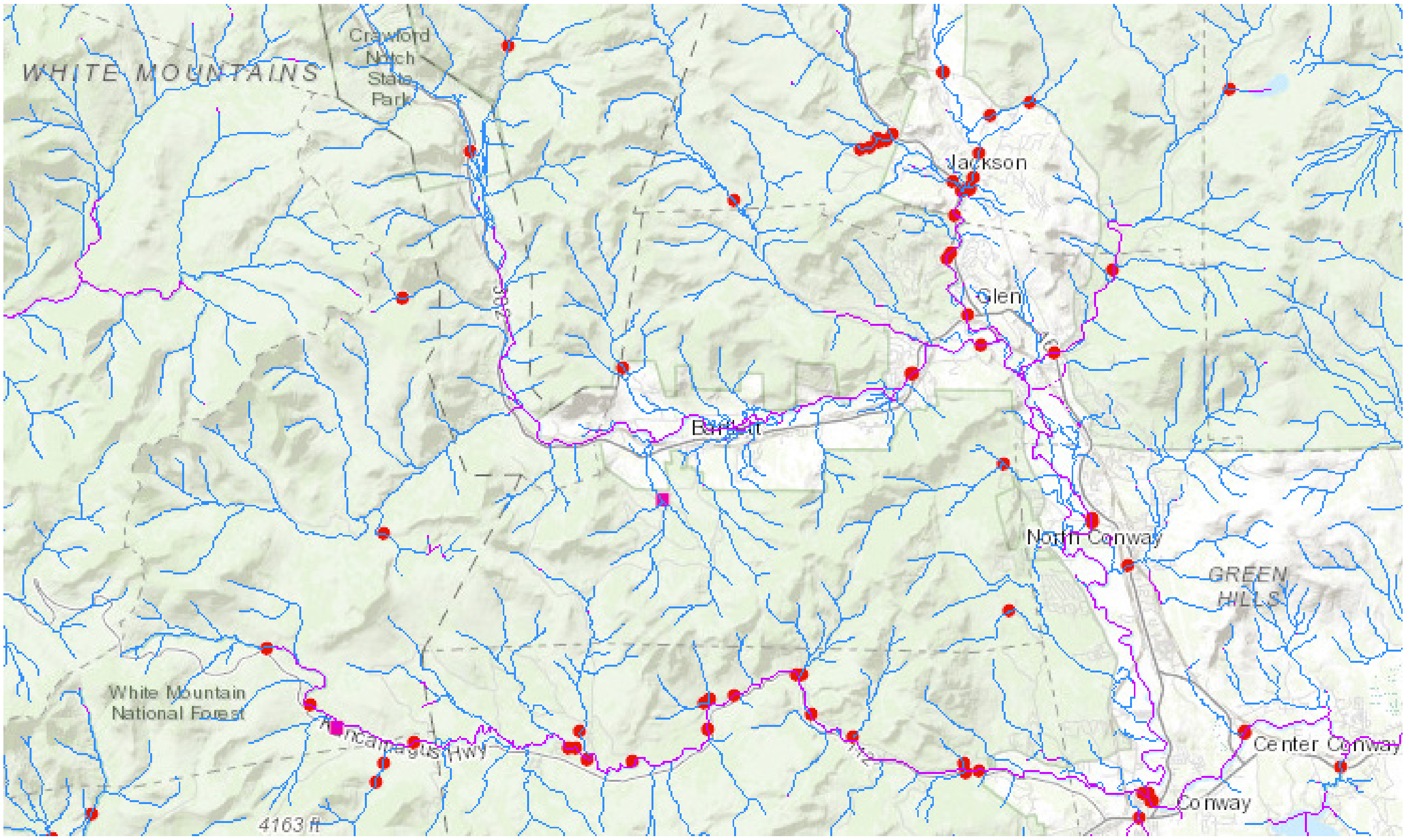
NOAA has developed the Climate Data Record Program to develop a time series of measurements from multiple weather stations and satellites of high quality and consistency to monitor climate variability. Data available include station location information, date of the recorded observation, daily air temperature maximum and minimums, and daily total precipitation for both rain and snowfall within the Saco Headwaters watershed. The weather station data search query included temperature and precipitation data between the dates of 1/1/1950 and 12/21/2019 at dozens of stations within the Saco Headwaters watershed, with highly robust and complete datasets for stations in North Conway, Mount Washington, Fryeburg, Tamworth, Lovell, and more. Using multiple weather stations within the study area ensures temporal gaps within the data are closed via a secondary station.

NHDES Environmental Monitoring Database

Developed in 2003, the NHDES EMD serves as a comprehensive standardized database for all stream, river, lake, pond, estuary, and ocean data collected by or submitted to NHDES. Data can be accessed using the NHDES OneStop Data and Information portal, or by submitting a data query request. FBE requested all surface and groundwater data within the watershed area identified by the 41 HUC12 IDs. Melanie Cofrin of the NHDES Watershed Management Bureau supplied the results of the query on 1/27/2020. The available data within the Saco Headwaters watershed includes 896 sample stations with data collection dates ranging from 1976 through 2019. Site information includes but is not limited to the site type, latitude and longitude, and the waterbody associated with the site. These 896 sample stations represent culverts, river/stream sites, lakes/ponds, and riverine impoundments; all surface water sites. 156 parameters are included within the dataset, including water temperature, dissolved oxygen, E. coli, total nitrogen, nitrate, specific conductance, total phosphorus, ortho phosphate, total suspended solids, alkalinity, and salinity. Although the EMD includes groundwater quality data at some sites across New Hampshire, the query did not return any such data within the study area.

New Hampshire Hydro Server Mapper

The Hydro Server Mapper is a new platform created by a collaboration between NHDES and the New Hampshire Geological Survey. The mapper provides stream temperature and groundwater monitoring data for state-operated sample stations in New Hampshire. Dozens of stream temperature stations are included and range from small headwater streams to the Saco



New Hampshire Hydro Server Mapper display showing stream temperature station locations in the Bartlett-Conway area.

River, with variable data records that range from a few scattered observations to continuous five- to 15-minute records with thousands of points over periods of years.

Two groundwater monitoring locations (three sensors) within the mapper are found within the Saco Headwaters watershed (well sensors ADW-14 and ADW-15 in Albany and well sensor OXW-38 in Ossipee). The available data is limited to depth to water table. Each dataset, separated by individual well and date range, can be exported as a Microsoft Excel file. The data provided in each dataset includes the variable, the method used, the date and time of the data collection, the numeric value of the data, and the units in which the data was collected.

MEDEP Environmental and Geographic Analysis Database (EGAD)

Maine's EGAD is a publicly available online database administered by MEDEP to provide a wide variety of environmental monitoring data, including a rich record of biological and surface water quality sampling data. As with the NHDES EMD, this long-term state-managed dataset provides excellent coverage of the state's water quality data. FBE requested access (via email to Tracy Krueger) on 1/27/2020 to all surface and groundwater quality data for sample stations located within the Saco Headwaters watershed, organized by the 16 HUC12 IDs completely or partially in Maine. Data were received on 2/6/2020.

The query results can be split into two categories: surface water quality data from the Division of Environmental Assessment; and groundwater and remediation site data collected mostly by MEDEP's Bureau of Remediation and Waste Management. The data from the MEDEP EGAD does not include lake data; see the Gulf of Maine Knowledge Base section below for lake data. Data within the surface water quality database were collected at 25 sites between the years of 1987 and 2018 from rivers, streams, stream/river biomonitoring, and wetlands. Water quality samples from these locations include the analysis for parameters such as chloride, chlorophyll-a, dissolved oxygen, E. coli, nitrate, pH, orthophosphate, temperature, total phosphorus, and total nitrogen in a variety of compounds (in addition to others).

Data within the groundwater and remediation site database were collected between 2004 and 2018 from 103 sites including building sumps, discontinued water supplies, ditches, excavation groundwater, extraction wells, impoundments, lagoons, monitoring wells, piezometers, private water supplies, and springs. Water quality samples collected from these locations include the analysis for 207 parameters including chloride, dissolved oxygen, E. coli, nitrate, pH, several per- and polyfluoroalkyl substances (PFAS), and water depth.

Gulf of Maine Knowledge Base

The Gulf of Maine Knowledge Base is a publicly available online database created and administered by the Gulf of Maine Council on the Marine Environment and the University of Maine Mitchell Center for the Environment. A key lake data source for the Saco Headwaters watershed, the Gulf of Maine Knowledge Base contains MEDEP's monitoring data for Maine lakes numerous lake submitted to MEDEP via the Lake Stewards of Maine. Each record in this dataset includes the name of the lake and the town in which it is located, along with the lake's MIDAS and station number. No longitude and latitude datapoints are provided, so location data is limited to the towns within the watershed area instead of the watershed area itself. The latitude and longitude associated with each MIDAS number can be found in the MIDAS data layer form the Maine Office of GIS. Information for each datapoint includes the date, depth, and the type of sample (grab or composite) collected. Parameters include pH, color, conductivity, alkalinity, chlorophyll-a, and total phosphorus.

SRCC and GMCG Databases

The SRCC database is available online for download in PDF form on the SRCC website. In addition, SRCC staff maintain a Microsoft Excel database that FBE requested access to and received in January 2020. Parameters include dissolved oxygen, pH, conductivity, temperature, and turbidity collected in the field, and total Kjeldahl nitrogen, total phosphorus, orthophosphate, alkalinity, and E. Coli measured in the laboratory by Katahdin Analytical. The length of records varies among sites and parameters from one to 19 years, with many of the core monitoring stations having a detailed record going back decades with multiple observations each year. No late fall or winter observations (November to March) exist.

All data in the GMCG database are also contained within the NHDES EMD, but to ensure completeness, FBE corresponded with Jill Emerson, the Water Quality Coordinator at the GMCG, and received the database directly on 1/28/2020. The database contains three main categories of data, each stored within a separate tab: Total Phosphorus Data, Field Data, and UNH Lab Data. Included in the database are data from 53 sampling stations with observations made during the period from 5/7/2002 to 11/15/2019.

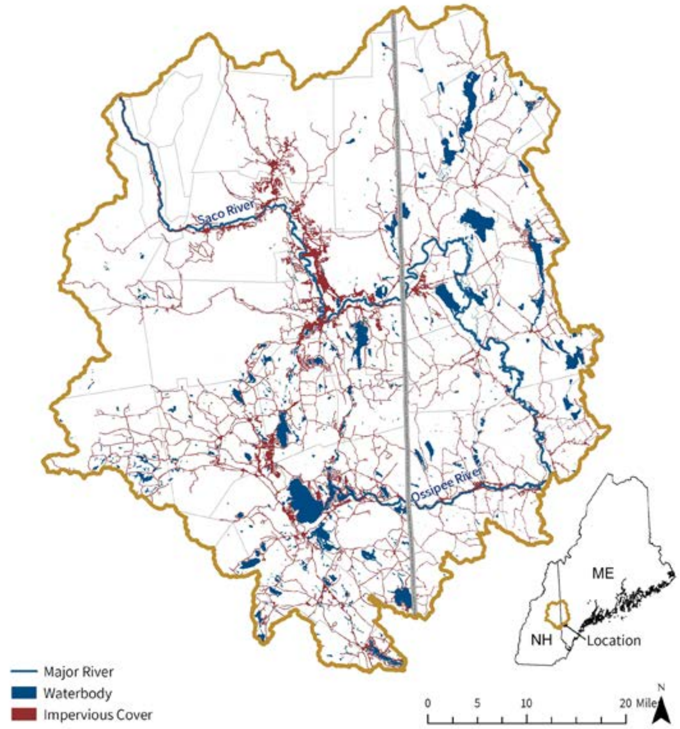
Data Reported in Scientific Literature

Two key USGS scientific reports were published in the 1990s detailing the Saco Headwaters watershed's stratified drift aquifers: *Hydrogeology, water quality, and effects of increased municipal pumpage of the Saco River Valley glacial aquifer; Bartlett, New Hampshire to Fryeburg, Maine* by Tepper et al. (1990) and *Geohydrology and water quality of stratified-drift aquifers in the Saco and Ossipee River basins, east-central New Hampshire* by Moore and Medalie (1995). The 1990 study investigated the effects that increasing withdrawals could have on groundwater levels relative to the size of the contributing area/volume of inputs to the aquifer (Tepper et al. 1990). Data from 1980-1984 are summarized in this report including stream flow, groundwater discharge to the Saco River, average annual water withdrawals from the Saco River, water quality data, computed recharge, and discharge percentages from different sources. Water quality data were included and provided as a raw data appendix from Moore and Medalie (1995). These data include the ID, latitude, longitude, and altitude of each sample station, with water quality parameters including, but not limited to, specific conductivity, pH, water temperature, dissolved oxygen concentration, total nitrogen, total phosphorus, and an assortment of metals. These parameters were collected in 1992 at up to 29 sites.

Spatial Data Sources

FBE created a Saco Headwaters watershed spatial data repository of all spatial data gathered to aid in the analyses of surface and groundwater quality, natural resources, and development related tasks. The use of spatial data is an essential tool in natural resource protection, and greatly informs the interpretation of water quality data, among its many applications. Spatial data compiled by FBE includes data from the NH Statewide Geographic Information System, the Maine Office of GIS, USGS, Maine Geological Survey, MEDEP, and the Web Soil Survey. This section describes the data collected, the data sources, and any data discrepancies.

There are two types of spatial data files: raster and vector data. Raster data are represented along a coordinate plain that has been broken out into quadrilateral pixels. Each pixel is assigned a single category (i.e., forested, water, urban, etc., within a land cover layer), which represents the parameter covering most of the pixel as compared to aerial photography. Raster datasets serve as a beneficial tool when the scale of the area of interest is very small (a large amount of area is shown). Raster datasets at regional scales often contain significant inaccuracies when applied to the local scale. Vector data use points, lines, and polygons to represent the landscape. Vector datasets are more detailed but take much longer to create. Raster layers can be converted into vector layers to provide a more detailed analysis and editing at a larger scale. Metadata accompany each data layer to provide the original source of the data, a more through explanation of the data, and as a reference for any code coefficients within the attribute tables of the data layers.



Impervious cover in the Saco Headwaters watershed. See Appendix 1 for full-size maps.

Political Boundaries

Political boundaries identify municipal, state, and federal jurisdictions. Data layers in the Saco Headwaters watershed spatial data repository include the town boundary vector polygons for both New Hampshire and Maine. Each town polygon also contains an attribute field which identifies its respective county. A simple union of the NH towns creates the NH state area, as does a union of the ME towns for Maine state area.

Transportation Networks

The road network layer for New Hampshire from NH GRANIT covers the full watershed area in New Hampshire, as well as the entire state of New Hampshire and is maintained by the New Hampshire Department of Transportation (NHDOT). As a vector line layer, the NH roads layer includes the name of the street and town in which it is located, the length of the street, the functional system (i.e., local, major collector, etc.), proprietorship of the roads (i.e., federal, town, etc.), and whether the road is paved or unpaved. A railroad data layer exists in NH GRANIT, but these data cannot be represented due to a missing layer component in the download. There is no layer for bridges or stream crossings in NH GRANIT.

The road network layer for Maine was sourced from the Maine Office of GIS. This vector line file covers the full watershed area in Maine, as well as the entire state of Maine. It includes the name of the road, its functional system, the ownership of the road, the town and county in which the road resides, and the length of the road. The Maine Office of GIS also provides a line file data layer of the railroads in Maine, as well as a point file of the bridges in Maine. The Maine bridge layer does not include all stream crossings, nor do all bridges cross streams. See the section on Stream Crossings below for more information.

Impervious Cover

Impervious areas are roadways, parking lots, driveways, and rooftops that inhibit water from infiltrating directly into the ground. The more impervious cover there is in a given area, the less direct recharge to groundwater there is from infiltration, and the more overland surface sheet flow occurs. During large storms in areas with high impervious cover, stormwater runoff can become channelized and create more erosion as it builds speed traveling over land. In addition to risks to water quality, impervious surfaces can also exacerbate flooding and pose significant risks to human safety, buildings, stream crossings and roads, natural geomorphology, and wildlife habitat. A large body of research shows that water quality in streams and lakes starts to decline precipitously when impervious cover in the watershed reaches 15%, as all the above deleterious impacts combine and compound each other. Impervious cover in the Saco Headwaters Watershed is currently at less than 5% when taken as a whole, though in some subwatersheds it is approaching or exceeding 15% (e.g. the Kearsarge Brook watershed.

The New Hampshire impervious cover data layer (a polygon vector file) was sourced from NH GRANIT, and the Maine impervious cover data layer (a raster file) was sourced from the Maine Office of GIS. Both data layers identify areas as either impervious or pervious. However, the New Hampshire impervious cover data layer does not cover the full Saco Headwaters Watershed – only the southernmost part of the watershed area within Carroll County. Impervious cover for New Hampshire cannot be extrapolated from urban land cover categories because this will not account for every impervious area such as driveways and sidewalks. The Maine data layer for impervious cover also poses some challenges in resolution and accuracy because it was created as a raster data layer.

Land Cover

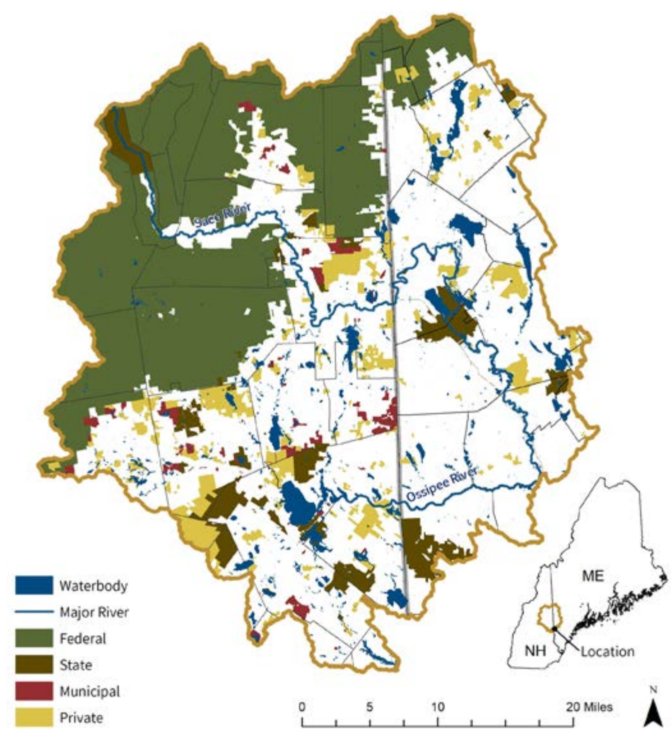
Land cover is the essential element in modeling and estimating pollutant loads contributing to a waterbody via stormwater runoff and groundwater seepage. Characterizing both land cover and impervious cover within a watershed can help to identify potential sources of pollutants that would otherwise go unnoticed in a field survey of the watershed.

Land cover and land use can change dramatically over the scale of decades or even individual years, and these changes are often not reflected in the most recently available land cover data layers. The statewide layers were last updated for New Hampshire in 2001 and for Maine in 2004, so analysis using these layers requires a detailed check by a qualified GIS user. Their accuracy, however, is better than other land use/land cover mapping products created at larger spatial scales. The USGS National Land Cover Database (NLCD) is an important data layer available online. USGS maintains this nationwide layer and regularly updates it, most recently in 2016. For coarser resolution applications, the NLCD has the advantages of more up-to-date data and consistent land cover types across state boundaries. At the scale of the Saco Headwaters watershed, however, the NLCD falls short of the accuracy required for water quality modeling or other related land use analysis applications.

Conserved Lands

Spatial data for land held under conservation protection was found for New Hampshire from NH GRANIT and for Maine from the Maine Office of GIS. The New Hampshire conservation data layer covers the entire study area within the state of New Hampshire, and the Maine conservation data layer covers the entire study area within the state of Maine. Both datasets include public lands owned by federal, state, and local governments and set aside for conservation and protection from development, as well as other forms of protection such as private conservation easements, water supply protection lands, etc. The period of protection – perpetual, limited term, etc. – is also contained within these layers.

In total, conservation land within the Saco Headwaters Watershed accounts for approximately 43% of the watershed area. This total includes federal lands such as the White Mountain National Forest (which comprises over 200,000 acres – nearly 30% - of the watershed), state lands such as Crawford Notch State Park and Maj. Gregory Sanborn (Brownfield Bog) Wildlife Management Area, town conserved lands, preserves and easements owned by land trusts like the Upper Saco Valley Land Trust (more than 12,000 acres), the Greater Lovell Land Trust, and GMCG.

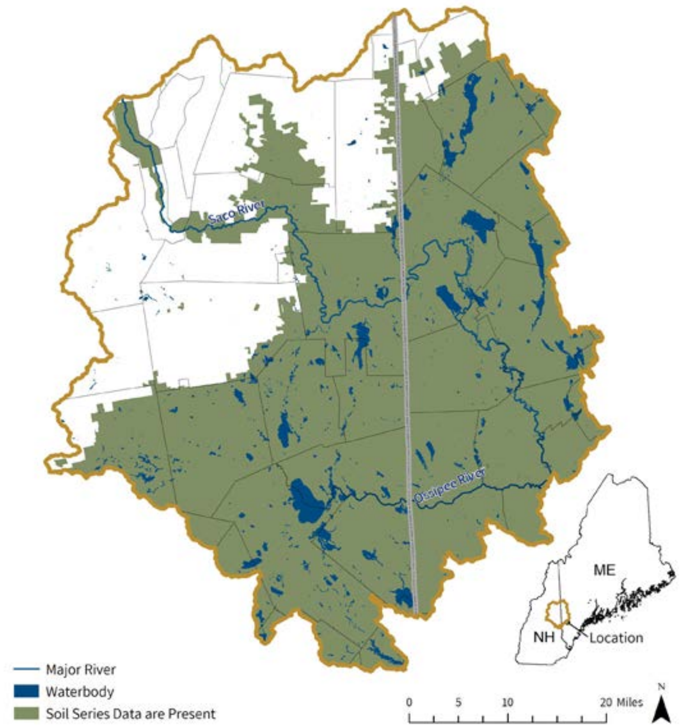


Conserved lands in the Saco Headwaters watershed. See Appendix 1 for full-size maps.

A notable conservation tract is the Leavitt Plantation forest in Parsonsfield, ME, an 8,600-acre forested conservation easement held by the State of Maine.

Topography

Owing to its mountainous headwaters, the Saco Headwaters Watershed encompasses complex topography and dramatic elevation changes from upstream to downstream. The highest point of elevation within the watershed (6,288 feet above sea level) occurs at the summit of Mount Washington. The lowest point of known elevation is 265 feet in Cornish, ME. The available contour layers from NH GRANIT and the Maine Office of GIS do not cover the complete study area. The contour intervals are also different between the two state layers; Maine contours progress at intervals of 10 feet, while New Hampshire contours progress at intervals of 100 feet. Contour layers if needed for the complete study area can be derived from the digital elevation model (DEM) layers provided for each state from the previously listed sources.



Soil series data availability in the Saco Headwaters watershed. See Appendix 1 for full-size maps.

Soils

Spatial data on the soil series present within the Saco Headwaters watershed was gathered from NH GRANIT and from the Web Soil Survey. Created and maintained by the United States Department of Agriculture, the Web Soil Survey is an online platform of soil data for the United States. Data can be downloaded from the platform and loaded into ArcGIS. Data for Oxford, Cumberland, and York counties were downloaded for the land area within Maine. The soil series data provided for New Hampshire and Maine both have attributes for the MUTYPE (the soil series) but do not cover the entire watershed. Soil series data layers have not been created for the White Mountain National Forest because the area has not been mapped for soils, though initial mapping is in progress.

Soil Erosion Potential

Soil erosion potential is dependent on a combination of factors including land contours, climate conditions, soil texture, soil composition, permeability, and soil structure (O'Geen et al. 2006). Data on soil erosion potential can identify areas more vulnerable to soil loss in developed areas. Soils with negligible soil erosion potential are primarily low-lying, clay and organic matter-dominated wetland areas near abutting streams. Soil erosion potential can be derived from the Web Soil Survey and manually edited into the Soil Series data layer; each soil series has been given an erosion potential rating from slight to severe. The created soil erosion potential data layer will only cover the extent of data present for soil serie,s which do not yet cover the entire Saco Headwaters watershed area.

Habitats and Wildlife

New Hampshire Fish and Game ranks habitat based on value to the state, biological region (areas with similar climate, geology, and other factors that influence biology), and supporting landscape. The Biological Region classification within the 2015 NH Wildlife Action Plan is a subdivision of New Hampshire based on ecoregional subsections. The habitat rankings include the Highest Ranked Habitat in New Hampshire, the Highest Ranked Habitat in Biological Region, and Supporting Landscapes. These data layers cover the entire New Hampshire portion of the Saco Headwaters watershed. Categories within the biological region classification include but are not limited to alpine, floodplain forest, grassland, northern hardwood-conifer, open water, rocky ridge, and temperate swamp.

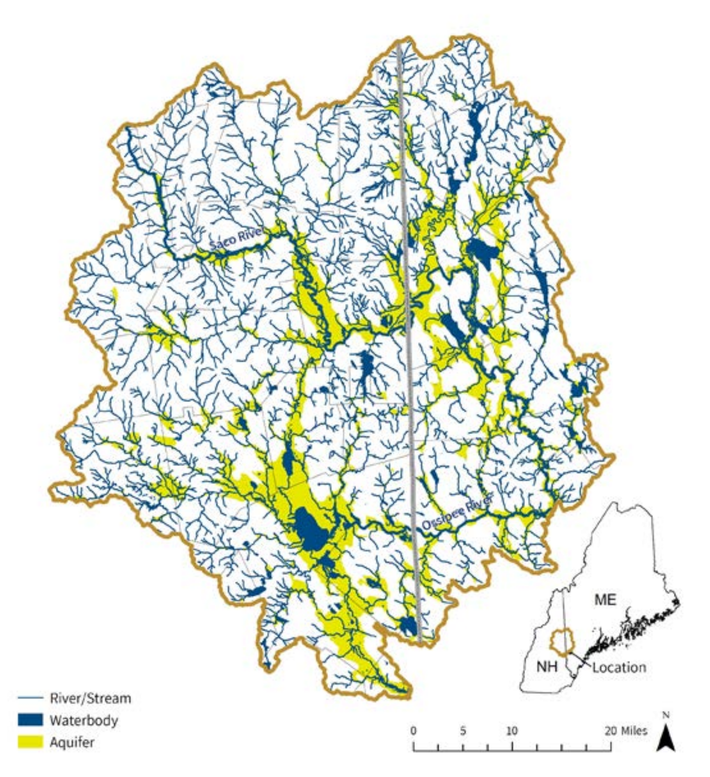
The Maine Department of Inland Fisheries and Wildlife (MDIFW) maintains multiple habitat and wildlife map layers with mapped areas in the Saco Headwaters watershed: Maine Endangered Threatened and Special Concern Wildlife; Deer Wintering Areas; Inland Waterfowl and Wading Bird Habitat; and Maine Significant Vernal Pools. MDIFW also has a Maine Endangered and Threatened Fish layer, but a review by FBE staff showed no mapped habitats for threatened or endangered fish in the watershed. These layers can all be downloaded from the Maine GeoLibrary Data Catalog as statewide shapefiles or viewed interactively at the Maine Inland Fisheries and Wildlife Habitat Data Web Viewer. The wildlife habitat data is generally adequate for informing natural resource protection.

Waterbodies and Rivers

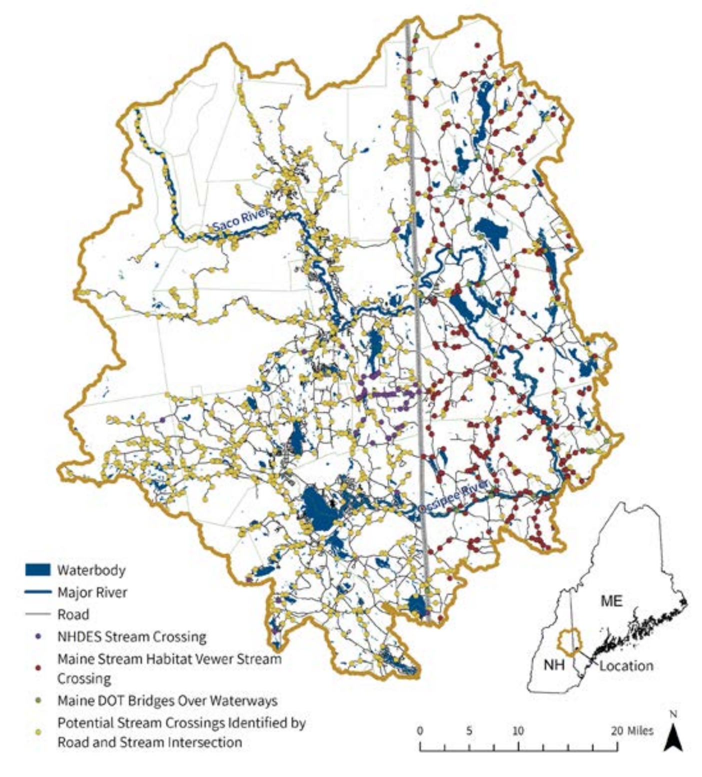
Waterbodies and rivers (flowlines) were gathered for New Hampshire from NH GRANIT and for Maine from the National Hydrography Dataset (NHD). The NH GRANIT sourced their waterbody and flowline layers from the NHD; therefore, the two states have consistent and comparable data layers. The high resolution NHD was developed at a 1:24,000 or 1:12,000 scale for the continental United States. The waterbody layers consist of polygons for lakes, ponds, reservoirs, swamps, and marshes. The flowline layers consist of polylines for artificial paths, canals and ditches, coastlines, connectors, pipelines, streams and rivers, and underground conduits. Spatial data for waterbodies and flowlines cover the full Saco Headwaters watershed.

Floodplains

The National Flood Insurance Program administered by the Federal Emergency Management Agency (FEMA) is the ultimate source for authoritative floodplain map and flood hazard data in the United States. FEMA undertakes or supports flood studies nationwide that contribute to the National Flood Hazard Layer database, an online repository from which the more familiar Flood Insurance Rate Maps are created for communities. These maps typically feature the boundaries of the "100-year flood," an anachronism for the more accurate "1% annual chance flood event" – a flood of a height or severity such that there is a 1% chance of it occurring in any given year, based on the hydrologic records for the area and a computer model of the river corridor and how it responds to large amounts of precipitation. These boundaries enclose what FEMA calls the Special Flood Hazard Area, commonly called the "FEMA floodplain" or the "100-year floodplain."



Water resources in the Saco Headwaters watershed. See Appendix 1 for full-size maps.



Stream crossings in the Saco Headwaters watershed. See Appendix 1 for full-size maps.

FEMA Flood Insurance Rate Maps and Special Flood Hazard Area data are available for download at the Flood Map Service Center, with coverage for most of the Saco Headwaters watershed. The notable exception is the highest headwaters of the Saco River in Hart's Location, NH (see Gap Analysis). FEMA floodplains include a great deal of overlap with stratified drift aquifers in the Saco Headwaters watershed, but they are not completely coterminous. In general, the aquifers cover a greater swath of the valley bottoms by virtue of having been deposited over centuries by meandering glacial meltwater streams, rather than being confined to only the active floodplains along today's river channels.

Groundwater and Aquifers

Most of New Hampshire and Maine are underlain by a thin layer of glacially derived sediments, such as stratified drift, sitting atop granitic bedrock. Stratified drift aquifers and fractured bedrock are thus both important groundwater sources for private wells, public water systems, and commercial extractors such as bottled water companies. In New Hampshire, a rich database exists for aquifers that is available by request. Layers include Aquifers – Aquifer Boundaries, Aquifers – Low Flow Stream Measurements, Aquifers – Saturated Thickness, Aquifers – Seismic Lines, Aquifers – Transmissivity, Aquifers – Water Table, Aquifers – Wells, Borings, and Spring Sites.

The Maine GeoLibrary provides a Maine Aquifers layer that includes mapped boundaries of significant sand and gravel aquifers, roughly equivalent to the aquifer boundary maps provided upon request to NH GRANIT.

Stream Crossings

Stream crossings are points where roads intersect and cross over streams or rivers. These locations often involve culverts or bridges, are areas with a high potential for erosion, and are easily affected by roadway activities (spills and road salt application). Inadequately sized stream crossings can worsen flooding upstream by allowing stormwater to back up and spill over banks, while also increasing the velocity of water passing through and causing downstream erosion.

The locations of stream crossings within the Saco Headwaters watershed were gathered from the NHDES Aquatic Restoration Mapper and from the Maine Stream Habitat Viewer. The NHDES Aquatic Restoration Mapper identifies stream crossings structures that have undergone a detailed assessment for geomorphic compatibility, fish passage, and condition. This data layer was not constructed to identify all stream crossings, but only those that have been assessed. Only a handful of points in this database were located within the area of interest. The Maine Stream Habitat Viewer identifies stream crossings along public roads, trails, and railroads; private roadways were not included. The Maine Department of Transportation (MEDOT) Bridges data layer represents all bridges owned and maintained by MEDOT. These bridges are not exclusively stream crossings but there is an attribute field which can be used to filter out the bridges that do not cross streams/rivers.

FBE is not aware of any data layer that provides a comprehensive inventory of stream crossings. As a preliminary method of estimating the number of stream crossings in the study area, FBE conducted intersect functions in GIS to find every point where a road intersects a stream/river. The intersect used the two road layers listed under Transportation Networks and the NHD Flowline layers for each state. This simple analysis produced a list of all locations in the Saco Headwaters watershed where stream crossings should exist, according to the road and stream datasets. As the NHD Flowline data sometimes omits small and ephemeral drainages, this first order estimate should be considered a rough, low-end estimate. Other organizations are using similar methods to estimate numbers of stream crossings and predict where they will be encountered, and sharing said methods and datasets has already greatly enhanced efforts to plan for and conduct assessments.

Dams

A vector point layer was accessible for both New Hampshire and Maine from NH GRANIT and the Maine Office of GIS, respectively. Published in 2015, the dam point layer for New Hampshire provides the locations of all registered dams within the state. Along with general location and size of dam information, each dam also has associated metadata for the purpose of the dam (hydro, recreation, mill, water supply, fire protection, etc.). Each dam has been classified with a hazard that represents downstream damage that would result from the dam failing, not a measure of the dam's structural condition. Published in 2006, the dam layer from the Maine Office of GIS was created at a 1:24,000 scale and includes the location of each dam, levee, and impoundment in Maine. The dams located in Maine were also classified with their use and a hazard level of the effects a dam failure would have on the downstream environment, along with other data.

Wetlands

Wetlands store and slowly release stormwater, recharge groundwater, and mitigate water pollution by natural processing of some contaminants. Wetland areas were identified from the NH GRANIT and the National Wetland Inventory. The NH GRANIT data layer was constructed from the National Wetland Inventory. Comprised of freshwater emergent wetlands, freshwater forested/shrub wetlands, palustrine unconsolidated bottom/palustrine aquatic beds, lake or reservoir basins, farmland wetlands, and rivers, this layer includes a more detailed scope of wetlands than the swamp and marshes category from the NHD Waterbody data layer, but a less detailed scope of rivers, streams, and lakes from the NHD Waterbody and Flowline layers.

Point Source Pollution Sites

Point source pollution (a.k.a., pipe outfalls or discharge locations) can be traced back to a specific source. Through the Clean Water Act, the USEPA created the NPDES permit process to allow for the discharge of pollutants into the waters of the US up to defined limits. The permit also requires monitoring and reporting agreements to ensure compliance with environmental law and protection of public safety. Locations of all NPDES permits on file in New Hampshire (current through 2014) can be found through the NH GRANIT shapefile "NPDES2014" which represents the facilities registered within the NPDES program as of 2014. These facilities are often wastewater treatment plants, hydroelectric facilities, aquaculture facilities, and facilities with groundwater seepage. No comparable data layer is available from the Maine Office of GIS. The NPDES layers do not represent all point source pollutants within their given areas.

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GAP ANALYSIS

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A gap analysis of water resource monitoring is a systematic evaluation of what required data and scientific information are missing and needed to guide protection, management, and sustainable use of water resources.

A gap analysis of water resource monitoring is a systematic evaluation of what required data and scientific information are missing and needed to guide protection, management, and sustainable use of water resources. Scientific information is the review, analysis, synthesis, and communication of water resource data and its resulting insights. Our review of existing monitoring data, programs, and repositories in the previous section demonstrates that a great deal of data and scientific information are readily available and that commendable effort and resources are being expended by a handful of institutions and agencies to adequately monitor surface and groundwater resources in the Saco Headwaters watershed. Crucial work is done daily by these organizations, and this gap analysis is in no way meant to highlight shortcomings in the work currently being done. Instead, the gap analysis identifies many areas in which future work can build off of the insights that have been gained from what has been accomplished to date.

The organizing principle of this gap analysis is that current and anticipated threats to water quality constitute the highest priority subjects for collecting, analyzing, and reporting monitoring data. A threat is defined as a specific pathway by which water quality may be degraded for drinking or non-drinking use, recreation, aquatic ecosystem integrity, and other ecosystem services – or, in the parlance of the Clean Water Act, USEPA, and the state environmental agencies, designated uses. Structuring the gap analysis around threats that we know are real and credible allows us to focus on what data are needed for effective action – a key component of resilience.

Key Gaps for Water Resource Threats

Increased Frequency of Severe Storms

Severe storms have always been a feature of life in the Saco Headwaters watershed. An infamous example is the Crawford Notch landslide in August of 1826 that killed the Willey family and washed out the turnpike bridges was precipitated by an immense storm following a severe drought. Hurricane Irene in 2011 and the storm of October 29-30, 2017 caused widespread flooding in New Hampshire and Maine. Climate researchers overwhelmingly agree that the northeastern US is experiencing more frequent severe storms resulting from anthropogenic warming and climate change and that the trend toward increasing frequency will continue (National Climate Assessment 2018). A higher frequency of severe storms threatens water quality in multiple, complex, and interacting ways, but the core threat is severe flooding along river and stream corridors, which can mobilize contaminants from floodplains when infrastructure is damaged and severe erosion and sedimentation occur.

Proper floodplain management for water resource protection relies on accurate flood hazard mapping, which in turn relies on the modeling of a watershed's response to large precipitation events. In the Saco Headwaters watershed, accurate precipitation and streamflow records go back decades and are sufficient to construct flood hazard maps. As noted in Section 1.1, flood hazard maps for the highest headwaters of the Saco River in Hart's Location are a key data gap. The Town of Hart's Location, supported by the Saco Headwaters Alliance, secured funding from the NHDES Clean Water State Revolving Fund to fill this data gap. Work will commence in summer 2020 to produce flood hazard maps from the US-302 bridge north of the Dry River confluence downstream to the terminus of the existing maps near the Bartlett town line. Future floodplain mapping efforts should take into account climate modeling scenarios predicting a continued trend toward greater precipitation events. The rapid rate of change in flooding frequency renders the term "100-year floodplain" obsolete as such floods occur much more frequently – an example of how the continued use of anachronistic language to describe environmental threats can be a barrier to awareness and an obstacle to taking appropriate preventative action.

Buildings and other structures located in floodplains, including grandfathered or otherwise nonconforming structures, constitute a threat for water quality in the form of untreated wastewater contained in septic systems, home heating oil, and any other substances with the potential to contaminate water if floodwaters overwhelm the vicinity. Data on such buildings and the potential hazards they pose is not publicly available, though many towns have adequate GIS data on buildings to conduct this type of analysis.

The risks posed by stream crossings constitute a key data gap for water resource protection. There is no comprehensive database of stream crossings in New Hampshire or Maine, though as discussed in Section 2.1 above, different institutions have created mapping tools to aid with estimation of the uncounted, unassessed crossings. At least 1,000 unassessed crossings are estimated to be in the New Hampshire portion of the watershed, with a reasonable estimate of 500 for the Maine portion.

Lastly, in this report we have only considered data on the effects of increased flooding from severe storms on water resources. We have not reviewed the data on the economic and social impacts of increased flooding, but a comprehensive analysis would include damages to property, transportation networks, and infrastructure; repair and recovery costs; lost productivity; and threats to safety. All these dimensions of flooding impact point to the fact that the environmental, economic, and social benefits of building flood resilience are inextricably linked.

Erosion and Sedimentation

Altered hydrology or disturbance in buffer areas can also increase the threat of polluted runoff through increased erosion, ultimately carrying sediment and nutrients such as phosphorus into surface waters. Land clearing, new development and roads, logging, and soil disturbance on uplands can cause greater runoff and sedimentation. In addition, extensive armoring of a stream channel and manipulation of floodplains and riparian areas can cause channel alteration, resulting in artificially high flows that cause severe erosion to stream banks and damage important stream habitats. Stream crossings using inappropriately sized or installed culverts are points of flow alteration that often cause erosion upstream and downstream. Failure of stream crossings is also a significant risk with the attendant mobilization of fill material and the potential failure of adjacent banks.

Increased Temperature of Surface Waters

Climate change-induced heating of surface waters threatens aquatic life across the northeastern US, one of the fastest warming regions in the world (National Climate Assessment 2018). The warming trend in average air temperatures being experienced regionally and globally affects surface water temperatures as well. In addition, impervious cover can also cause thermal pollution in surface waters, as impervious surfaces heat up quickly when exposed to direct sunlight and transfer this heat readily to runoff during storm events, causing unnaturally warm water to enter the waterway. This effect, termed thermal pollution, can negatively affect native aquatic life such as coldwater fish species that depend on an optimal range of water temperatures for reproductive function and juvenile fish growth (e.g., native brook trout).

Temperature records exist at a wide variety of locations in New Hampshire and Maine. As noted in Section 1.1, the New Hampshire Hydro Server Mapper provides online access to data locations in New Hampshire. There is no comparable Maine database, but several Maine locations within the watershed are contained within the SHEDS map viewer and database sponsored by NOAA. A selection of Saco River Corridor Commission temperature data is housed in the SHEDS database. A review of the available data finds that the datasets are of widely varying completeness and length of record and no "gold standard" exists. A key data gap is to have paired temperature records at streamflow stations, as the relationship between temperature and flow is determined by a range of hydrologic factors.

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Nutrient Enrichment

Nutrient enrichment in surface waters can cause negative water quality impacts such as low dissolved oxygen concentrations, excessive filamentous plant, algae, or cyanobacteria growth, and possibly release of cyanotoxins. In freshwater systems, phosphorus is most often the nutrient of highest concern, because it is the most common limiting nutrient for algae and plant growth. Thus, the amount of algae production in a body of water is set by the available supply of phosphorus. Whether attached to soil particles, animal waste, or fertilizer, phosphorus is washed off the landscape when it rains or snow melts into waterbodies. Increased algae and plant growth decreases water clarity during the growing season. Dying algae and plants provide their biomass as fuel to decomposer organisms, which consume oxygen as they break down these materials.

Depletion of dissolved oxygen can harm or kill benthic organisms (aquatic life that dwells in lake bottom sediment or riverbeds). In lakes and ponds, low oxygen is also harmful to coldwater fish species because the cooler bottom waters they require during summer are the depths most likely to experience dissolved oxygen depletion. Low oxygen can also cause the release of phosphorus back into the water column, creating a positive feedback loop and leading to eutrophication.

Most nutrient samples are collected within the second and third quarters of the year (April-June and July-September). For parts of the first and fourth quarters, some surface waters may freeze over and inhibit sampling efforts. Within the USGS data collected for the Saco Headwaters watershed, 67% of groundwater samples and 54% of surface water samples were collected from April through September. Only 2% of all groundwater data from this region were collected from January through March. Biological and chemical processes that occur over winter strongly influence the productivity of lakes in summer. To more accurately understand the groundwater and water quality dynamics of the region throughout the course of a year, more groundwater and surface water samples should be collected during the

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first and fourth quarters in addition to the second and third quarters.

Chloride and Road Salt

Chloride is a nontoxic ion present in all waters in low concentrations, but human activity can cause increases in chloride concentrations that are dangerous to aquatic life and to humans in drinking water. Chloride enters surface waters through stormwater runoff from road and parking lot salting (or from salt storage or snow dumps) and can also infiltrate and contaminate groundwater. Chloride is highly soluble in water and very mobile, and once chloride enters the groundwater system, it remains dissolved in the water and is virtually impossible to remove. Chloride cannot be filtered, making prevention key to reducing chloride pollution. The amount of chloride found in surface waters directly relates to the population density and the proportion of impervious surfaces in the watershed.

Road salt, the most important source of chloride in developed areas in northern climates, is a persistent and worsening problem in many areas of the US. Some researchers refer to it as the acid rain of our time. For the Saco Headwaters watershed, a long-term study of trends in road salt contamination has not yet been done. A model that aids understanding of how municipalities, businesses, highway departments, and the environment interact to create the long-term increasing trend in salt contamination, and the effects of salt on the ecosystem, is a key data gap in the Saco Headwaters watershed.

Changes in the Timing and Magnitude of Streamflow

A corollary to frequent severe storms is that these large events make up an increasing share of the annual precipitation budget. At the same time, winters are shortening and snowpack is decreasing as melting occurs sooner and more winter precipitation falls as rain. The overall effect is an earlier spring runoff season with a lower peak flow and lower flows during the summer, despite a higher overall average streamflow (National Climate Assessment 2018).

Streamflow timing and magnitude are adequately measured in the Saco River and its largest tributary, the Ossipee River. The data quality and accessibility are excellent. As noted above in Section 1.1, Saco River streamflow is measured in real time by USGS at three locations. The Cornish station is particularly notable for the length of its record – 1916 to the present, for over a century of flow data. (A fourth USGS gauging station is located at the Saco Estuary in Biddeford and includes tidal influence.) Also noted above, the NHDES Dam Bureau provides Ossipee River streamflow data in real time at a gauging station located between the Ossipee Dam and the NH-153 bridge, and streamflow for the Bearcamp River (a major tributary to Ossipee Lake) at a gauging station at NH-25.

Other than the Saco and Ossipee Rivers, however, there is a paucity of streamflow data for major tributaries. As noted in Section 1.1, KLWA collects streamflow data at the Kezar Lake Outlet, which drains the entire Kezar Lake watershed, emptying into the Saco River Old Course. From upstream to downstream, the unmeasured tributaries are: Dry River, Sawyer River, Rocky Branch, Ellis River, East Branch Saco River, Swift River, Weeks Brook, Cold River, Little Saco River, Shepards River, and Tenmile River. These tributaries are at least several miles long and drain hundreds to thousands of acres. Several are important drinking water supplies (e.g., the Ellis River). Many of their headwater streams support coldwater fisheries. Real time streamflow records at a selection of these tributaries would provide a wealth of insight into watershed responses to precipitation and drought and would support flood and in-stream flow studies.

Micropollutants (Pharmaceuticals, Personal Care Products, and Endocrine Disruptors)

Micropollutants are a class of environmental contaminants that derive from everyday consumer products and medicines and reach soils, aquifers, surface waters, and eventually the tissues of organisms that come in contact. Micropollutants include prescription and over-the-counter drugs, veterinary drugs, nutritional supplements, fragrances, cosmetics, and sunscreen agents. Many are difficult to measure and detect, but as analytical methods improve, they are found to be more widespread than previously thought. The compounds in many products can enter water via wastewater in the form of metabolic excretion from people or pets, or through disposal of unused or expired drugs from households, hospitals, pharmacies, or industrial manufacturing systems. Micropollutant contamination of groundwater and surface water is often associated with septic wastewater, but municipal drinking and wastewater treatment facilities often have little to no ability to remove micropollutants. In addition, washing or bathing in open waters, aquaculture systems, sewer system or septic system leaks, or storm event overflow can directly release pharmaceutical and personal care product compounds into surface and groundwaters. The long-term effect of low doses of micropollutant compounds on humans is still relatively unknown.

Micropollutants comprise a major gap not only in water quality monitoring in the Saco Headwaters watershed but in drinking water and wastewater treatment infrastructure and technology. USEPA has not moved to regulate any compounds on the list of micropollutants despite the fact that they are known contaminants in wastewater (Phillips et al. 2014) and are known to cause endocrine disruption in fishes and other aquatic biota at trace levels in the environment (Iwanowicz et al. 2016). Neither Maine nor New Hampshire has taken up the responsibility for these contaminants that USEPA has delined. Pharmaceutical drugs intended for consumer use are tested by the Food and Drug Administration in specified therapeutic doses and in isolation, but the real toxicology of these compounds in the environment – at trace doses over long exposure periods and in various combinations – lags far behind our clear scientific understanding that they are ubiquitous in our waters.

Groundwater Depletion

Groundwater supplies are depleted when extraction outpaces recharge. In particular, wells that tap stratified drift aquifers can be extremely productive of groundwater that is easy to withdraw from the large pore spaces between sand and gravel materials. Unfortunately, the easy groundwater flow and shallow depth of stratified drift aquifers also make them more vulnerable to contamination than deeper aquifers. Stratified drift aquifers are also more connected to surface water than is commonly understood, meaning that excessive extraction in a well can decrease the water available to nearby streams, ponds, wetlands, etc.

State laws govern large groundwater extraction. In New Hampshire, any well that withdraws 57,600 gallons or more over a 24-hour period is regulated by the state's Groundwater Protection Act, requiring a testing process to show that no adverse impacts to other water resources will occur before a permit can be issued. Similarly, in Maine, any well that withdraws 216,000 or more gallons during any week or at least 144,000 gallons on any day is regulated by the Maine Natural Resources Protection Act and must be permitted by MEDEP (though the threshold drops to 75,000 gallons during any week or at least 50,000 gallons on any day if the well is located within 500 feet of other water supply wells, wetlands, streams, lakes, vernal pools). Both states use these large-withdrawal wells to monitor groundwater levels during times of drought, but the data are not publicly available. The Maine Geological Survey maintains a geographic water well database of well drilling records including the well's depth, yield, overburden thickness (the depth to bedrock), and drill date. The NHDES OneStop portal provides access to a similar database by user query. In general, the publicly available data on groundwater hydrology and quality is lacking for detailed analysis, particularly the stratified drift aquifers. This lack of data and ongoing monitoring increases the vulnerability of these crucially important resources.

In recent decades, commercial groundwater extraction has been a topic of public controversy in Maine. The ability of local aquifers to sustain the current extraction rates remains in dispute, especially given the lack of clear scientific information. We consider this important question outside the scope of this study at this time given how politically fraught the question has become.

Lack of Water Resource Protection Regulations and Planning

Much of the authority for water protection is delegated to the local government in New Hampshire and Maine, which are both "home rule" states that give municipalities the right to govern land use by residents and businesses as they see fit. The power of state and federal agencies to protect water is limited to enforcement of state and federal law and environmental regulations, and the limitations on NHDES's or MEDEP's authority are not widely understood by the public. This situation makes municipalities the most important actors for protecting water in the region.

Despite the key role of municipalities, and the importance of the Saco Headwaters watershed's water resources, local water protection is lacking. Several factors may contribute to this situation. First, municipal leaders are under pressure to focus on immediate priorities rather than on proactive, long-term resource protection. Second, local leaders may not have training in water resource science or management and must rely on outside technical support, which may be lacking. Third, some municipalities cede water protection management responsibility to water precincts despite the precincts' lack zoning authority or other regulatory controls. Fourth, the perspective that the watershed is an interconnected ecosystem and that floods, droughts, and pollution know no municipal boundaries is not widely held. Lastly, municipal leaders are influenced by a longstanding New England culture of the "power and authority" of the individual municipality. The body of local and state law that has grown over centuries continuously reinforces the power and authority of the local municipality over its own resources, including water. An unintended consequence is the absence of a culture of collaboration among municipalities to address shared problems such as protection of water from floods, droughts, and pollution.

One powerful tool for water protection is municipal ordinances that create protective zoning for specific resources like groundwater, shorelines, and floodplains, restricting land use to only what will pose low or no risk. In addition, regulations that govern routine development are crucial to water resource protection. As one example, site plan regulations can give planning boards the authority to require strict pre- and post-construction erosion control and stormwater management practices. A comprehensive review of zoning regulations, site plan, and subdivision regulations remains a key data gap.

Two studies have analyzed local ordinances for regions of the New Hampshire portion of the watershed. First, the Lakes Region Planning Commission and GMCG worked with local leaders from towns in the Ossipee watershed – Effingham, Freedom, Madison, Ossipee, Sandwich, and Tamworth – to draft and advocate for groundwater protection ordinances. Five of the six towns successfully implemented groundwater protection ordinances establishing protection districts. In 2017, USVLT and FB Environmental conducted an ordinance review with respect to groundwater protection in Albany, Bartlett, Chatham, Conway, Eaton, Hart's Location, Jackson, and Madison, New Hampshire. Madison had the only ordinance that extended protection to the stratified drift aquifer. Since that effort, Hart's Location has enacted a groundwater protection ordinance that closely follows the NHDES Model Groundwater Protection Ordinance, and leaders in Albany and Jackson are organizing similar initiatives.

A key planning data need follows from enhanced data on local ordinances. A buildout analysis takes the existing geography of tax parcels, zoning ordinances, and population growth rates and extrapolates into the future to determine what a geographic area will look like in the hypothetical scenario that all buildable areas have been developed, termed "full build-out." It is a powerful planning tool that takes current conditions and extends them to their most extreme conclusion, allowing for an examination of the ramifications of business as usual for natural resource protection and overall livability in a community. FBE has conducted two buildout analyses for towns in the watershed: Conway and Eaton NH in 2013 and Lovell, ME in 2016. Having buildout projections for towns across the watershed is a key data gap.

Potential Contamination Sources

Surface waters and groundwater can be contaminated through leaks and spills at sites that store or handle reg-

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ulated contaminants, such as crude oil, petroleum products (diesel, gasoline), liquefied natural gas, propane, fertilizers, and pesticides, or other hazardous substances that pose a drinking water risk, such as road salt and wastewater. Leaks and spills can occur during the storage or transfer of these chemicals, such as at farms, industrial and manufacturing sites, vehicle maintenance operations, shipping areas, and along transportation corridors. Stored chemicals can fail due to corrosion or deterioration, lack of maintenance, construction flaws, overfilling, or lack of containment for leaks, and then flow into waterways and contaminate drinking water and groundwater. The siting of these facilities is crucial to ensuring that hazardous substances do not contaminate drinking water supplies in the event of spills or leaks.

State agencies, and to a lesser extent, local governments, are responsible for the administration of regulations that control how these contaminants are handled, stored, and disposed of, and for ensuring that remediation efforts follow suit in the event of a spill or contamination event. In New Hampshire, the NHDES Drinking Water Source Protection Program keeps a database of potential contamination sources, defined by statute as sites that represent a potential threat to drinking water supplies because they may use, handle, or store hazardous substances (data accessible through the EMD). In Maine, the MEDEP Waste Management Bureau keeps a database of potential and actual sources of contamination (data accessible through EGAD). These databases are updated periodically to reflect changes in the status of potential contamination sources. Sites that lie within designated source water protection areas are required to enroll in inspection programs carried out by municipal staff, and land uses are tightly controlled in these areas. The Saco River Drinking Water Resiliency Project produced a helpful visualization of EGAD potential and actual contamination sources to the Saco based on proximity, as well as road crossings.

Taking a broader view of source water protection, we acknowledge the physical reality of a hydrologically connected aquifer in which an impact in one location could have a far-reaching effect on municipal and private wells, in addition to the connected surface waters. In this light, we argue that municipalities should consider the entirety of these aquifers to be present and future source waters, and to take action to protect them. In its Guide to Groundwater Reclassification, NHDES lays out the road map to local groundwater protection, including land conservation, prohibition of risky activities in sensitive resource areas (such as above stratified drift aquifers), and management of PCSs to ensure compliance with best management practices (e.g. inspection or self-monitoring programs). Whatever the mix of protective actions a municipality ultimately chooses, the PCS data that exists now is sufficient to inform these decisions (though both the Maine and the New Hampshire databases should be updated as soon as possible).

Legacy Contaminants at Industrial Sites

Nineteenth and twentieth century heavy industry largely occurred before the advent of modern environmental laws and regulations and frequently left behind a legacy of contamination that varied with the industry in question. The Saco Headwaters watershed does not have an extensive history of heavy industry, with the nearby paper industry largely focused on the Androscoggin Valley. The Kearsarge Metallurgical Corporation manufactured stainless steel castings from 1964 to 1982 on a nine-acre property on the north shore of Pequawket Pond in Conway, NH. The facility dumped waste casting sands, wax, and solvents in a wooded wetland east of the facility during its years of operation, contaminating the groundwater with volatile organic carbons. The site was designated as a Federal CERCLA (Superfund) site and cleanup by the USEPA and NHDES began in 1990. In 1992, the surficial source materials were removed, and from 1992-2003, the groundwater contamination was addressed through the pump and treat method. Monitoring has been ongoing in the decades since. In 2003, there was still significant contamination in the soils and groundwater, leading to soil removal and continued groundwater pumping and treating. In 2015, due to continued high contaminant concentrations, a soil mixing and treatment remedy was applied to solidify and stabilize soils in order to prevent leaching of both inorganic and organic contaminants.

As a Superfund site, the Kearsarge Metallurgical Corporation property has received attention and resources far beyond what most remediation sites would be allotted. Superfund designation is reserved for exceptionally contaminated sites, which are usually only detected by environmental monitoring once a problem is suspected. As such, these sites are among the best examples for the utility and successful employment of monitoring. The monitoring and remediation efforts that have been conducted there are designed to assess and mitigate any ongoing risk from the movement of contaminated groundwater.

Pathogenic Microorganisms

Bacteria, viruses, and protozoa in water can be pathogenic and threaten human health. These microorganisms can enter surface waters or groundwater through stormwater runoff from animal waste or fertilizer, malfunctioning or improperly maintained septic systems, or presence of infected wildlife such as waterfowl or beavers. The main pathogenic microorganisms of concern include salmonella, campylobacter, rotavirus, giardia, norovirus, and hepatitis. The fecal indicator bacteria E. coli are used to assess whether fecal contamination is present in groundwater and freshwater. Enterococci are used for the same purpose in marine and brackish waters. Fecal indicator bacteria data are generally adequate to protect human health via beach advisories and closures, and also generally adequate to inform nonpoint source management decisions such as prioritizing sites for restoration and/or BMP installation.

Cyanobacteria have become an emerging microorganism of concern for contact recreation in lakes and ponds, as well as for drinking water. Nutrient enrichment is understood to be the single most important risk factor for cyanobacteria blooms; though the impact of warming temperatures and road salt on lake food webs may also encourage blooms. This subject is under intense research scrutiny, but in general the approach to preventing cyanobacteria blooms is the same as controlling other nonpoint source pollution problems: prevent excess nutrients by limiting nutrient inputs from fertilizers and septic systems, controlling erosion, and infiltrating stormwater. MEDEP provides an online map of harmful algal bloom risk in Maine lakes, according to which Kezar Pond and Pleasant Pond in Fryeburg are at moderate risk of occasional blooms (no other Maine waterbodies are identified as at any risk). NHDES lists advisories for cyanobacteria in New Hampshire lakes on its cyanobacteria alert page.

Emerging Contaminants

A contaminant of emerging concern is an identified chemical or substance with no regulatory standards set by the USEPA but that could potentially cause harm to aquatic life or human beings at environmentally relevant concentrations. Emerging contaminants are not necessarily newly invented or manufactured chemicals or substances, with many in commerce since the mid-twentieth century. The reason they are seen as "emerging" is usually due to improved analytical chemistry technology that allows better detection of instances of contamination. Emerging contaminants include chemicals and substances such as persistent organic pollutants (POPs, polybrominated diphenyl ethers used in flame retardants, furniture foam, plastics, etc.), pharmaceuticals and personal care products (PPCPs), veterinary medicines, perfluorochemicals (PFCS), endocrine disrupting chemicals (EDCs), and nanomaterials (carbon nanotubes or nanos-scale titanium dioxide). Two categories of emerging contaminants, micropollutants and PFAS, are discussed separately because we consider them the highest priority constituents on the list.

The Maine Surface Water Ambient Toxics (SWAT) monitoring program was started in 1993 by MEDEP. The program monitors for the nature, scope, and severity of toxic contamination in surface waters and fisheries. Monitoring for indicators of toxic contamination includes biological tissue and sediment testing and biomonitoring of the health of individual organisms. The collected data are used to assess risks to human and ecological health from contaminants. There are no monitoring stations in the Saco Headwaters watershed currently.

Per- and Polyfluoroalkyl Substances (PFAS)

As a class of compounds dubbed "forever chemicals" for their extreme durability in products and the environment, PFAS compounds are highly persistent and mobile organic chemicals that are manufactured for heat, water, oil, or stain resistance and have been applied to a wide variety of consumer, industrial, and commercial products (e.g., Class B firefighting foam, Teflon, Gore-Tex, stain resistant products, food wrappers, etc.). They can be emitted to the air, soils, aquifers, and surface waters near manufacturing sites, but they can also reach the environment through wastewater. People exposed to drinking water contaminated with PFAS have higher rates of a wide range of poor health outcomes, from kidney and liver disease to immune, reproductive, and developmental problems, and high cholesterol. The toxicology of PFAS exposure is a quickly developing science, but it is widely recognized that even what were previously thought of as safe levels of contamination in drinking water can pose a significant health risk. Some families of PFAS compounds strongly bioaccumulate in fatty tissues of people, pets, wildlife, and fish, exacerbating the toxicity over long periods of exposure, even at low doses.

New Hampshire has set strict drinking water limits on a subset of PFAS chemicals. These new regulations will impact public water supplies, landfills, and wastewater treatment plants across the state. New Hampshire will be enforcing strict limits for PFAS contamination in drinking water and currenlty requires local water systems, landfills, and wastewater treatment plants to regularly test and treat for key PFAS chemicals of concern, specifically PFOA, PFOS, PFHxS, and PFNA, since October 1, 2019. The limits for PFOA, PFOS, PFHxS, and PFNA are 12, 15, 18, and 11 ng/L, respectively.

Though PFAS chemicals have been manufactured widely since the 1940s, the threat they pose to drinking water has only been recognized in recent decades. Due to this emerging understanding, and to the highly specified sampling and analytical methods required, there is very little historical data available for PFAS in New England. The Saint-Gobain plant's contamination of soil and water in Merrimack, NH and surrounding towns serves as a powerful lesson learned about the human, environmental, and economic costs of PFAS pollution. Along with many states, Maine and New Hampshire have been rapidly accelerating testing of public drinking water and wastewater biosolids at plants statewide. Outside of water and wastewater utilities, only two water samples with data on PFAS compound concentrations were located by FBE within the Saco Headwaters watershed, found in the Maine EGAD database.

In New Hampshire, the NHDES Drinking Water and Groundwater Trust Fund has taken on the data gap of PFAS in private well water with its Statewide Private Well Sampling Initiative. 500 randomly selected private wells across the state were voluntarily enrolled in the program, which tested for 22 PFAS compounds (among a number of other drinking water contaminants). In an innovative approach, this well testing program was paired with the NH Department of Health and Human Services in a public health study looking for the presence of toxic contaminants in the blood and urine samples volunteer participants, which can then be statistically related to the presence of drinking water contaminants in their water. MEDEP has undergone similar, though less extensive, selective testing of private drinking water wells, closed landfill monitoring wells, and other sites, though these data are not currently available in the EGAD repository.

Pesticide Application

Pesticides, along with their residues and degradation byproducts, can contaminate surface waters and groundwater following agricultural or residential application to crops, lawns, and gardens. The health effects vary based on the pesticide but are as widely varying as nervous system effects, hormone and endocrine system impacts, and carcinogenic effects. The contamination or leaching of pesticides depends on the quantity applied, the solubility of the compound in the pesticide, soil properties, site conditions, and management practices. Pesticides that degrade quickly or are tightly bound to soil particles are more likely to stay in upper soil layers and less likely to pose a threat to groundwater. Pesticides with higher solubility (i.e., dissolve more easily in water) have a higher risk of leaching into groundwater or travelling to surface waters through stormwater runoff. Groundwater contaminated by pesticides is challenging to treat due to the cold temperatures and low microbial activity in groundwater, causing pesticides to degrade more slowly than in soils at the surface. Pesticide application, specifically neonicotinoids, which are a type of insecticide pesticide used both residentially and agriculturally, can also negatively affect pollinators. USEPA has worked to protect pollinators from pesticide exposure by encouraging states to develop pollinator protection plans and best management practices, and implement measures such as restricting neonicotinoid use on blooming crops. Both Maine and New Hampshire have pesticide application guidelines and pollinator protection programs.

The USEPA has established ambient water quality criteria, aquatic life benchmarks, and ecological risk assessments for registered pesticides. Both Maine and New Hampshire have state pesticide control boards that handle the regulation of pesticides and the registration of pesticide applicators. The Maine Board of Pesticide Control conducts periodic groundwater quality sampling campaigns and issues reports on observed levels of contamination, but the reports specify groundwater sampling locations at the county level only. New Hampshire does not have a pesticide monitoring program for testing water.

Table 1. List of causes, data gap analysis results, and action item numbers for each identified threat in the Saco Headwaters watershed. See Action Plan for action descriptions.

THREAT	CAUSES	GAP ANALYSIS RESULT	ADDRESSED BY ACTION #
Increased Frequency of Severe Storms	Climate change	Adequate data coverage for flood magnitude; floodplain mapping currently underway; stream crossing data needed	1, 2
Erosion and Sedimentation	Flooding, gravel roads, stream crossings, disturbed areas, natural causes	Inadequate data coverage; stream crossing and watershed survey needed	1, 2, 3
Increased Temperature of Surface Waters	Climate change, impervious surfaces	Inadequate data coverage; more in-situ sensing needed	3, 4
Nutrient enrichment	Nonpoint source pollution (wastewater, agriculture), atmospheric deposition	Inadequate data coverage; more sampling stations, winter sampling, and parameters needed	3, 4
Chloride and Road Salt	Winter road deicing, wastewater	Inadequate data coverage; more sampling stations, winter sampling, and parameters needed	3, 4, 9
Changes in the Timing and Magnitude of Streamflow	Climate change	Inadequate data coverage; more stream gaging needed in tributaries and headwaters	5, 8
Micropollutants	Wastewater, direct contact recreation (swimming)	Inadequate data coverage; initial study needed	6
Groundwater depletion	Excessive groundwater extraction, inhibition of recharge	Inadequate modeling data for future scenarios; regional groundwater model needed	7
Lack of water resource protection regulations and planning	Lack of funding, lack of reliable resource data, economic concerns, aversion to regulations by members of public	Inadequate municipal ordinance data; inadequate planning data	10, 11, 12, 13
Potential Contamination Sources	Leaks, spills, and improper waste disposal or storage	Adequate data coverage in New Hampshire (recently updated); unknown in Maine	14
Legacy Contaminants at Industrial Sites	Leaks, spills, and improper waste disposal at legacy industrial sites (e.g. Superfund sites)	Adequate data coverage at Kearsarge Metallurgical Corp. site	14
Pathogenic Microorganisms	Nonpoint source pollution	Adequate data coverage for fecal indicator bacteria	14

THREAT *(continued)*	**CAUSES**	**GAP ANALYSIS RESULT**	**ADDRESSED BY ACTION #**
Emerging Contaminants	Wastewater, direct contact recreation (swimming), consumer products, broadcast application of septage and biosolids (composted sludge)	Data adequacy unknown	14
Per- and Polyfluoroalkyl Substances (PFAS)	Wastewater, broadcast application of septage and biosolids (composted sludge)	Inadequate data coverage; large-scale groundwater sampling effort currently underway in New Hampshire	14
Pesticide Application	Lawn and agricultural broadcast over-application	Data adequacy unknown	14

ACTION PLAN

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A strategic action plan provides a list of recommendations that will help to fill in key gaps and blaze a trail toward better informed water resource management in the region.

A strategic action plan for water resource monitoring must lay out a clear road map for strengthening the monitoring system. Actions need to be practical, geared toward those gaps already identified, able to address those yet to be discovered, and detailed enough to answer what, how, when, where, by whom, and how much it will cost. This strategic action plan envisions a robust threat detection system for the Saco Headwaters watershed, with a sustainable social and institutional foundation that can provide skills, resources, and funding that are secure over years and decades. The actions presented below address known threats and what we need to know to respond effectively, but the action plan as a whole also strengthens a multifaceted monitoring program that can detect new threats as they arise. Building resilience demands attention to known unknowns and to unknown unknowns. The larger purpose of this work is to build a toolbox of watershed-wide diagnostic tools that are employed to guide interventions for threat prevention and avoidance and rapid remediation across the entire, interconnected watershed ecosystem; that are rigorously scientific and data-based; and that employ continuously improving 21st century technology.

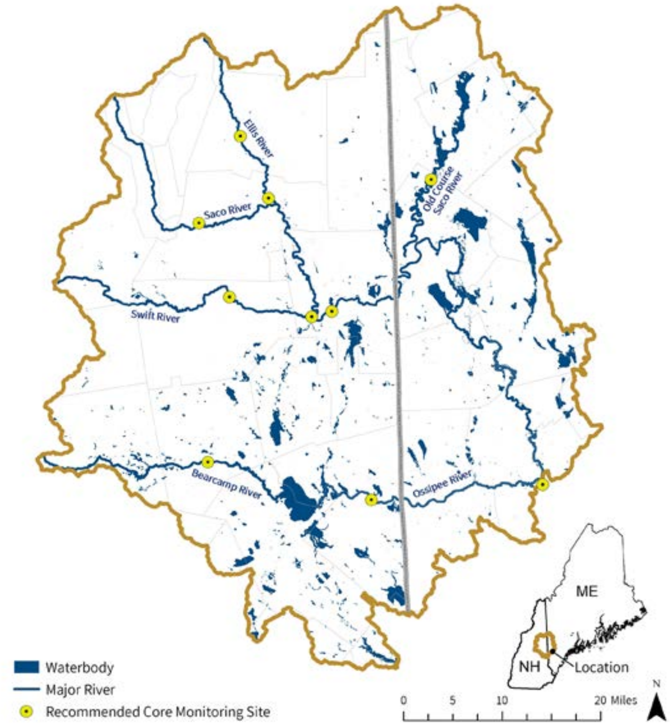
The fourteen actions detailed below are categorized by the type of gap they fill: **Data Gaps** such as stream crossings, water quality data coverage, and pharmaceuticals and personal care products; **Natural Science Gaps** such as in-stream flow studies, road salt loading and ecosystem effects, and regional groundwater modeling; **Social Science Gaps** such as conceptual models of social and institutional change at the local and regional levels and projections of land use change with residential/commercial/industrial development. A final recommended action is to reassess the monitoring system, repeat the gap analysis, and create a new strategic action plan in five years.

Actions that Address Data Gaps

1. Assess all stream crossings in the New Hampshire portion of the Saco Headwaters watershed. Inadequate stream crossings are flood vulnerability points, potential erosion and sedimentation sites, and barriers to aquatic organism passage, with the smaller crossings on gravel roads, camp roads, and recreational trails often more problematic and under the radar. An estimated 1,000 crossings need assessment in New Hampshire, where a collaborative effort is coalescing around the Saco Headwaters watershed using a unified methodology that covers geomorphic suitability, flood resilience, and aquatic organism passage. The New Hampshire Department of Fish and Game, the New Hampshire Geological Survey, NHDES, the North Country Council, Trout Unlimited, GMCG, and SHA, in addition to other partners, are actively collaborating to leverage resources to close this gap. Efforts to locate, map, and assess stream crossings should be shared and evaluated by these groups collaboratively. The total cost to assess all stream crossings in New Hampshire is estimated at $500,000 and, if funds are secured, this effort can be completed in the next two to four years.

2. Assess the watershed's stream crossings in Maine. The Maine portion of the watershed contains another estimated 500 stream crossings, making the rough estimate of assessment cost $250,000. Efforts in Maine are in earlier stages than in New Hampshire, but a preliminary list of stakeholder organizations in closing this data gap includes MEDEP, the Maine Department of Inland Fisheries and Wildlife, the Maine Geological Survey, Trout Unlimited, the Nature Conservancy, SHA, and others.

3. Expand surface water quality monitoring efforts to cover more of the Saco's major tributaries and headwater streams, and to cover winter conditions. Water quality sampling on the Saco River should continue to be a core function of the monitoring program, with SRCC monitoring stations and USGS streamgaging stations as the obvious candidates to be considered core sites. Monitoring the tributaries and headwater streams is also extremely important because data at a far downstream site may not capture the signal of a threat in a distant upland subwatershed. Thus, a range of drainage sizes and land uses should be prioritized, as should certain valuable resources. The Swift River and Ellis River watersheds in particular should receive monitoring attention. Water quality sensors that record, at a minimum, temperature and conductivity, should be installed where practical at monitoring stations, so that a continuous record of dense observations during all flow conditions (e.g. flood, baseflow, low flow/drought) can be



Recommended core monitoring stations in the Saco Headwaters watershed. See Appendix 1 for full-size maps.

maintained. The choice of sensors should reflect the state of the technology in 2020 and beyond, and the data should be hosted online and publicly available.

4. Ensure the continuity of a core set of water quality parameters to be tested and add selective parameters based on specific research or regulatory questions. At its core, a water quality monitoring program for the Saco Headwaters watershed must be able to detect changing conditions in chronic threats and must also adapt to developing threats. Routine grab sampling will always have a crucial role to play in both of these functions, and the parameters to be analyzed should all serve multiple purposes and/or assess multiple threats. For example, nitrogen parameters measure the presence of contamination from wastewater, stormwater, and agricultural runoff, and allow evaluation of the risk of nutrient enrichment and eutrophication. Major anion analysis yields chloride data that is essential for assessing road salt contamination, but also sulfate which is a key component in acid rain.

The proposed list of core water quality parameters for laboratory analysis is as follows: Major anions (chloride, sulfate, nitrate) and cations (sodium, potassium, magnesium, calcium); Ammonia/ammonium; Total dissolved nitrogen; Dissolved organic carbon; Soluble reactive phosphorus; Total phosphorus; Total nitrogen.

For a rough cost estimate, we turned to at the Water Quality Analysis Laboratory at the University of New Hampshire-Durham (UNH), a state-of-the-art research laboratory that collaborates with numerous monitoring programs. The cost per sample to run this suite of lab analyses is $63 per sample. In addition, the UNH laboratory has a graduated pricing for the first 20 samples (per year, per client) which would effectively add a $2,560 surcharge to the analysis costs for a monitoring program. For rivers and streams, weekly samples scheduled for the same day of each week are a time-tested method of gaining representation of a wide distribution of conditions. The annual cost for one station would thus include 52 weekly samples for $3,276 in lab fees, or roughly $4,000 once shipping and supplies are accounted for. Samples can be frozen without special equipment for up to three months and shipped or dropped off in batches.

Each time a grab sample is collected, at least four field parameters should be measured by a qualified sampler with a properly calibrated and maintained field meter: temperature, dissolved oxygen, pH, and conductivity.

An industry standard multiparameter probe (e.g. the YSI 556a) costs roughly $2,000-$2,500 depending on options, requires minimal maintenance, is ruggedly durable, and has small costs for calibration standards (less than $50 per year).

5. Expand the network of streamflow measurement stations to cover more tributaries of the Saco and Ossipee rivers. Include temperature and conductivity monitoring in the network. Establishing a new streamgaging station requires staff with technical expertise and inexpensive monitoring equipment (a depth logger, temperature/conductivity logger, stilling well, and staff gage for in-stream deployment and velocity meter and wading rod for field measurements) and a long-term commitment to extending the record of observations. It would not require expensive or disruptive projects that require heavy construction equipment or permitting.

6. Conduct the first study of micropollutants in surface waters of the region. Identify 15-30 surface water sites to sample, ranging from sites with potential micropollutant exposure (e.g., small streams in densely developed neighborhoods with septic systems, such as Hale's Location) to sites with no expected exposure (e.g., the Cold River headwaters in Evans Notch). This is a crucial gap in our understanding of the ubiquity of these compounds that can be addressed with a one-time sampling campaign. Laboratory cost per sample is estimated at $1,500-$2,500, and labor for sampling and reporting is estimated at $2,500-$5,000, for a total estimated range of $25,000-$75,000.

Actions that Address Natural Science Gaps

7. Build a state-of-the-art groundwater model of the region's stratified drift aquifers. The last time a comprehensive study of groundwater was conducted in the region was in the early 1990s, before the advent of the personal computer. An updated version would consist of a numerical groundwater model built to approximate current aquifer volume, storage, recharge, and withdrawal availability in the region's stratified drift aquifers and to model future scenarios given climate change predictions and changes in withdrawal rates for the aquifer. This numerical groundwater model would provide baseline information to inform regional water resource planning and management of the stratified drift aquifer. Groundwater withdrawals, if sufficiently large, can change the direction and magnitude of flow through the aquifer, potentially exposing drinking water supplies to new contamination sources and changing the planning considerations surrounding new groundwater supplies. Changes in precipitation and streamflow regimes can have similar effects on groundwater flow dynamics.

8. Conduct in-stream flow protection studies of the Saco, Swift, and Ossipee rivers. In-stream flow protection is the science and policy of balancing water users with the needs of the aquatic ecosystem to support the integrity of the entire social-ecological system. It combines hydrologic and hydraulic modeling with use management. First, the necessary flows to protect fish, recreational uses, and riparian vegetation are calculated. Then a water use management plan is developed that allocates water withdrawals in different flow scenarios and determines emergency actions when flows drop below critical thresholds. This kind of study is being implemented elsewhere in New Hampshire and will be a key management tool in light of altered streamflow timing and magnitude with climate change. Depending on how much new data needs to be collected in the field or modeled, the estimated cost range for these studies is $75,000-150,000.

9. Create a road salt model for the Saco Headwaters watershed and set a target reduction. The Fund for Lake George in upstate New York has led the way on the kind of effort that is needed. Along with numerous partner organizations including Rensselaer Polytechnic Institute and IBM, this group has undertaken an ambitious and innovative program to significantly reduce the amount of road salt that is applied and ultimately reaches the lake.

Actions that Address Social Science Gaps

10. Through engagement, dialogue, education, and outreach with the region's municipalities, build a conceptual model of social and institutional water resource protection in the Saco Headwaters watershed. SHA is focused on working with municipalities to enhance their knowledge and commitment in protecting ground and surface waters under their aegis. This includes developing groundwater and floodplain and development ordinances, maintaining and remediating stream crossing infrastructure for long term resilience and managing PCSs and implementing BMPs for groundwater protection. The power of state and federal agencies to protect water is limited to enforcement of the law and environmental regulations, and these limitations on NHDES's or MEDEP's authority are not widely understood by the public. This situation makes municipalities the most important institutions for protecting water in the region. The interplay between various governing bodies such as select boards, planning boards, and conservation commissions is largely determined by who is engaged and what the network of relationships looks like on the local level. A conceptual model of the dynamics of these institutions, and how different municipalities fit or do not fit the model, is key to finding the right collaborators and leverage points to foster positive change for water protection.

11. Comprehensively review municipal ordinances in the watershed with respect to water protection. An ordinance review takes a critical look at the regulations, zoning, and overlay districts a municipality has on the books, and makes recommendations based on the findings. Properly done, an ordinance review will lay out the best practices and model ordinances from similar regions and applicable situations in order to inform the proper steps to take.

12. Conduct a buildout analysis of the entire Saco Headwaters watershed. A buildout analysis for the entire watershed would need to incorporate the conditions specific to each municipality. Alternative scenarios could also be tested, such as an uptick in population growth due to climate or water scarcity in other regions. There is not confirming evidence that the region will be increasingly attractive for migration by the end of the century, but many have posited that this will be the case. A buildout analysis provides an opportunity to test reasonable assumptions on this front. The results and their implications would spur dialogue across municipal boundaries about how to improve regional planning integration.

Buildout analyses are most often commissioned by individual municipalities, funded by grants, and carried out by consultants, but a wide variety of models exists for how to conduct them. For the Saco Headwaters watershed, a joint effort by a collaborative of municipalities would be necessary to conduct a project of this scale, ensuring buy-in and access to the required geographic and ordinance information. A preliminary estimate of the cost for this project is $75,000-$150,000, depending on the level of completeness of existing GIS data such as zoning and other development restrictions, and existing buildings.

13. Write a comprehensive watershed plan for the entire Saco Headwaters watershed. A USEPA nine-element plan, often called an a-i plan (for the nine plan elements denoted "A" through "I") is a time-tested process for writing a watershed-based management plan: conducting a preliminary analysis of threats to water quality; pulling together stakeholders and setting water quality goals; determining the amounts of pollutant load reduction necessary to achieve these goals; and developing the roadmap to implementation of the plan and measurement of the goals.

Future Iterations of the Gap Analysis

14. Finally, the gap analysis conducted as part of this project provides a snapshot in time that will lose relevance as years pass. Adaptive management is a natural resource management concept that focuses on learning from past actions in an iterative process, and adapting one's management actions accordingly. The recommended approach is for SHA to revisit this 2020 report in five years and assess whether the monitoring programs, data sources, threats to water resources, and gap analysis results still stand. In addition, we recommend assessing whether new threats have arisen, how successful the bolstering of the monitoring system has been, and whether the actions in this plan have been successfully implemented.

To support the urgent vision of a resilient watershed, SHA will lead the creation a multi-stakeholder body with an ongoing commitment to maintaining and improving the monitoring capability across the entire Saco Headwaters watershed. To do this, SHA will convene local, state, and federal leaders of the institutions discussed in this report, who are currently collecting data across the watershed (USGS, NHDES, MEDEP, GMCG, SRCC, KLWA, etc.), to review and update this "Watching our Waters" Report. Regular focus by a collaborative group on adapting and strengthening the monitoring program for this watershed will not only improve the data and scientific information available, but will also foster enhanced collaboration among agencies and stakeholders.

Table 2. List of recommended actions (1-14) that address the identified gaps is data, natural science, and social science for the Saco Headwaters watershed. Each action item identifies the responsible parties, timeframe, funding source, and cost estimate.

GAP	ACTION	DESCRIPTION	RESPONSIBLE PARTY	TIMEFRAME	FUNDING SOURCE	COST ESTIMATE
ACTIONS THAT ADDRESS DATA GAPS						
Stream crossing data, New Hampshire	1	Conduct 500-700 stream crossing assessments in New Hampshire	NHF&G, NHDES, NHGS, NCC, GMCG, TU, SHA	2020-2022	State and federal grants and loans (e.g. State Revolving Fund, US Econ. Dev. Agency	$500,000
Stream crossing data, Maine	2	Conduct 250-350 stream crossing assessments in Maine	MDIFW, MEDEP, MGS, SMPDC, TNC, TU, SHA	2021-2023	State and federal grant and loan programs	$250,000
Water quality monitoring coverage, spatial and temporal	3	Expand water quality monitoring efforts to cover more of the watershed.	NHDES, MEDEP, GMCG, SRCC, SHA	2021-ongoing	State and federal grant and loan programs	$20,000 per year (based on paid field staff and annual reports)
Continuity of water quality parameters	4	Ensure the continuity of a core set of water quality parameters to be tested.	NHDES, MEDEP, GMCG, SRCC, SHA	2021-ongoing	State and federal grant and loan programs	$40,000 per year (based on 10 monitoring stations)
Streamflow measurement	5	Expand the network of streamflow measurement stations.	USGS, SHA	2021-ongoing	State and federal grant and loan programs	$10,000 per year (based on five stream gaging stations)
Micropollutant data	6	Conduct the first study of micropollutants in surface waters of the region.	USEPA, NHDES, MEDEP, SHA	2021	State and federal grant and loan programs	$25,000-$80,000
ACTIONS THAT ADDRESS NATURAL SCIENCE GAPS						
Groundwater modeling	7	Build a state-of-the-art groundwater model of the region's stratified drift aquifers.	USGS, NHGS, MGS, universities	2022-2024	State and federal grants, private philanthropy	$190,000-480,000

GAP	ACTION	DESCRIPTION	RESPONSIBLE PARTY	TIMEFRAME	FUNDING SOURCE	COST ESTIMATE
In-stream flow protection	8	Build an in-stream flow protection model and management plan for the Swift and Saco rivers	NHDES, NHGS, USGS	2022-2024	Internal NHDES funding sources	$100,000-$150,000
Road salt modeling	9	Expand water quality monitoring efforts to cover more of the watershed.	USGS, NHDES, MEDEP, universities	2022-2024	State and federal grants, private philanthropy	$100,000-250,000
ACTIONS THAT ADDRESS SOCIAL SCIENCE GAPS						
Municipal water protection model	10	Build and field-test a conceptual model of social/institutional water resource protection in the watershed.	SHA, municipalities	2020-2021	State and federal grants, private philanthropy	$50,000-$100,000
Regional ordinance review	11	Do a comprehensive ordinance review of all municipalities with respect to water protection.	SHA, municipalities	2021-2022	State and federal grants, private philanthropy	$50,000-$100,000
Regional buildout analysis	12	Conduct a buildout analysis of the entire Saco Headwaters watershed.	SHA, municipalities	2023-2025	State and federal grants, private philanthropy	$75,000-$150,000
Watershed management plan	13	Write a comprehensive watershed plan for the entire Saco Headwaters watershed.	Municipalities, NHDES, MEDEP, USEPA, SHA	2022-2025	State and federal grants, private philanthropy	$500,000
FUTURE ITERATIONS OF THE GAP ANALYSIS						
Future Iterations of the Gap Analysis	14	Revisit previously studied threats and assess whether 2020 gap analysis results still stand. Assess whether any new threats have arisen.	SHA	2025-2026	State and federal grants, private philanthropy	$15,000-$20,000

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APPENDIX 1

Map 1: Water Resources

Map 2: Conserved Lands

Map 3: Soil Series Data Availability

Map 4: Land Cover

Map 5: Impervious Cover

Map 6: Stream Crossings

Map 7: State-Listed Impaired Waterbodies

Map 8: Monitoring Stations

Map 9: Recommended Core Monitoring Stations

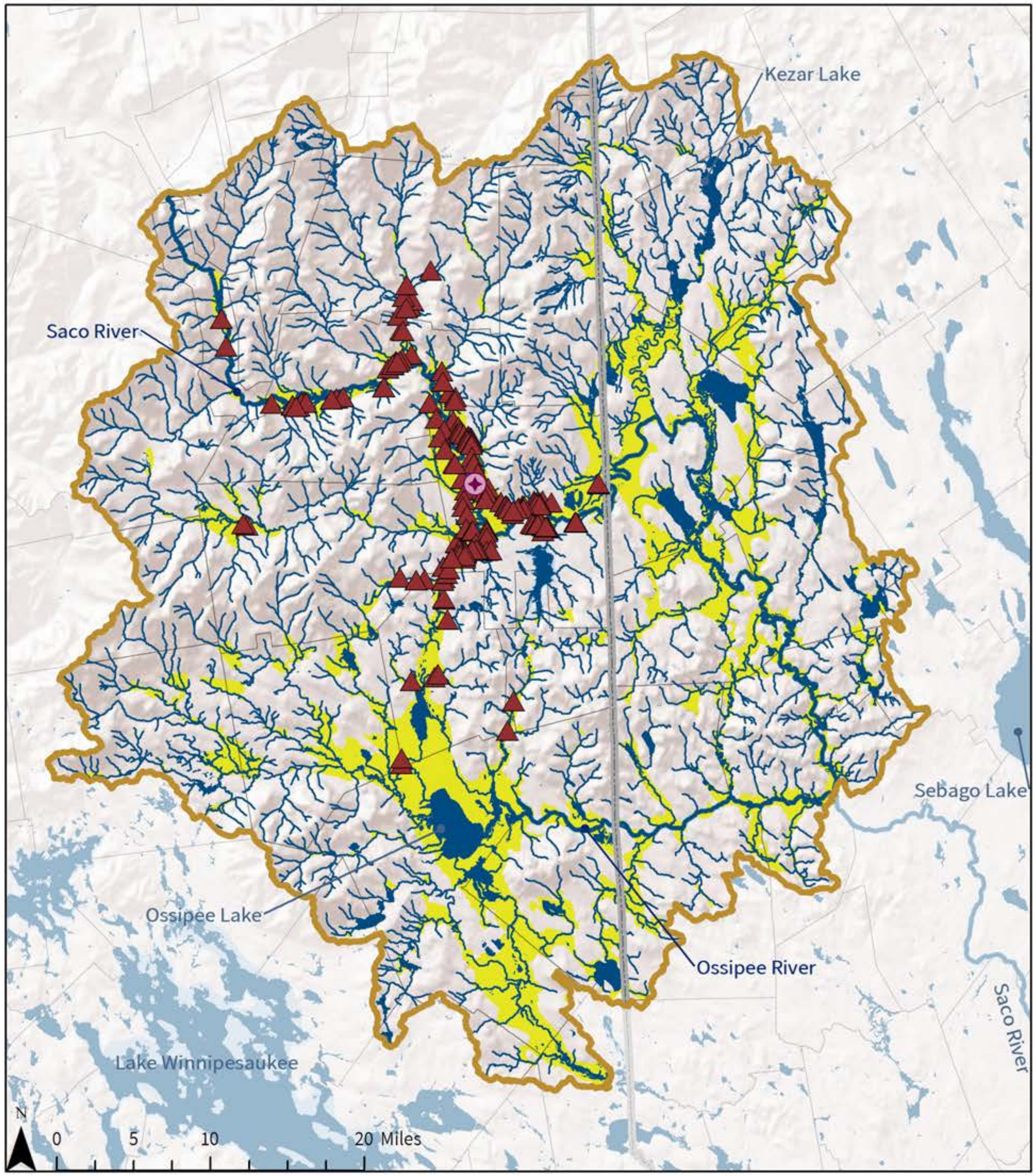
Saco Headwaters Watershed

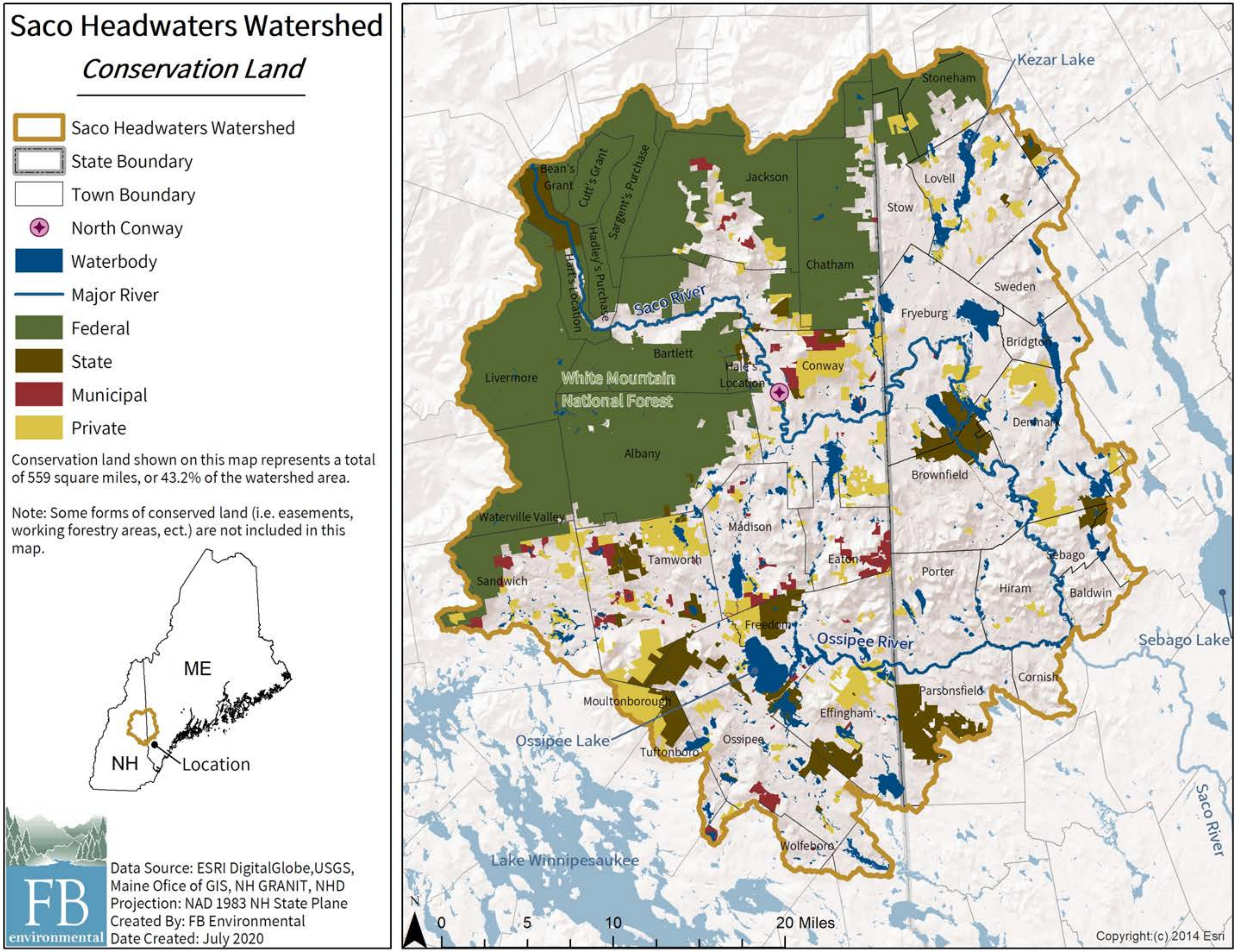
Stratified Drift Aquifers and Potential Contamination Sources

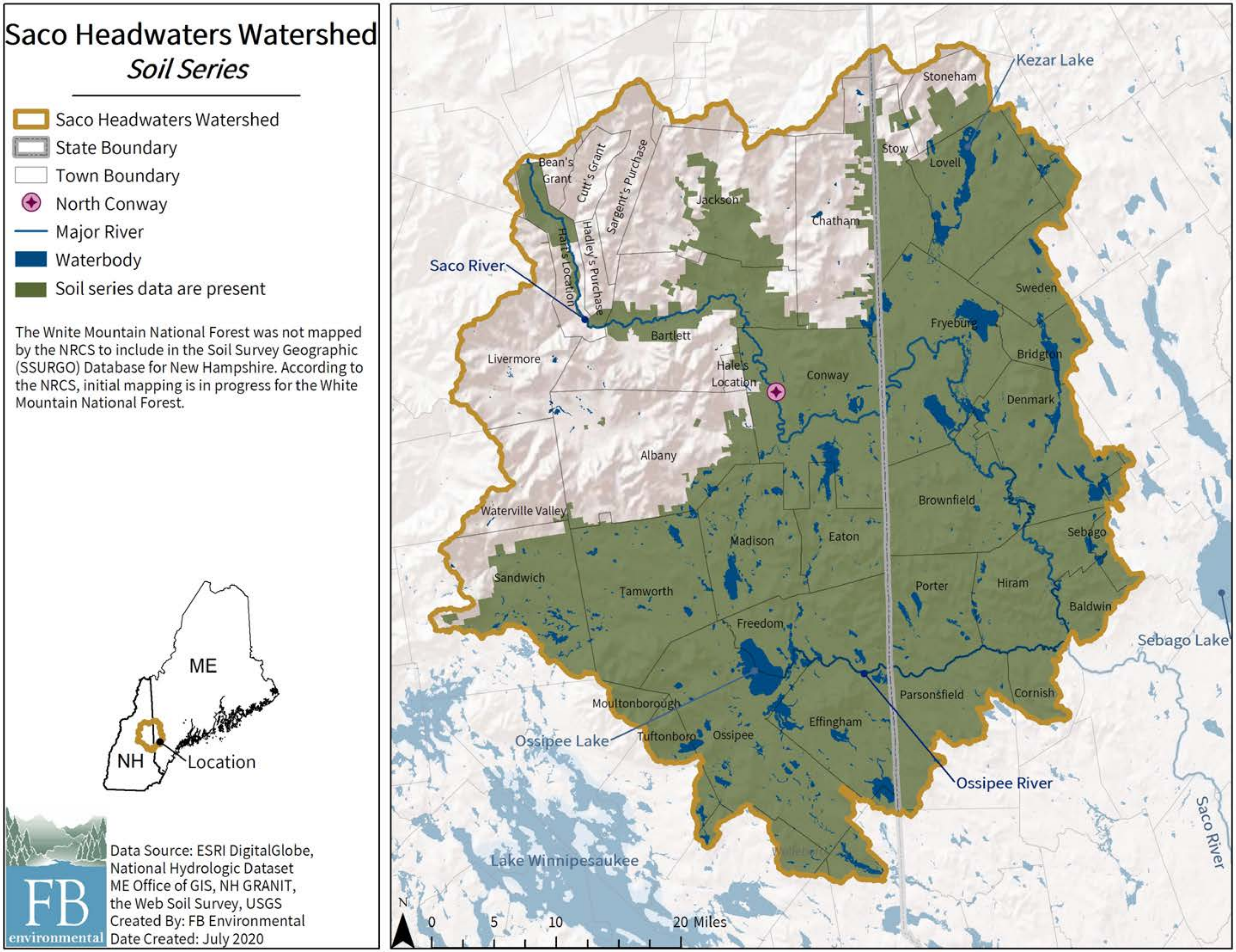
- Saco Headwaters Watershed
- State Boundary
- North Conway
- Major River
- River/Stream
- Waterbody
- Aquifer
- PCS

The NHDES identified potential contamination sourrces (PCSs) from conducting Windshield Surveys (watershed surveys) for the DES's Chemical Monitoring Waiver Program and source water protection programs. Maine DEP does not have a state-wide database. There may however be site-by-site surveys available by individual organizations within the area.

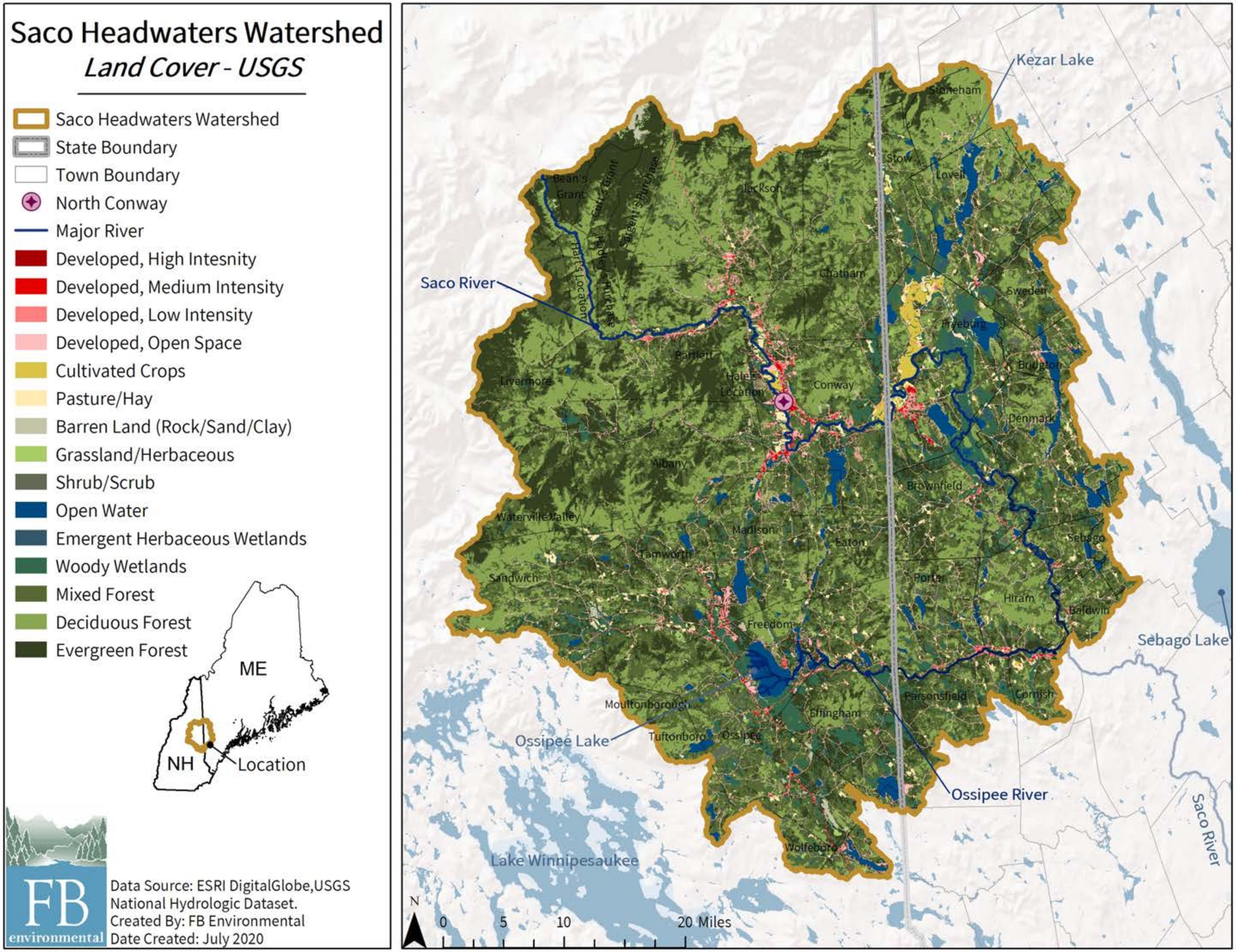
Data Source: ESRI DigitalGlobe, National Hydrologic Dataset, NHDES, ME Office of GIS and NH GRANIT
Created By: FB Environmental
Date Created: July 2020




Saco Headwaters Watershed
Conservation Land
Saco Headwaters Watershed
State Boundary
Town Boundary
North Conway
Waterbody
Major River
Federal
State
Municipal
Private
Conservation land shown on this map represents a total of 559 square miles, or 43.2% of the watershed area.
Note: Some forms of conserved land (i.e. easements, working forestry areas, ect.) are not included in this map.
ME
NH
Location
FB environmental
Data Source: ESRI DigitalGlobe,USGS, Maine Ofice of GIS, NH GRANIT, NHD
Projection: NAD 1983 NH State Plane
Created By: FB Environmental
Date Created: July 2020
Kezar Lake
Stoneham
Bean's Grant
Cutt's Grant
Sargent's Purchase
Jackson
Lovell
Stow
Hadley's Purchase
Hart's Location
Chatham
Sweden
Saco River
Fryeburg
Bridgton
Bartlett
Hale's Location
Conway
Livermore
White Mountain National Forest
Denmark
Albany
Brownfield
Waterville Valley
Madison
Tamworth
Eaton
Sebago
Porter
Sandwich
Hiram
Baldwin
Freedom
Ossipee River
Sebago Lake
Cornish
Parsonsfield
Moultonborough
Effingham
Ossipee Lake
Ossipee
Tuftonboro
Wolfeboro
Lake Winnipesaukee
Saco River
N
0
5
10
20 Miles
Copyright:(c) 2014 Esri



Saco Headwaters Watershed
Soil Series
Saco Headwaters Watershed
State Boundary
Town Boundary
North Conway
Major River
Waterbody
Soil series data are present
The Wnite Mountain National Forest was not mapped by the NRCS to include in the Soil Survey Geographic (SSURGO) Database for New Hampshire. According to the NRCS, initial mapping is in progress for the White Mountain National Forest.
ME
NH
Location
FB
environmental
Data Source: ESRI DigitalGlobe, National Hydrologic Dataset ME Office of GIS, NH GRANIT, the Web Soil Survey, USGS
Created By: FB Environmental
Date Created: July 2020
Kezar Lake
Stoneham
Stow
Lovell
Bean's Grant
Cutt's Grant
Sargent's Purchase
Hart's Location
Hadley's Purchase
Jackson
Chatham
Saco River
Sweden
Fryeburg
Bartlett
Livermore
Hale's Location
Conway
Bridgton
Denmark
Albany
Brownfield
Waterville Valley
Madison
Eaton
Sebago
Sandwich
Tamworth
Porter
Hiram
Baldwin
Freedom
Sebago Lake
Moultonborough
Parsonsfield
Cornish
Effingham
Ossipee Lake
Tuftonboro
Ossipee
Ossipee River
Lake Winnipesaukee
Saco River
N
0
5
10
20 Miles

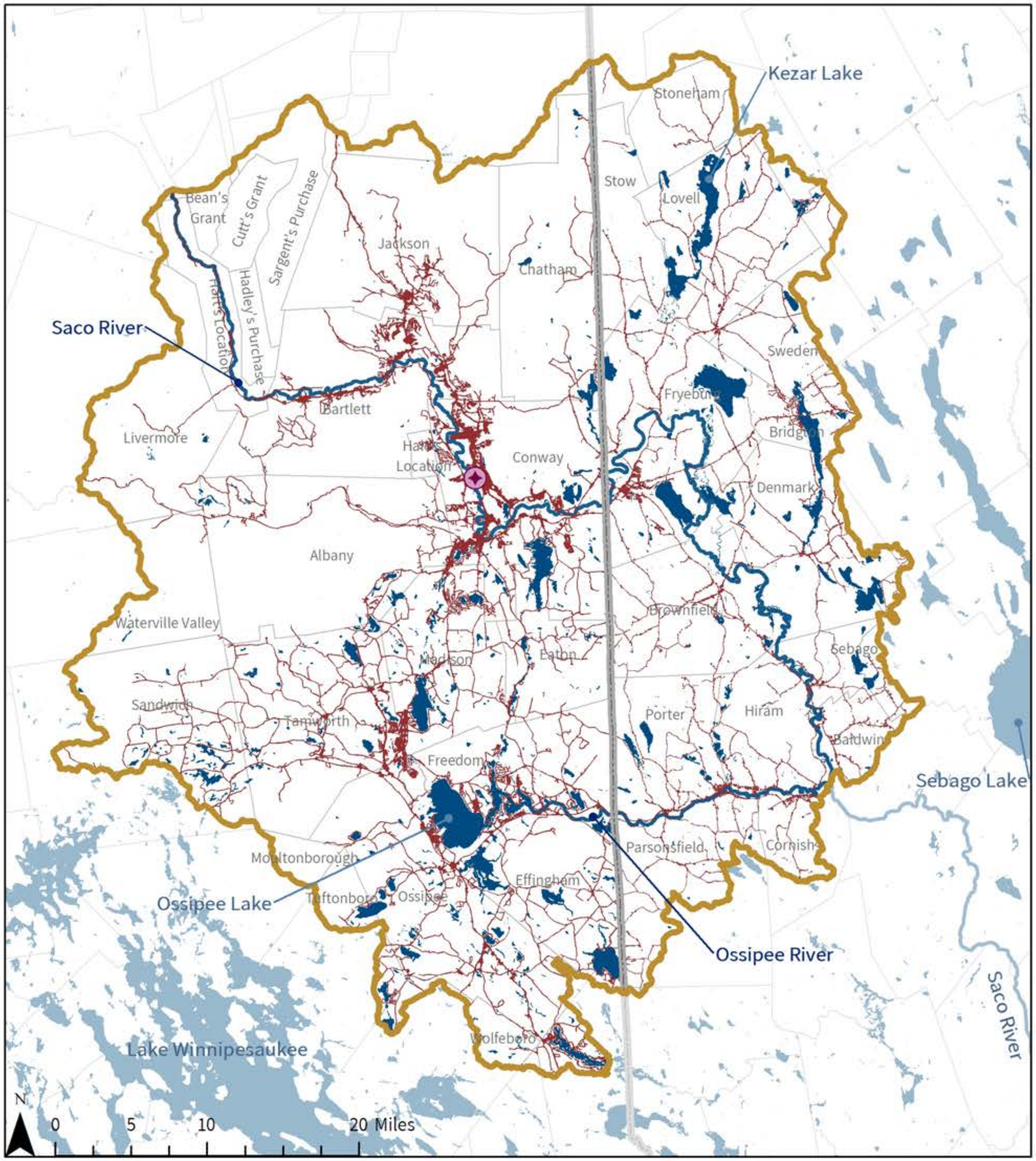

Saco Headwaters Watershed
Land Cover - USGS
Saco Headwaters Watershed
State Boundary
Town Boundary
North Conway
Major River
Developed, High Intesnity
Developed, Medium Intensity
Developed, Low Intensity
Developed, Open Space
Cultivated Crops
Pasture/Hay
Barren Land (Rock/Sand/Clay)
Grassland/Herbaceous
Shrub/Scrub
Open Water
Emergent Herbaceous Wetlands
Woody Wetlands
Mixed Forest
Deciduous Forest
Evergreen Forest
ME
NH
Location
FB
environmental
Data Source: ESRI DigitalGlobe,USGS
National Hydrologic Dataset.
Created By: FB Environmental
Date Created: July 2020
Kezar Lake
Saco River
Stoneham
Stow
Lovell
Jackson
Chatham
Sweden
Fryeburg
Bridgton
Bartlett
Livermore
Hale's Location
Conway
Denmark
Albany
Brownfield
Waterville Valley
Madison
Eaton
Sebago
Tamworth
Porter
Sandwich
Hiram
Baldwin
Freedom
Sebago Lake
Parsonsfield
Cornish
Moultonborough
Effingham
Ossipee Lake
Tuftonboro
Ossipee
Ossipee River
Wolfeboro
Lake Winnipesaukee
Saco River
N
0
5
10
20 Miles

Saco Headwaters Watershed

Impervious Area

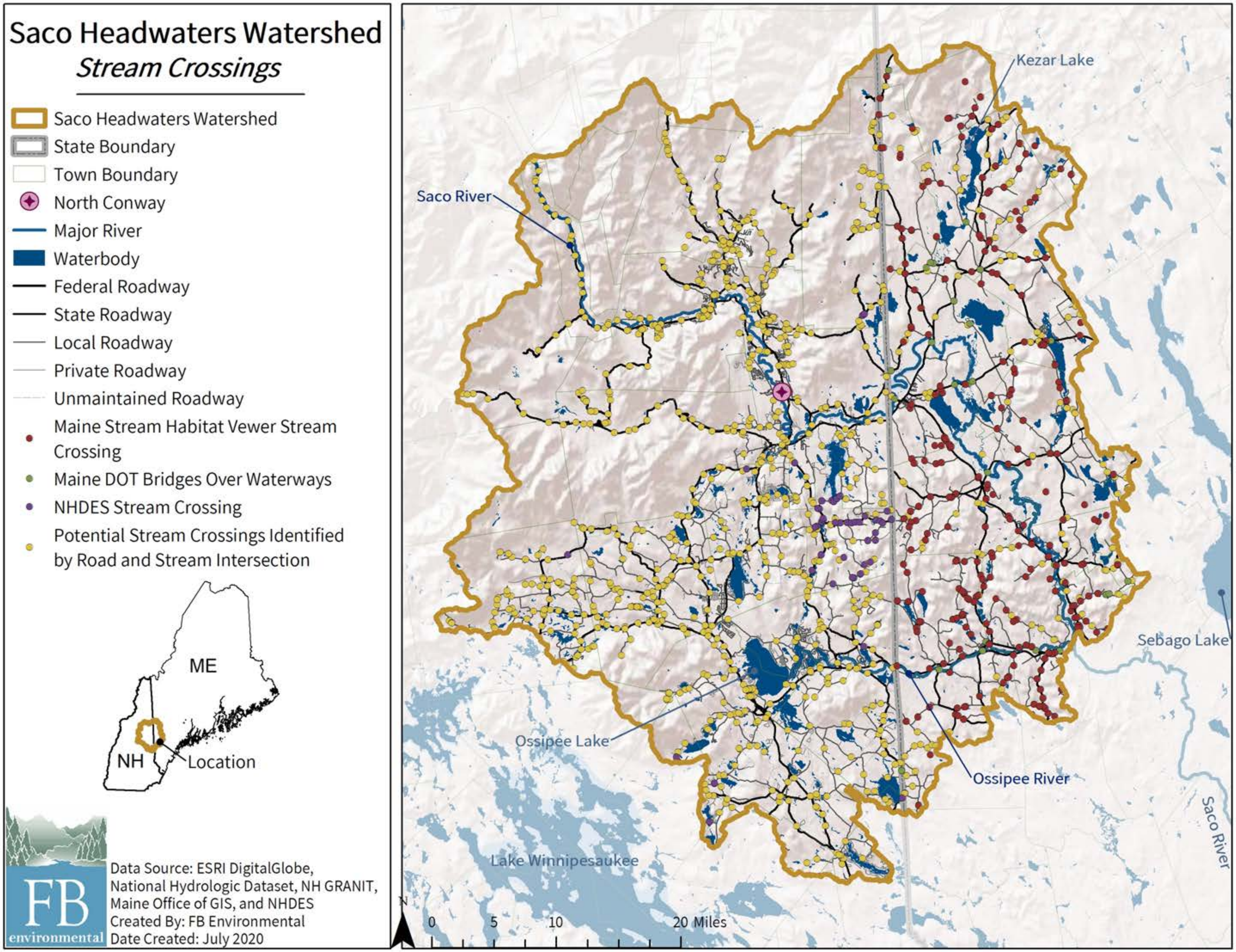
- Saco Headwaters Watershed
- State Boundary
- Town Boundary
- North Conway
- Major River
- Waterbody
- Impervious Cover

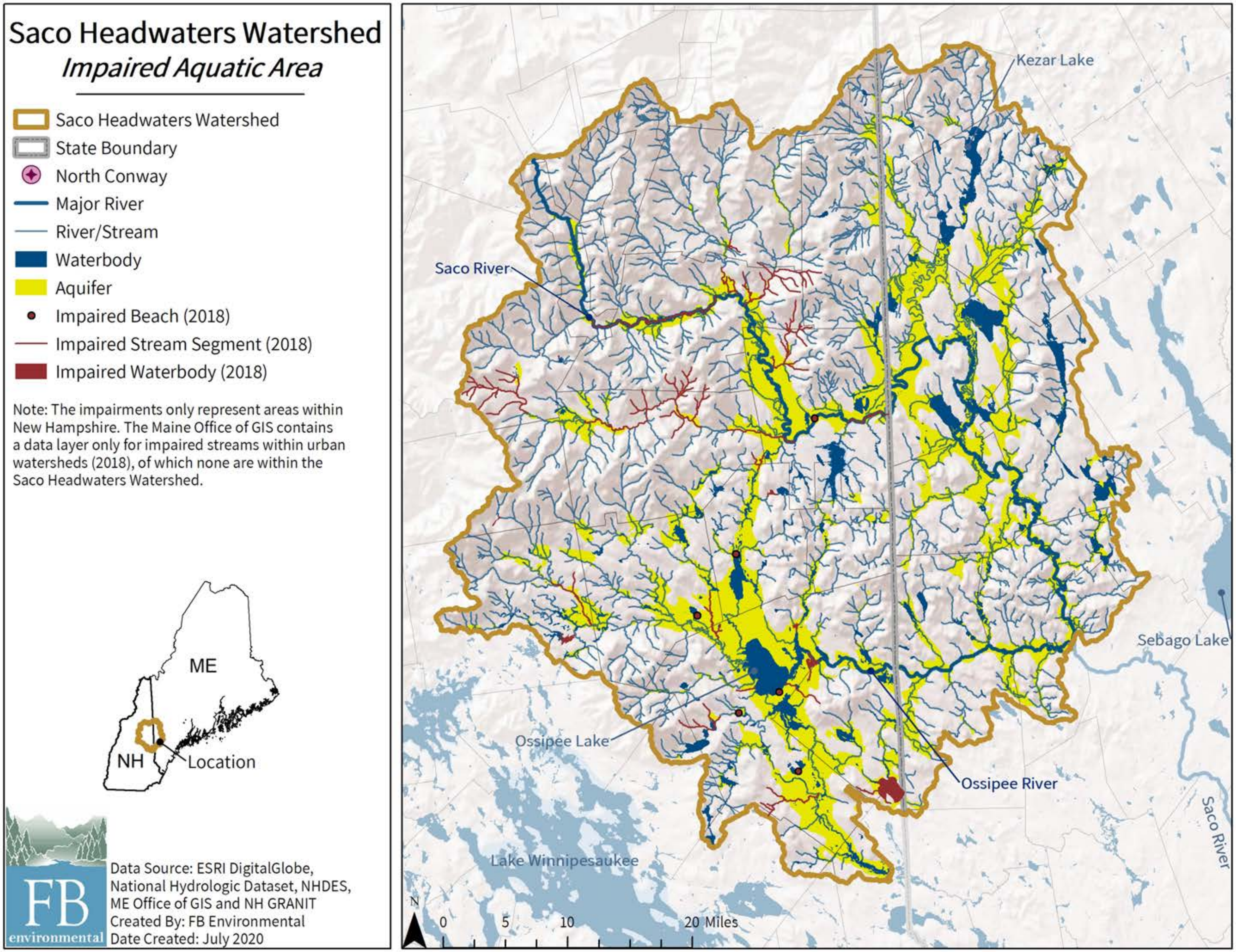
Impervious surface data for the New Hampshire portion of the watershed area was collected from the USGS. Impervious surface data for the Maine portion of the watershed area was collected from the Maine Office of GIS. According to these sources, impervious surfaces cover approximately 60 square miles in New Hampshire and 7 square miles in Maine. Covering a larger percent of the watershed area and containing more town centers, the New Hampshire portion is expected to contain more impervious surfaces. However, the two data layers were created under different resolutions. The impervious cover layer for Maine was created at a much finer resolution and is likely more accurate than that for New Hampshire which was created at a much smaller scale and is likely over estimating the total impervious area for New Hampshire. There is a total of 67 square miles, or 5% of the total watershed area.



FB environmental

Data Source: ESRI DigitalGlobe, National Hydrologic Dataset, USGS, Maine Office of GIS and NH GRANIT
Created By: FB Environmental
Date Created: July 2020


Saco Headwaters Watershed
Stream Crossings
Saco Headwaters Watershed
State Boundary
Town Boundary
North Conway
Major River
Waterbody
Federal Roadway
State Roadway
Local Roadway
Private Roadway
Unmaintained Roadway
Maine Stream Habitat Vewer Stream Crossing
Maine DOT Bridges Over Waterways
NHDES Stream Crossing
Potential Stream Crossings Identified by Road and Stream Intersection
ME
NH
Location
FB
environmental
Data Source: ESRI DigitalGlobe, National Hydrologic Dataset, NH GRANIT, Maine Office of GIS, and NHDES
Created By: FB Environmental
Date Created: July 2020
Kezar Lake
Saco River
Sebago Lake
Ossipee Lake
Ossipee River
Lake Winnipesaukee
Saco River
N
0
5
10
20 Miles


Saco Headwaters Watershed
Impaired Aquatic Area
Saco Headwaters Watershed
State Boundary
North Conway
Major River
River/Stream
Waterbody
Aquifer
Impaired Beach (2018)
Impaired Stream Segment (2018)
Impaired Waterbody (2018)
Note: The impairments only represent areas within New Hampshire. The Maine Office of GIS contains a data layer only for impaired streams within urban watersheds (2018), of which none are within the Saco Headwaters Watershed.
ME
NH
Location
FB
environmental
Data Source: ESRI DigitalGlobe, National Hydrologic Dataset, NHDES, ME Office of GIS and NH GRANIT
Created By: FB Environmental
Date Created: July 2020
Kezar Lake
Saco River
Sebago Lake
Ossipee Lake
Ossipee River
Saco River
Lake Winnipesaukee
N
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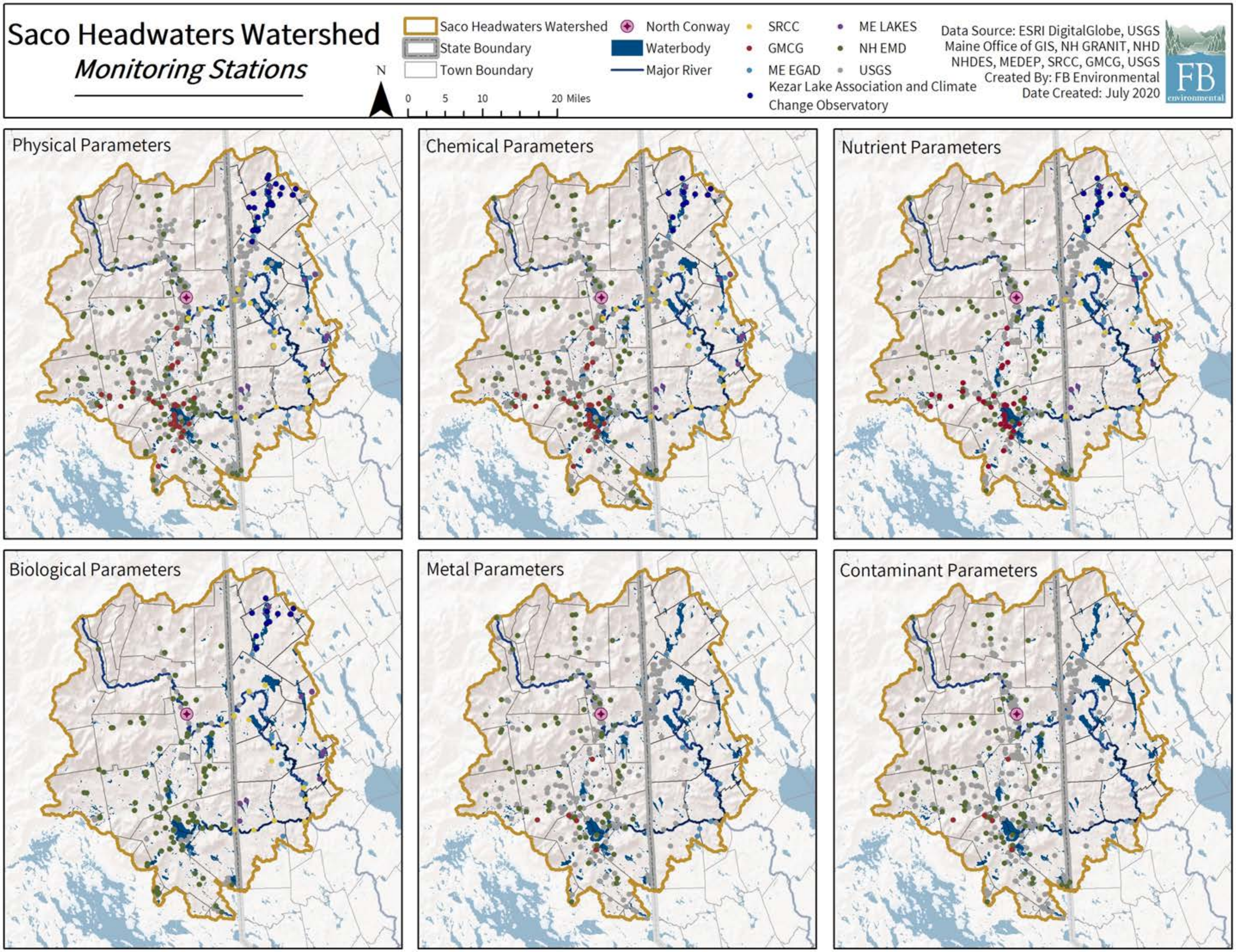

Saco Headwaters Watershed
Monitoring Stations
Saco Headwaters Watershed
State Boundary
Town Boundary
North Conway
Waterbody
Major River
SRCC
GMCG
ME EGAD
ME LAKES
NH EMD
USGS
Kezar Lake Association and Climate Change Observatory
Data Source: ESRI DigitalGlobe, USGS Maine Office of GIS, NH GRANIT, NHD NHDES, MEDEP, SRCC, GMCG, USGS
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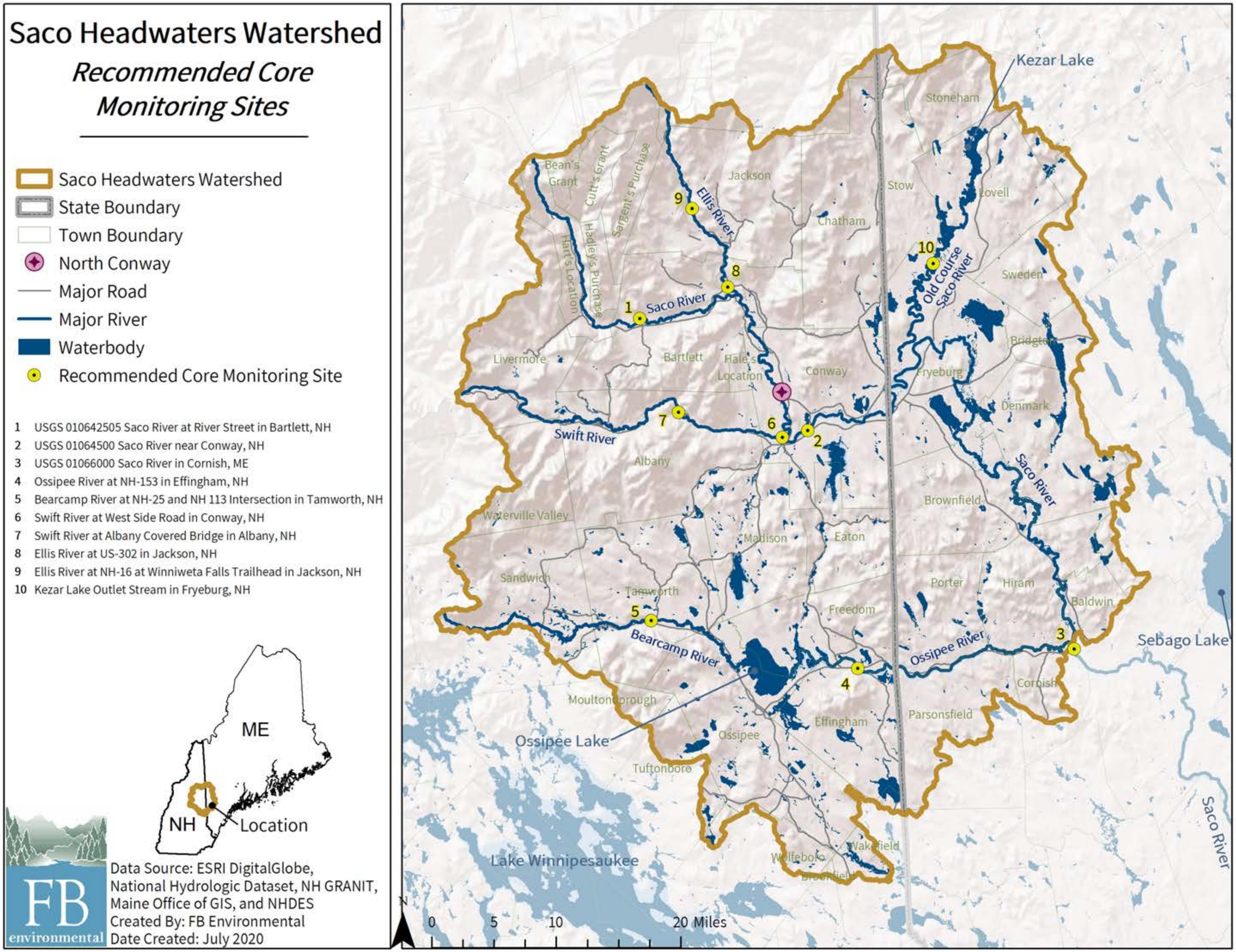
Date Created: July 2020
N
0 5 10 20 Miles
Physical Parameters
Chemical Parameters
Nutrient Parameters
Biological Parameters
Metal Parameters
Contaminant Parameters


Saco Headwaters Watershed
Recommended Core Monitoring Sites
Saco Headwaters Watershed
State Boundary
Town Boundary
North Conway
Major Road
Major River
Waterbody
Recommended Core Monitoring Site
1 USGS 010642505 Saco River at River Street in Bartlett, NH
2 USGS 01064500 Saco River near Conway, NH
3 USGS 01066000 Saco River in Cornish, ME
4 Ossipee River at NH-153 in Effingham, NH
5 Bearcamp River at NH-25 and NH 113 Intersection in Tamworth, NH
6 Swift River at West Side Road in Conway, NH
7 Swift River at Albany Covered Bridge in Albany, NH
8 Ellis River at US-302 in Jackson, NH
9 Ellis River at NH-16 at Winniweta Falls Trailhead in Jackson, NH
10 Kezar Lake Outlet Stream in Fryeburg, NH
ME
NH
Location
Data Source: ESRI DigitalGlobe, National Hydrologic Dataset, NH GRANIT, Maine Office of GIS, and NHDES
Created By: FB Environmental
Date Created: July 2020
FB
environmental
Kezar Lake
Stoneham
Bean's Grant
Cutt's Grant
Sargent's Purchase
Jackson
Stow
Lovell
Ellis River
Chatham
Hart's Location
Hadley's Purchase
Saco River
Old Course Saco River
Sweden
Bridgton
Livermore
Bartlett
Hale's Location
Conway
Fryeburg
Denmark
Swift River
Albany
Saco River
Brownfield
Waterville Valley
Madison
Eaton
Sandwich
Tamworth
Porter
Hiram
Baldwin
Freedom
Bearcamp River
Ossipee River
Sebago Lake
Cornish
Moultonborough
Effingham
Parsonsfield
Ossipee Lake
Ossipee
Tuftonboro
Wakefield
Wolfeboro
Brookfield
Lake Winnipesaukee
Saco River
N
0 5 10 20 Miles

SACO HEADWATERS ALLIANCE

FB environmental