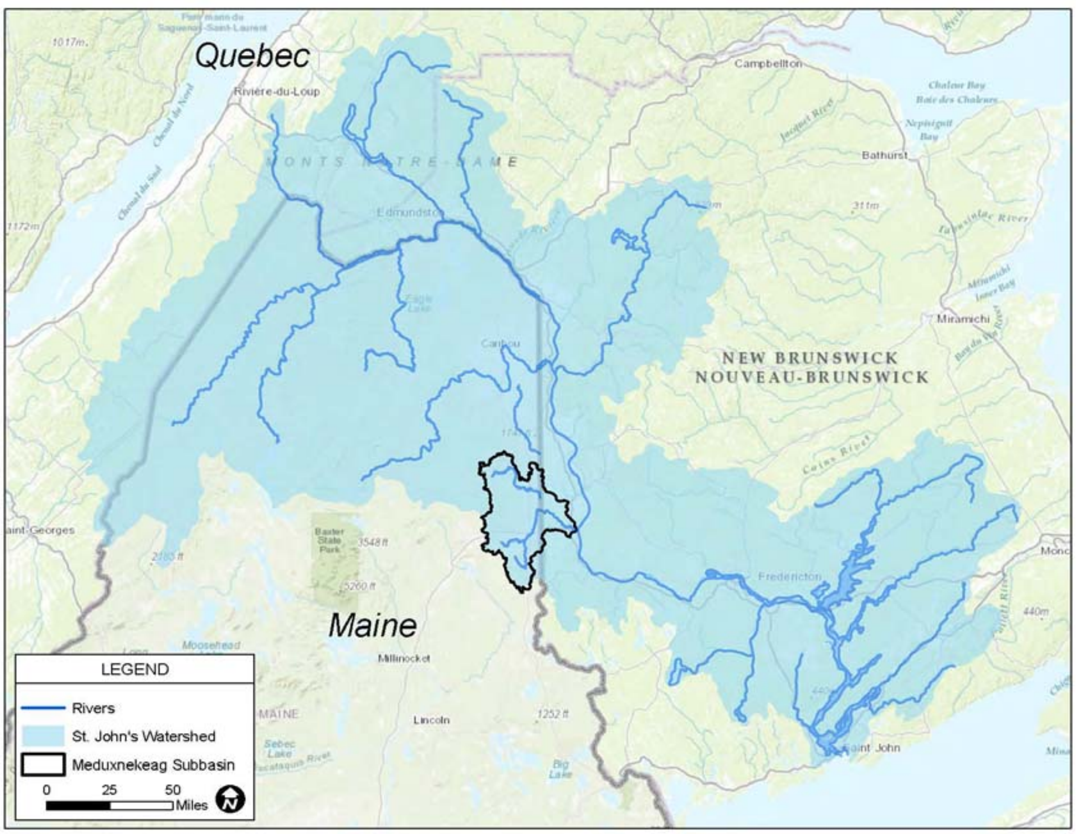
Tribal Partnership Program
Section 729 Watershed Assessment
Draft Watershed Assessment and Management Plan

Wolastoq (Saint John River)

Meduxnekeag Subbasin

State of Maine and Canadian Provinces of New Brunswick and Quebec



US Army Corps of Engineers®
New England District

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DRAFT

Wolastoq (Saint John River) Watershed Assessment and Management Plan, Meduxnekeag Subbasin

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The information presented in this report is to provide strategic framework of potential options to address problems within the Meduxnekeag River of the Wolastoq (Saint John River) Watershed. Options identified will follow normal authorization and budgetary processes of the appropriate agencies. Any costs presented are rough order magnitude estimates used for screening purposes only.

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List of Acronyms and Abbreviations

BMP	best management practice
CER	Comparative Environmental Review
COSEWIC	The Committee on the Status of Endangered Wildlife in Canada
CRI	Canadian Rivers Institute
DDT	dichloro-diphenyl-trichloroethane
DEP	Department of Environmental Protection
DFO	Department of Fisheries and Oceans
DMR	Department of Marine Resources
DO	dissolved oxygen
DOT	Department of Transportation
DPS	Distinct Population Segment
eDNA	Environmental DNA
ESA	Endangered Species Act
GIS	Geographic Information System
GOM DPS	Gulf of Maine Distinct Population Segment
HCD	habitat connectivity design
HBMI	Houlton Band of Maliseet Indians
IBOF	Inner Bay of Fundy
IJC	International Joint Commission
LGB	live gene bank
MBF	Mactaquac Biodiversity Facility
MDIFW	Maine Department of Inland Fisheries & Wildlife
MNCC	Maliseet Nation Conservation Council
MRWA	Meduxnekeag River Watershed Association
NB	New Brunswick
NGO	non-governmental organization
NOAA	National Oceanographic and Atmospheric Administration
NOAA Fisheries	National Oceanographic and Atmospheric Administration, National Marine Fisheries Service
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resource Conservation Service
NRD	Natural Resources Department
OBOF	Outer Bay of Fundy
PCB	polychlorinated biphenyl
PCE	Primary Constituent Elements
SARA	Species at Risk Act
SASWCD	Southern Aroostook Soil and Water Conservation District
SNB	Service New Brunswick
TMDL	total maximum daily load
TNC	The Nature Conservancy
U.S.	United States
USACE	United States Army Corps of Engineers
USDA	United States Department of Agriculture

US EPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
WAS/Plan	Wolastoq (Saint John River) Watershed Assessment and Management Plan, Meduxnekeag Subbasin
WRDA	Water Resources Development Act
WWF	World Wildlife Federation

List of Abbreviations for Units of Measure

°C	Degrees Celsius
cfs	cubic feet per second
°F	Degrees Fahrenheit
ft	feet
in	inch/inches
mg/L	milligrams per liter
MW	megawatts
NTU	Nephelometric Turbidity Units
µS/cm	micro Siemens per centimeter
pH	hydrogen ion concentration
%	percent
sec	second

1. Introduction

This report presents the results of a Watershed Assessment Study and Plan for Fish Habitat Restoration in the Meduxnekeag River Watershed, titled; "Wolastoq (Saint John River) Watershed Assessment and Management Plan, Meduxnekeag Subbasin" (hereinafter, "WAS/Plan"). The study was conducted by the United States (U.S.) Army Corps of Engineers (USACE) in partnership with the Houlton Band of Maliseet Indians (HBMI) which requested assistance in 2009. The Meduxnekeag River is a tributary of the Wolastoq (Saint John) River, which flows through HBMI Tribal Lands in Littleton and Houlton, Maine (Figure 1-1). This report was prepared by AECOM and DK Water Resource Consulting under contract to the USACE.

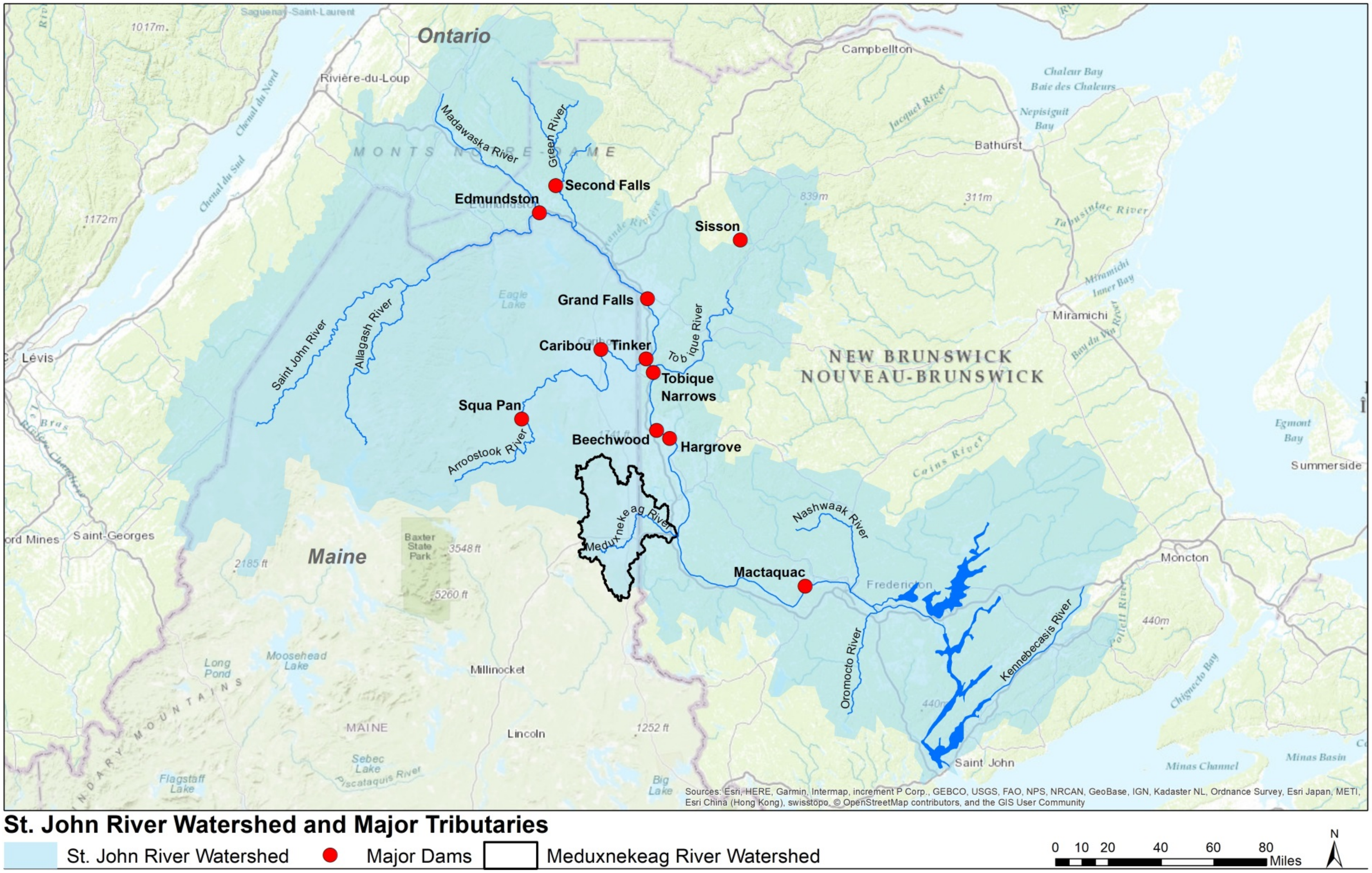
The USACE authority for partnering in the development of WAS originates with Section 729 of the Water Resources Development Act (WRDA) of 1986, Public Law 99-662 (100 Statute 4164, as amended (33 U.S. Code 2267a). That authority was modified by Section 2011 of the WRDA of 2007, Public Law 110-114 (33 U.S. Code 2269) to allow studies that may not result in authorized water resources projects. Section 203 of the WRDA of 2000, Public Law 106-541 (114 Statute 2572), as amended establishes the USACE Tribal Partnership Program, and authorizes USACE to carry out water-related planning activities and studies (including watershed assessments) and to determine the feasibility of undertaking water resources development projects that will substantially benefit Indian tribes and are located primarily within Indian country. These authorities provide the basis for the USACE and tribes to cooperatively develop WAS/Plans such as that presented in this report for the Meduxnekeag River Watershed.

This WAS/Plan for the Meduxnekeag River Watershed is focused on collaboration between partners, rightsholders, and stakeholders to develop a broad set of recommendations to restore diadromous fish populations, specifically within the Meduxnekeag River Watershed, and to improve the overall watershed health to support those populations. Beyond the scope of this document, the ultimate goal of trans-boundary rightsholders and stakeholders is to use this WAS/Plan as a model for other subwatersheds of the Saint John River (and the Saint John River Watershed, itself) to assess the water resources (physical, chemical, and biological components) within the international watersheds, identify problems and opportunities, and recommend actions for improving native fish habitat.

1.1 History and Background

The Maliseet Indians refer to themselves as Wolastoqiyik, meaning "People of the Beautiful River", in reference to the "Wolastoq", the Maliseet name for the Saint John River. Today, the Maliseets primarily live in New Brunswick, Canada with about 6,000 people comprising the Maliseet First Nations. A smaller contingent resides in the United States and comprises HBMI with 1,804 members currently living along the Meduxnekeag River. The Maliseet Tribe (the Tribe) was federally recognized as a governing body in 1980.

HBMI and their First Nations counterpart in Canada are working towards improving wild Atlantic salmon (*Salmo salar*) returns, maintaining unique, local genetic stocks, and improving habitat conditions within the Saint John River Watershed for salmon and related fisheries. In 2004, the Maliseet First Nations founded the Maliseet Nation Conservation Council (MNCC), a non-profit organization that works collaboratively with other Canadian organizations such as the Department of Fisheries and Oceans (DFO) Canada to co-manage and conserve natural resources in traditional Maliseet territory. One of the major challenges that MNCC faces is the management of international watersheds (i.e., implementation of trans-boundary efforts within Tribal/First Nation lands in U.S. and Canadian waters). MNCC is working with HBMI to build relationships within the U.S. in order to restore wild Atlantic salmon runs and preserve native fisheries.



Adapted from: USACE 2011

Figure 1-1. Saint John River Watershed Subbasins Within the U.S. and Canada

In 2009, HBMI requested support from the USACE in restoring diadromous fish populations to the Meduxnekeag River Watershed, within the context of watershed planning efforts in the greater Saint John River Watershed. The USACE conducted a reconnaissance study under Section 203 (Tribal Partnership Program) of the WRDA 2000, as amended, to determine the federal (USACE) interest in partnering with HBMI. Initial USACE funding was used to document the reconnaissance study findings in a Section 905(b) report (required reconnaissance phase, before the Section 729 Watershed Assessment could be initiated). As part of the reconnaissance phase, several meetings were held with the Tribe, state and federal agencies, Canadian agencies, the International Joint Commission (IJC), watershed associations, and the general public. The output of this stakeholder and rightsholder coordination revealed a shared vision to improve the habitat and migration of Atlantic salmon and other native fish species throughout the Saint John River Watershed. The 905(b) report concluded that there was federal interest in proceeding with a watershed assessment or ecosystem restoration feasibility study; the report was approved by the USACE North Atlantic Division on June 14, 2011. The USACE and the HBMI executed a study cost-sharing agreement for the WAS/Plan on March 19, 2014

The Saint John River Watershed is large and difficult to assess in its entirety. Therefore, USACE and HBMI proposed to develop this WAS/Plan focused on the Meduxnekeag River Watershed (a subbasin to the Saint John River Watershed). This WAS/Plan evaluates problems and opportunities and identifies recommended actions to be undertaken by various partners, stakeholders, and rightsholders in order to achieve a balance between native fish habitat and other (potentially competing) watershed goals; it includes an evaluation of downstream activities or processes that are interrelated with resources of the Meduxnekeag River Watershed. The recommended actions may potentially lead to USACE-funded project(s), other studies, or additional Saint John River subbasin assessments. However, the USACE, together with an eligible non-federal sponsor (tribe or other), could complete watershed assessments for any of the Saint John River Watershed subbasins, such as the Meduxnekeag River Watershed, thereby achieving the “shared vision” of a Saint John River Watershed Assessment and Management Plan for native fish habitat restoration.

1.2 Purpose of the Watershed Assessment and Management Plan

The purpose of this WAS/Plan is to support the recovery of Atlantic salmon by restoring the Meduxnekeag River, riparian habitat, and watershed. The need for the recovery of Atlantic salmon is to support HBMI’s cultural practices and to ensure that the species is available for future generations of U.S. citizens to enjoy.

This document develops, assesses, and prioritizes options to restore fish habitats and habitat connectivity to maximize the extent to which the Meduxnekeag River Watershed can support diadromous and native fish populations. It assembles new and existing watershed information, presents restoration plan options, and provides a “roadmap” for restoration of the Meduxnekeag River Watershed. This plan is designed to be dynamic and adaptive. As new information is gained, the plan should be updated as needed. The restoration of Atlantic salmon populations to the Meduxnekeag River Watershed is a primary goal of the Tribe. Therefore, this document focuses on the restoration of Atlantic salmon populations and habitats, within the context of diadromous populations and habitats, with the understanding that improvements made to the fish habitat of the Meduxnekeag River Watershed will benefit all native diadromous species.

This WAS/Plan also provides a study framework to leverage existing information and data sources. These resources were obtained from HBMI, state, federal, and non-governmental sources, including, but not limited to, the following:

- Watershed Based Plan, Southern Aroostook Soil and Water Conservation District (SASWCD) (SASWCD 1993);
- Electrofishing Data from the Meduxnekeag River and Tributaries, Maine Department of Inland Fisheries & Wildlife (MDIFW) (MDIFW 2008);
- Fluvial Geomorphology and Culvert Assessment Report (Field 2010);

- Section 203 Studies 905(b) WRDA Analysis Report (USACE 2011);
- Canadian Rivers Institute (CRI), The Saint John River: A State of the Environment Report (CRI 2011);
- Meduxnekeag River Lowery Bridge to Covered Bridge Stream Restoration Plan (Field 2013);
- Meduxnekeag River Watershed Management Plan (SASWCD 2015);
- Preliminary Draft Outline Watershed Assessment Study (USACE 2016a);
- Ongoing water quality and hydrological monitoring data (HBMI 2017; USGS 2018);
- Ongoing stream crossing assessment data, from multiple partner sources, including HBMI, maintained in the “Maine Stream Habitat Viewer” tool (Maine DMR 2018); and
- Ongoing annual Atlantic salmon monitoring data (DFO Canada 2018a).

The USACE has also prepared a Project Risk Register, Decision Management Plan, Decision Log, Public Involvement Plan, and Review Plan as part of this WAS/Plan, which are requirements for the USACE planning process. These documents are included as appendices (electronic-only) to this report.

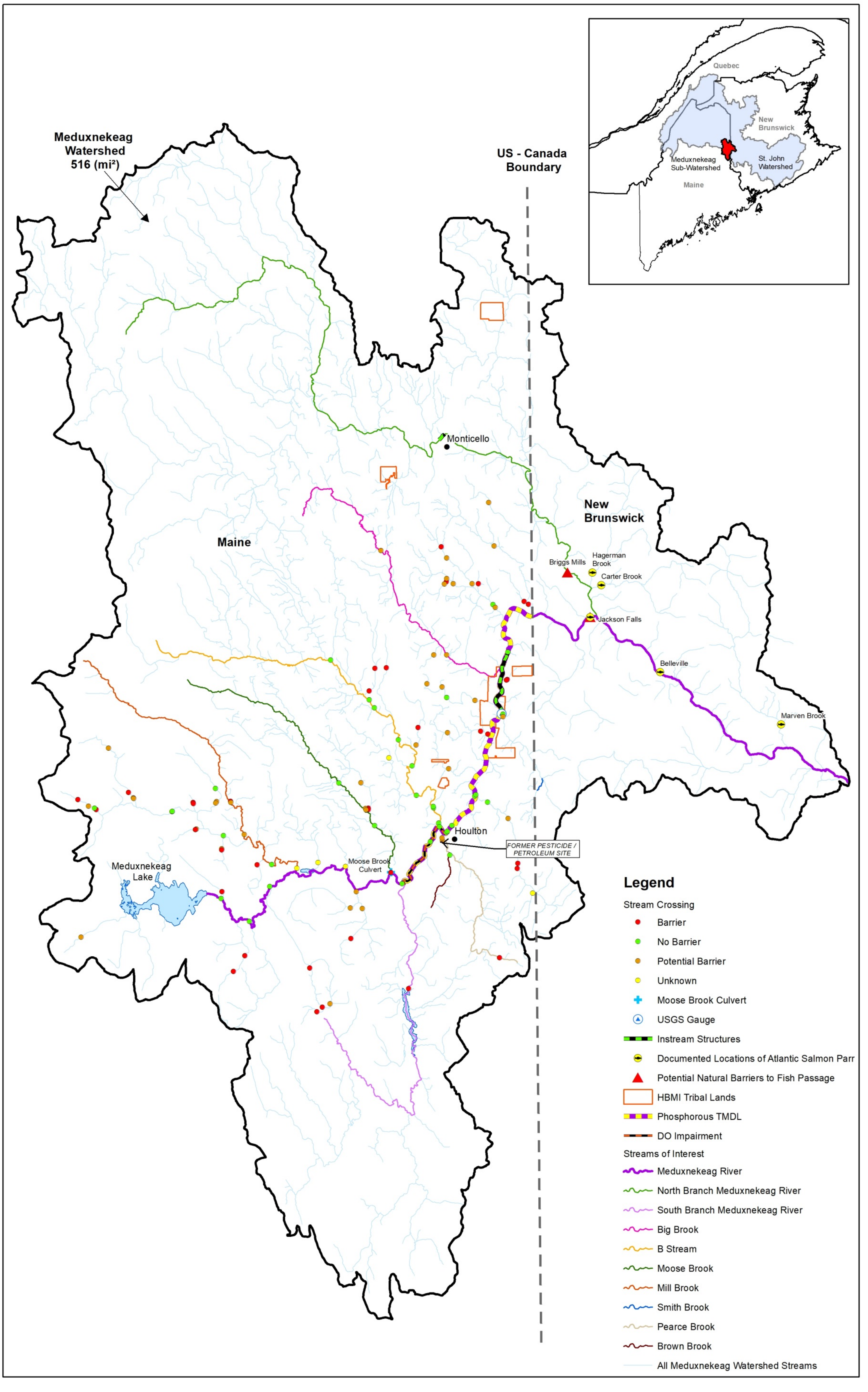
1.3 Watershed Location

1.3.1 Saint John River Watershed

The Saint John River originates in northern Maine at Fifth Saint John Pond, where the river flows through northern Maine parallel to the Quebec boundary for about 117 miles (Davies et al. 1999). It then turns east, where it ultimately forms the boundary between Maine and New Brunswick Canada, draining water from eastern Quebec. It subsequently flows southeast through New Brunswick, discharging into the Bay of Fundy (CRI 2011) at Saint John, New Brunswick (Figure 1-1). The river drops 1,578 feet (ft) in elevation between its headwaters and its termination point at the Bay of Fundy (CRI 2011). Approximately 51 percent (%) of the watershed lies in New Brunswick, while 36% is in Maine, and 13% is in Quebec (CRI 2011), as shown in Figure 1-1.

1.3.2 Meduxnekeag River Watershed

The Meduxnekeag River Watershed is located in the southeast portion of Aroostook County, Maine and flows through Maliseet Tribal Lands in Littleton and Houlton (Figure 1-1 and Figure 1-2). The Meduxnekeag River covers a total of approximately 38 river miles from its headwaters at Meduxnekeag Lake to its confluence with the Saint John River in Canada. As depicted in Figure 1-2, the Meduxnekeag River Watershed is a subbasin of the Saint John River Watershed; it comprises an area of 426 square miles within Maine, including the North Branch, South Branch, and mainstem of the Meduxnekeag River. The Meduxnekeag River Watershed contains all, or portions of, the towns of Hodgdon, Amity, Cary Plantation, Houlton, Linneus, Ludlow, Littleton, Hammond, and Monticello. The total area of the Meduxnekeag River Watershed (including Canadian lands), depicted in Figure 1-2, is 516 square miles.



Source: USACE 2011

Figure 1-2. Overview of the Meduxnekeag River Watershed

1.4 Study Authority and Guidance

In March 2011, the USACE completed a Section 905(b) WRDA Analysis, prepared under the authorization of Section 203 and Section 729, WRDA 2000, Tribal Partnership Program. The Implementation Guidance for Section 203 of WRDA 2000, Tribal Partnership Program was amended by Section 2011 of the WRDA of 2007 to expand the types of activities that are authorized under the Tribal Partnership Program. The 2007 expansion authorizes watershed assessment and planning activities that do not necessarily lead to project implementation. Funds were appropriated in fiscal year 2009 to conduct the reconnaissance phase of this WAS/Plan. The Meduxnekeag River Watershed is located outside of the Gulf of Maine Distinct Population Segment (DPS), and is considered part of the Outer Bay of Fundy population of Atlantic salmon (see Section 2.7.3.3.1), therefore planning activities to recover the federally listed endangered Atlantic salmon within the Meduxnekeag River Watershed are consistent with the U.S. Endangered Species Act of 1973, 16 U.S. Code Section 1531.

The planning activities described in this WAS/Plan follow the USACE process for completing watershed assessments (USACE 2016b). This watershed planning guidance also applies to this study and has been incorporated herein, by following six key steps to an effective watershed planning process:

1. Identify Problems and Opportunities;
2. Inventory and Forecasting;
3. Identify and Screen Measures;
4. Formulate Initial Array of Strategies;
5. Refine Initial Array and Evaluate Focused Array of Strategies; and
6. Strategy Comparison and Selection.

1.5 Watershed Goals and Vision Statement

As discussed in Section 1.2, the purpose of this WAS/Plan is to support the recovery of Atlantic salmon by restoring the Meduxnekeag River, riparian habitat, and watershed. The need for the recovery of Atlantic salmon is to support HBMI's cultural practices and ensure that the species is available for future generations of U.S. citizens to enjoy. The goals of this WAS/Plan are intended to align with HBMI's restoration goals for the Meduxnekeag River Watershed, as well as with the USACE-specific guidance identified in Section 1.4. The WAS/Plan goals include the following:

- Watershed Plan
  - Assess watershed characteristics and conditions;
  - Identify watershed issues/problems;
- Fisheries Restoration Plan
  - Identify and prioritize potential restoration projects to improve native fish passage within the watershed and downstream habitats, including:
    - Improvement of native fish habitat and fish passage (upstream/downstream) within the watershed;
    - Improvement of water quality;
    - Restoration of native Atlantic salmon and other native and diadromous fish populations; and
    - Creation of a "roadmap" for future watershed management planning efforts within the greater Saint John River Watershed.

There are 30 fish species that occur within the Meduxnekeag Watershed (Baum 1982; MDIFW 2008; DFO Canada 2018a). The populations of diadromous fish species, particularly Atlantic salmon, have been substantially reduced from historical abundances because of fish passage and habitat concerns both within and outside of the watershed. Atlantic salmon require access to cool, clear freshwater streams with suitable depth, flow, and cobble/gravel substrate for spawning with similar requirements for the rearing of juveniles. As individuals mature, they require downstream access to the ocean, where they mature, then migrate back to their natal streams to spawn (see Section 2.7.3.3.4 for specific habitat requirements by life stage). Access to the Meduxnekeag River Watershed by adult Atlantic salmon is restricted by barriers both in the Saint John River (dams), as well as in the Meduxnekeag River (culverts and water quality).

With respect to the historical and existing fish populations and habitat resources within the Meduxnekeag River Watershed, HBMI and the USACE developed the following shared vision statement. This statement is broad enough to encompass various goals and objectives of individual partners, stakeholders, and rightsholders, and includes sufficient detail to allow for subsequent development of specific planning objectives and associated metrics:

Shared Vision Statement – Meduxnekeag River Watershed
Since time immemorial, the Maliseet people have maintained an inherent connection to the Meduxnekeag River and the natural resources that it supported. This connection is foundational to Maliseet customs, language, and culture. Diadromous fish species were once a primary food resource for the Maliseet people, but now some of those species are absent from the watershed. Through restoration of the watershed ecosystem, the Maliseet Leaders seek the return of native diadromous fish species, particularly Atlantic salmon, to the watershed to re-connect the Maliseet people and their future relations with their heritage. This will also ensure all people living in the Meduxnekeag River Watershed, as well as the greater Saint John River and the Bay of Fundy, will have access to a fully-functioning ecosystem.

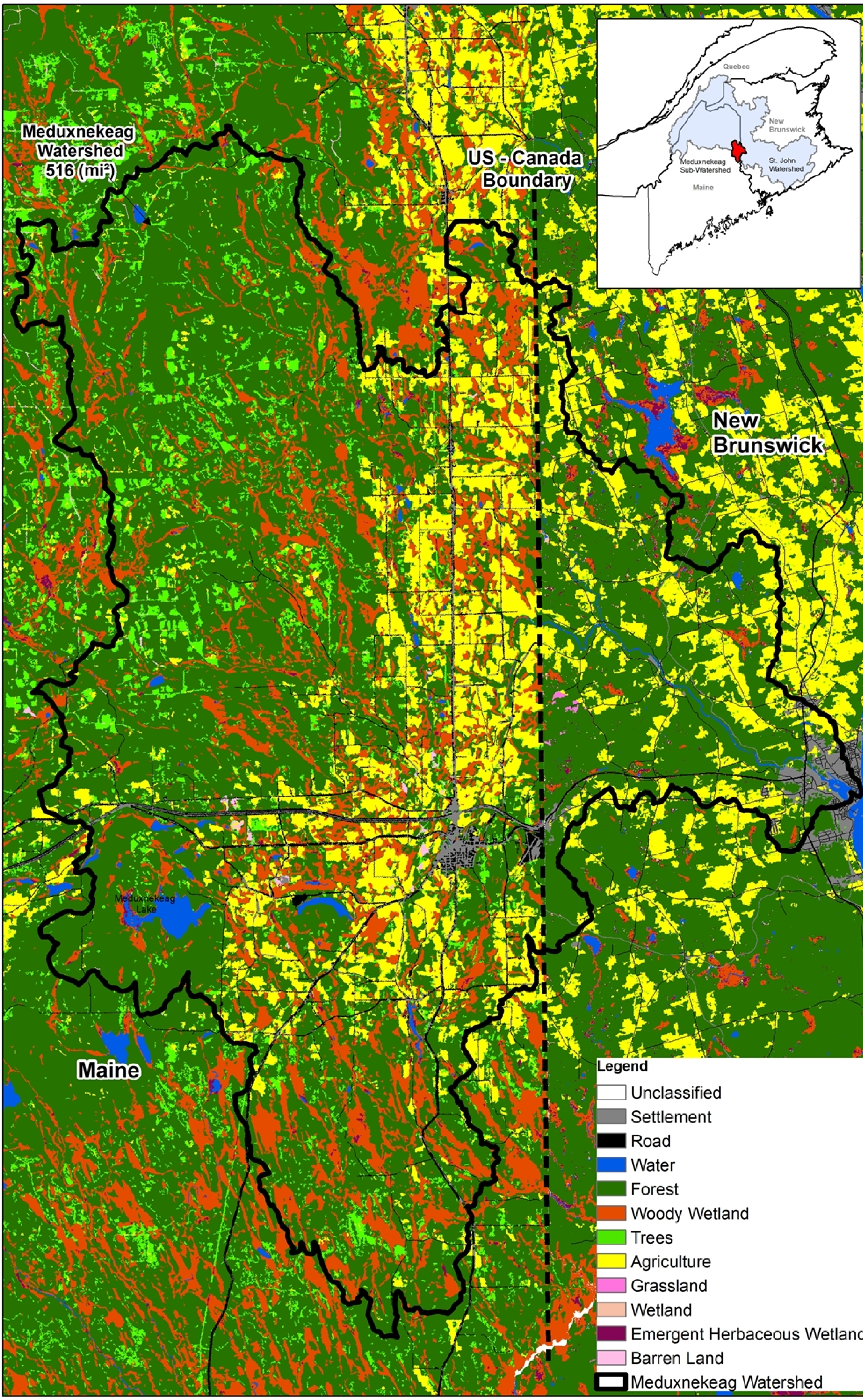
2. Watershed Assessment

As discussed in Section 1.2, the purpose of this WAS/Plan is to support the recovery of Atlantic salmon by restoring the Meduxnekeag River, riparian habitat, and watershed. The need for the recovery of Atlantic salmon is to support HBMI's cultural practices and to ensure that the species is available for future generations of U.S. citizens to enjoy. Background regarding the existing watershed and river conditions is presented in Sections 2.1 through 2.9., including existing conditions of water quality, fish resources, and fish habitat.

2.1 Existing Watershed Conditions

The Canadian Rivers Institute published "A State of the Environment Report" on the Saint John River (CRI 2011) which serves as the primary source of information to characterize the Saint John River ecosystem; it is used extensively within this section to characterize the Meduxnekeag River Watershed conditions within the greater Saint John River Watershed. Additional information was incorporated from other watershed planning documents and technical reports for the Meduxnekeag River (SASWCD 2015; Field 2010; SASWCD 1993).

The majority of the land within the U.S. portion of the Meduxnekeag River Watershed is forested (approximately 73%), particularly in the western portion of the watershed, but substantial agricultural lands (approximately 20%) are widespread on the minimally sloped uplands bordering the mainstem and the lower ends of the major tributaries (SASWCD 2015). Land cover over the remaining approximately 7% of the U.S. portion of the watershed is mostly evenly divided between urban, open water/wetland, and other (barren, grass, or shrub) types of land covers (SASWCD 2015). Similarly, land within the Canadian portion of the Meduxnekeag River Watershed is forested (approximately 83%), followed by agricultural (approximately 6%), and wetlands (approximately 5%), with the remaining approximately 6% is mixed-use land cover types (CRI 2011). The land cover for the entire Meduxnekeag River Watershed is shown in Figure 2-1.



Sources: Maine GIS 2006; SNB 2018

Figure 2-1. Land Cover within the Meduxnekeag River Watershed

The most highly developed portion of the watershed is in the town of Houlton, Maine which includes a concentrated urban area (including residential, light industrial, and retail development) along the river, as well as along Pearce Brook, a tributary to the Meduxnekeag River.

The State of Maine, Department of Environmental Protection (Maine DEP) lists portions of the Meduxnekeag River as impaired due to low dissolved oxygen (DO) concentrations attributed to excessive algal growth from nutrient enrichment (Maine DEP 2000). These water quality issues are related to land use practices, non-point and point source discharges, and hydrologic alteration (USACE 2011). Pearce Brook has experienced water and sediment contamination due to petroleum and pesticide leaks from underground storage tanks (SASWCD 2015). In 1998, petroleum and pesticide releases from two separate sites adjacent to Pearce Brook were responsible for the inclusion of those sites on the National Priority List (SASWCD 2015). Historical data from these sites indicated that 30 underground storage tanks (gasoline and diesel fuel) previously existed within 1,000 feet of Pearce Brook. A large number of these tanks were unregistered and, while many were removed in 1981, 1982, and the early 1990s, it is unknown if all were removed. Several of the tanks had leaked petroleum into the ground; the leaked petroleum traveled along utility trenches causing vapor intrusion concerns for nearby businesses and creating a substantial impact on the water quality of Pearce Brook (SASWCD 2012).

During previous studies, HBMI and USACE identified a number of issues and concerns within the Meduxnekeag River Watershed, primarily related to water quality, fish habitat, habitat connectivity, and the reduction (and loss) of native diadromous fish populations. A summary of these issues, identified by the USACE and HBMI, and potential opportunities to address them, are listed in Table 2-1.

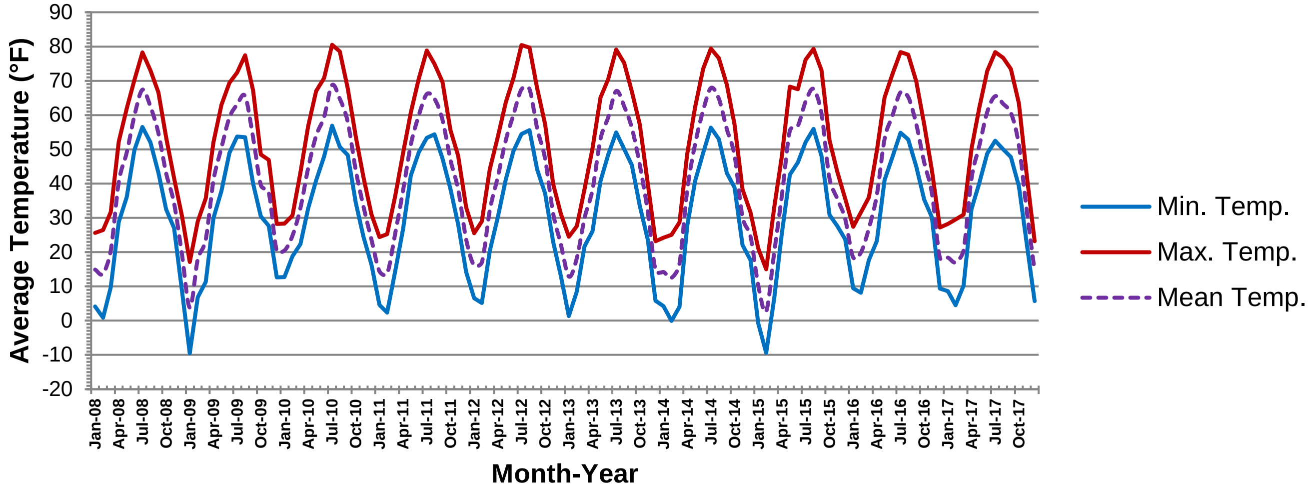
Table 2-1. Watershed Problems and Opportunities

Watershed Problems	Watershed Opportunities
Reduced diadromous fish populations and salmon returns.	Preserve the cultural and ecological role of diadromous fishes in the Meduxnekeag River Watershed, and increase the number of salmon returns to the watershed.
Lack of river connectivity via dams, culverts, or other barriers.	Improve river connectivity and open new habitat to diadromous fishes.
Altered flow regime and channelization.	Restore a more natural flow regime to promote habitat diversity within the river.
Loss of Atlantic salmon from the U.S. portion of the watershed and diadromous fish spawning/rearing habitat.	Improve aquatic habitat quality and restore a self-sustaining population of Atlantic salmon.
Poor or declining water quality, including water temperature, dissolved oxygen, and sedimentation.	Protection, conservation, and restoration of the Meduxnekeag watershed. Implementation of the 2015 watershed plan.
Riparian habitat degradation resulting in poor instream habitat, streambank and channel instability and temperature increases.	Restore riparian buffers and encourage bioengineered approaches to streambank stabilization, using natural materials.
Non-native and invasive fish species.	Reduce predation, competition, and fishing pressure.
Genetic alteration of remaining wild Atlantic salmon.	Protect and preserve the watershed-specific genetics of salmon stocks. Provide scientific data and information to support a comprehensive watershed fisheries plan.
Incidental catch of Atlantic salmon by anglers.	Increase fisheries management efficiency.

Source: USACE 2011

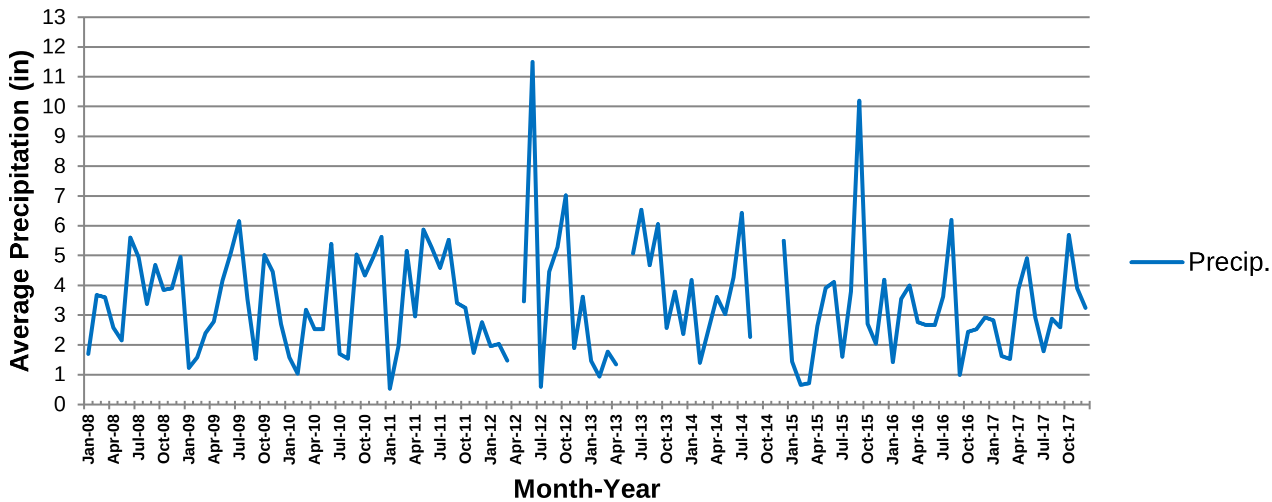
2.2 Climate

The Meduxnekeag River Watershed experiences seasonal temperature variations consistent with the humid, continental climate zone of the northeastern U.S. and Canadian Maritimes. The warmest month of the year is July, with an average maximum temperature of 78.4 degrees Fahrenheit (°F), while the coldest month of the year is January, with an average minimum temperature of 0.2°F. The average annual precipitation is 38.6 inches (in), which includes an average snowfall amount of 90 to 100 in. Precipitation is generally evenly distributed throughout the year, with a large part of the total annual runoff generated from spring snowmelt (SASWCD 1993). The frost-free period is about 120 days, which allows for a growing season that lasts between 100 and 125 days. Average monthly precipitation data including temperature and precipitation trends at Houlton, Maine are displayed in Figure 2-2 and Figure 2-3. Water temperature, an important climatic factor for native fish habitats, is discussed in Section 2.6.3.1.



Source: National Oceanographic and Atmospheric Administration (NOAA) 2018

Figure 2-2. Monthly Average Temperature at Houlton, Maine



Source: NOAA 2018 (months missing from original dataset: April 2012, May 2013, September 2014, November 2014)

Figure 2-3. Monthly Average Precipitation at Houlton, Maine

2.3 Soils and Geology

Most of the soils in the Saint John River Basin are morainal (glacially derived) sediments that were laid down at the end of the last glacial event, with pockets of more recent alluvial (deposited by flowing water) sand, gravel and cobble sediments along the banks and flood plains of the river and its tributaries (CRI 2011). Soils are dominated by humo-ferric podzols and gray luvisols; both are forest soil types typical within Maine and New Brunswick (CRI 2011). The humo-ferric podzols are underlain by sandy parent material including sandy glacio-fluvial deposits that underlie much of the Saint John River Basin (CRI 2011). Luvisolic soils are generally found in areas with underlying loamy tills derived from underlying sedimentary rocks (CRI 2011).

Most of the soils within the Meduxnekeag River Watershed are classified as highly erodible or potentially highly erodible (USDA 1994) with overburden of variable thickness. Most of the arable soils are in agricultural areas and the steep, stony, and poorly drained soils are in forests. The majority of land surfaces are rolling, with hills reaching an elevation of 200 to 500 ft above the valley floors. Some steeper banks are present within the watershed, primarily in the vicinity of Houlton, Maine (SASWCD 2015).

United States Department of Agriculture (USDA) soil surveys indicate that the agricultural land in the watershed consists primarily of shallow soils (Mapleton and Thorndike). All but one of the soil types are classified as prime farmland or farmland of statewide importance (SASWCD 2015). Bedrock is typically encountered at 12 to 28 in below the mineral soil surfaces and the seasonal high water table occurs in the bedrock, at a depth of more than five feet below the soil surface, in a zone of moderate permeability (SASWCD 2015).

2.4 Hydrology

The Meduxnekeag River is approximately 38 miles long from the headwaters in Maine to the outlet at Woodstock, New Brunswick, Canada. There are 54 lakes and ponds in the watershed; the largest is Meduxnekeag Lake (1,057 acres) (Baum 1982) (Figure 1-2), also called Drew’s Lake. In the upper watershed, Meduxnekeag Lake and many wetland areas, beaver impoundments, and natural log jams help attenuate the peak flow in the mainstem of the Meduxnekeag River (SASWCD 2015). The lower portion of the Meduxnekeag River flows mainly through areas that have a confined narrow valley with little to no floodplain, which results in higher flows and greater depths compared to rivers with wide floodplains (SASWCD 2015).

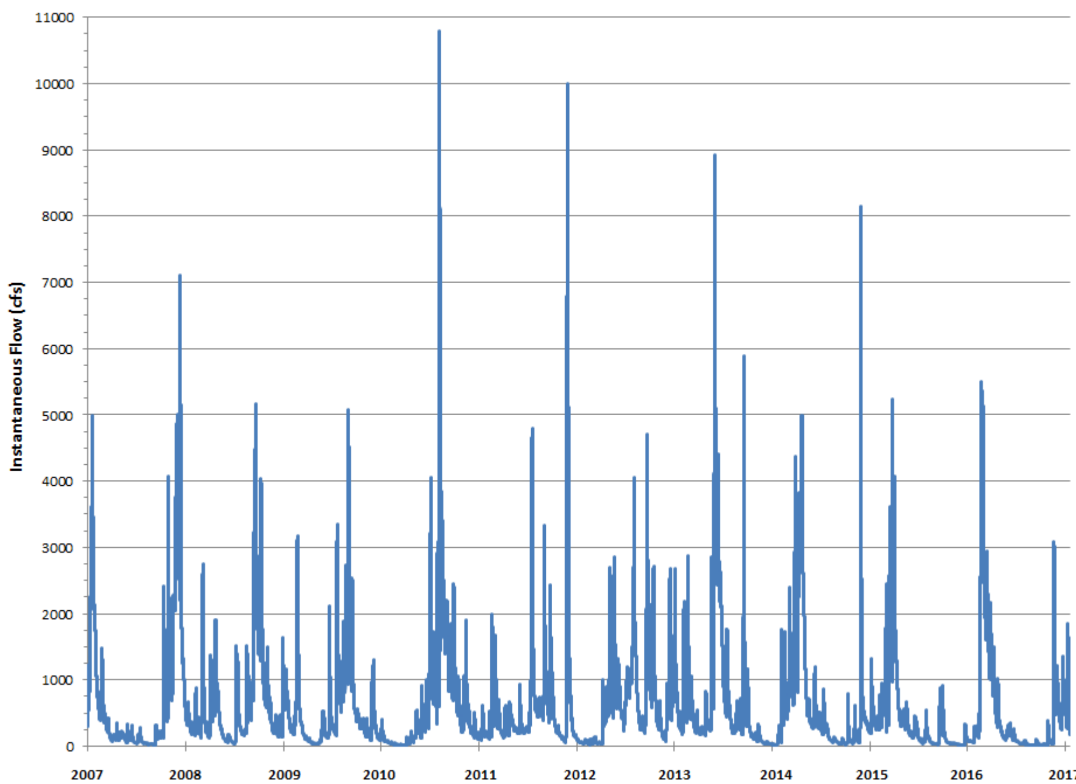
Upstream from Woodstock, at the confluence with the Saint John River in New Brunswick, the Meduxnekeag River divides into two branches near the U.S. border on the Canadian side – the mainstem and the North Branch (Figure 1-2). The mainstem has a total of 283 miles of tributary streams (Baum 1982), including Moose Brook and South Branch, which are the largest tributaries. In this reach, the gradient is approximately 11 feet per mile (Baum 1982). The North Branch is 22.5 miles long and joins the mainstem in Wakefield, New Brunswick (Frost 2002). The North Branch includes a total of 169 miles of tributary streams (Baum 1982). The gradient of the North Branch is 54 feet per mile (Baum 1982). The lower portion of the Meduxnekeag River has historically experienced channelization in areas to support historical logging operations (SASWCD 2015). Although channelization has not occurred since 1934, it has had long-term, negative impacts on the habitat quality in these reaches, as described in Field (2010).

The United States Geological Survey (USGS) maintains a single gaging station on the Meduxnekeag River, adjacent to tribal lands at the Lowery Road Bridge in Houlton, Maine. This gaging station has been in operation recording discharge measurements since 2006 (Table 2-2). In recent years, other parameters have been added as shown below in Table 2-2. For the period of record (2006 to present), the average annual flows range from approximately 435 to 754 cubic feet per second (cfs), with peak historic daily high flow (10,800 cfs), and low flow (9 cfs) both occurring in 2010 (USGS 2018). Figure 2-4 shows instantaneous discharge (flow) measured at the gaging station between 2007 and 2017.

Table 2-2. Meduxnekeag River Monitoring Parameters at the Lowery Road Bridge USGS Gaging Station (01018035)

Parameter	Date Range	Instrumentation
Water Temperature	2011 – present	Thermistor/sonde
Discharge	2006 – present	Chart/datalogger
Gage Height	2007 – present	
Specific Conductivity	2018 – present	Sonde
Dissolved Oxygen (DO)		
Hydrogen ion concentration (pH)		
Turbidity		

Source: USGS 2018



Source: USGS 2018

Figure 2-4. Meduxnekeag River Instantaneous Flow at the Lowery Road Bridge USGS Gaging Station (01018035) Between 2007 and 2017.

2.5 Fish Passage

2.5.1 Dams

There are 11 hydroelectric power dams located along the Saint John River (Davies et al. 1999), as shown in Figure 1-1 and Table 2-3. Only one of these is downstream from the Meduxnekeag River. New Brunswick (NB) Power's Mactaquac Dam is downstream of the confluence of the Meduxnekeag with the Saint John River, approximately 12 river miles upstream from Fredericton, New Brunswick, and acts as the first upstream barrier to the migratory pathway of diadromous species in the Saint John River (NB Power 2016; CRI 2011). Since the confluence of the Meduxnekeag River is located just upriver from the headpond of the Mactaquac Dam, it is the only upstream barrier to fish migrating into the Meduxnekeag River (see Figure 1-1). More than 40 at-risk fish species use the dam's headpond (on the Saint John River) – 11 of those are diadromous, including Atlantic salmon and river herring (NB Power 2016). Upstream migration of Atlantic salmon is currently managed at the Mactaquac Dam by corralling fishes into collection facilities located on the downstream side of the powerhouse and transporting them upstream by truck. The dam currently has no infrastructure for the downstream movement of fishes from the headpond past the dam. In order to successfully navigate downstream, an individual fish must move through a series of turbines, spillways, or over the diversion sluiceway, the latter of which is only accessible during periods of high water (NB Power 2016). The Mactaquac Dam, located upriver from the Bay of Fundy, is the only major infrastructure obstacle to ocean migratory species accessing the mouth of the Meduxnekeag watershed.

Table 2-3. Hydroelectric Stations on the Saint John River and Major Tributaries

River/Dam	Location	Year Built
Saint John River		
Mactaquac Dam	Fredericton, New Brunswick, Canada	1968
Beechwood Dam	Beechwood, New Brunswick, Canada	1957
Grand Falls Dam	Grand Falls, New Brunswick, Canada	1928
Monquart Stream (tributary to Saint John River)		
Hargrove Dam	Bath, New Brunswick, Canada	1966
Tobique River (tributary to Saint John River)		
Tobique Narrows Dam	Perth-Andover, New Brunswick, Canada	1953
Sisson Dam	Lorne Parish, New Brunswick, Canada	1965
Aroostook River (tributary to Saint John River)		
Tinker Dam	Aroostook Junction, New Brunswick, Canada	1906
Caribou Dam	Caribou, Maine, U.S.	1890
Squa pan Dam	Masardis, Maine, U.S.	1941
Green River (tributary to Saint John River)		
Second Falls Dam	Edmundston, New Brunswick, Canada	1924
Madawaska River (tributary to Saint John River)		
Edmundston/Madawaska Dam	Edmundston, New Brunswick, Canada	1918

Source: CRI 2011

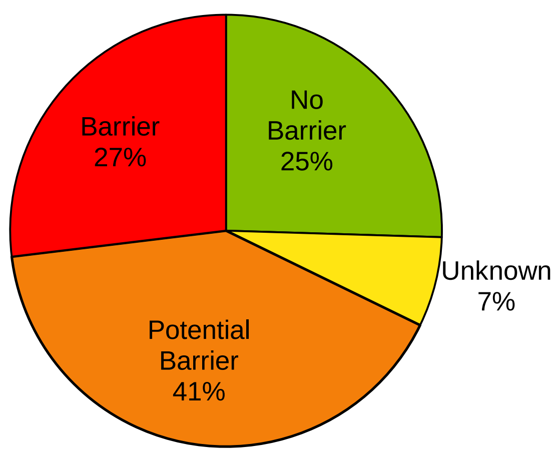
Historically, small dams were built on the Meduxnekeag River to provide power to mills or to assist with logging activities. The last of these dams, associated with a sawmill in Houlton, was removed in 1947 and resulted in a major improvement to natural flow conditions back to the mainstem of the Meduxnekeag River (SASWCD 2015). Currently, the only remaining dam on the mainstem of the Meduxnekeag is a low-head water control structure, located at the outlet from Meduxnekeag Lake, at the headwaters of the

Meduxnekeag River (SASWCD 2015). Since this dam is located at the headwaters, it is not considered to be a concern for fish passage within the majority of the watershed. There is also a low-head dam on the South Branch of the Meduxnekeag River (a tributary to the mainstem) with no fish passage, located approximately 3.5 river miles upstream from the confluence with the mainstem of the Meduxnekeag River (see Figure 1-2). The elevated water temperatures associated with this impoundment result in this tributary having some of the highest observed water temperatures within the watershed, despite the presence of cold water seeps within this tributary (HBMI 2017).

2.5.2 Stream Crossings - Culverts

Perched (overhanging) or undersized culverts function as barriers to upstream and downstream fish passage and can disrupt stream ecosystem functions, such as sediment/debris transport, nutrient loadings, and aquatic organism passage. Perched culverts located throughout the watershed prevent the safe passage of diadromous fishes (USACE 2011).

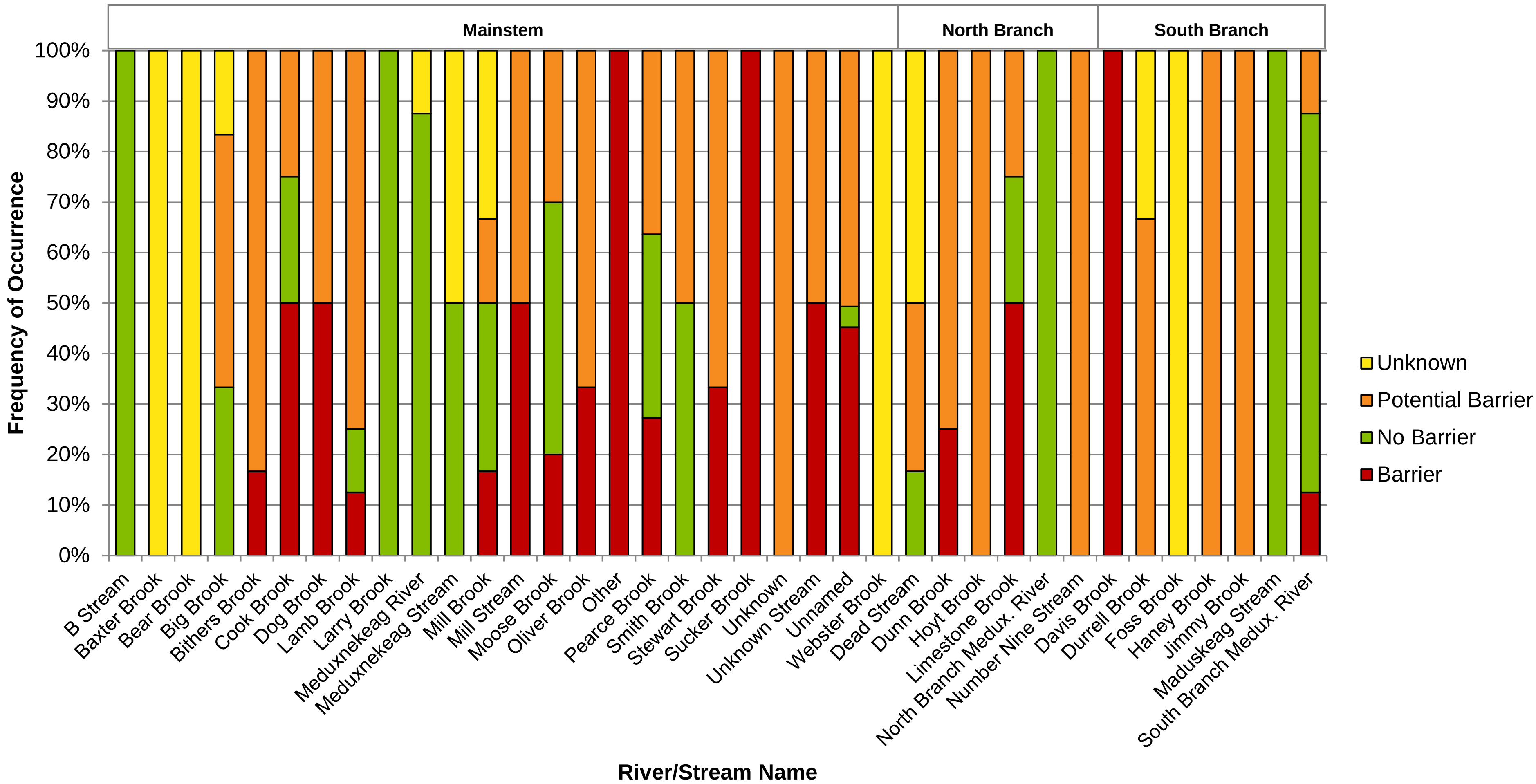
The Maine Department of Marine Resources (Maine DMR) maintains a database of stream crossings as part of their “Maine Stream Habitat Viewer” tool (Maine DMR 2018). This tool is a collective database of stream crossings from inventories conducted by various partners across the state of Maine. For the Meduxnekeag River, this database includes the stream crossing/culvert assessments conducted throughout the watershed by HBMI, MDIFW, and The Nature Conservancy (TNC). This database includes an assessment and inventory of 233 stream crossings (bridges or culverts) in the Meduxnekeag River Watershed (Maine DMR 2018). Of the 233 stream crossings inventoried, 25 are excluded as “no crossing,” meaning a bridge/culvert was not observed during the survey, leaving 208 actual stream crossings in the watershed. Of the 208 actual stream crossings identified and surveyed in the Meduxnekeag River Watershed, 53 (25%) were categorized as “no barrier”, 14 (7%) were given an “unknown” barrier status, 85 (41%) were determined to be “potential barriers”, and 56 (27%) were considered to be “barriers” to fish passage. Figure 2-5 depicts the proportional classifications assigned to each stream crossing. Figure 2-6 depicts the categorization of potential barriers to fish passage (excluding the “no crossing” category) and the frequency of occurrence for each stream (and tributaries to those streams, where data is available) within the watershed.



Note: Stream crossings categorized as “no crossing” are excluded, since those locations do not present barriers to fish migration.

Source: TNC 2015; Maine DMR 2018

Figure 2-5. Classification of the 208 Stream Crossings Inventoried within the Meduxnekeag River Watershed



Note: North Branch and South Branch refer to the respective branches of the Meduxnekeag River.

Source: Maine DMR 2018; MDIFW 2001; USACE 2017

Figure 2-6. Relative Abundance of Fish Barrier Status at Stream Crossings in the Meduxnekeag River Watershed, Including Tributary Streams

There are 16 stream crossings on the mainstem of the Meduxnekeag River from its confluence with the Saint John River to the water control structure at the outlet of Meduxnekeag Lake (Maine DMR 2018). Only three stream crossings exist on the North Branch and eight stream crossings exist on the South Branch of the Meduxnekeag River (Maine DMR 2018). With the exception of the low-head dam at Hodgdon Mills Rd (at the South Branch), all of these stream crossings are bridges and do not pose fish passage concerns under most flow conditions. Therefore, diadromous fishes generally have full access to the various habitat features associated with the mainstem of the Meduxnekeag River.

Culverts are more typical for tributary stream crossings, such as those draining into the mainstem, North Branch, and South Branch of the Meduxnekeag River. Some of the major tributary streams contain culverts that are largely passable (barrier-free) for a considerable portion of their length, under most flow conditions. For example, B Stream is barrier-free for its entire 15 mile length, and Big Brook is barrier-free for approximately the first 1/3 of its length, with only potential barriers beyond that point. Other major tributaries contain culverts that do not allow for fish passage. This is especially problematic when the impassable culvert is at or near the confluence of the tributary with the mainstem of the Meduxnekeag River, such as the case for Pearce Brook and Moose Brook, where access is almost entirely restricted by barriers. Pearce Brook flows through downtown Houlton and has several watershed issues (fish passage, contaminated sediments/water, and depleted habitat) that require restoration (see Sections 2.1 and 3.3). Of all the major tributaries to the mainstem of the Meduxnekeag River, Moose Brook is considered to have the most restrictive access because of an impassable culvert that exists at its confluence with the mainstem of the Meduxnekeag River. Therefore, Moose Brook has been viewed as a restoration priority by several stakeholders and rightsholders including HBMI, TNC, Town of Houlton, and Natural Resource Conservation Service (NRCS); this is discussed further, and a photograph is included, in Section 3.3.6 (Moose Brook Culvert Replacement).

2.5.3 Natural Barriers

In addition to the anthropogenic barriers described above, there are also natural barriers that may restrict fish passage within the watershed. Natural falls, cascades, or other topographic features may limit the range of migration for diadromous fish species within the watershed. Atlantic salmon were reported on the mainstem of the Meduxnekeag River during the early part of the 19th century; however, in the North Branch, two natural obstructions at Oakville, New Brunswick appear to present barriers to their upstream migration. These presumed barriers, shown in Figure 2-7, are approximately 1.6 to 1.9 miles upstream from the confluence of the North Branch with the mainstem (near the Briggs Mill site). Due to the presence of these natural features, Atlantic salmon may not have historically occurred above this section of the North Branch of the Meduxnekeag River (Baum 1982). The Meduxnekeag River Watershed Association (MRWA) notes that Jackson Falls, located on the mainstem of the Meduxnekeag River, may also partially obstruct the upstream passage of fish species within the mainstem (Figure 2-8) under certain flow conditions (MRWA 2015), perhaps imiting the migration potential of diadromous fish species into the U.S. portion of the watershed. However, historical records document an “abundant” population of Atlantic salmon occurring in the Meduxnekeag in the early 19th century (Kendall 1935), as described in Section 2.7.3.3.2. This is also confirmed by HBMI historical accounts.

Photo Credit: AECOM

Figure 2-7. Natural Potential Barriers to Fish Migration in the North Branch of the Meduxnekeag River Near Oakville, New Brunswick (Canada) at the Briggs Mill Site.

Photo Credit: Meduxnekeag River Watershed Association (MRWA)

Figure 2-8. Jackson Falls during High-Flow Conditions in the Mainstem of the Meduxnekeag River, Near Oakville, New Brunswick (Canada).

2.6 Water Quality

Seasonal water quality issues have been documented within the Meduxnekeag River and its tributaries, including high sediment loads during runoff events, occasional algal blooms, and increased phosphorus concentrations during low-flow conditions (USGS 2005).

Aquatic habitat quality in the Meduxnekeag River Watershed is threatened by development, land use practices (including agriculture and timber harvesting), historical alteration of the river channel (explosive removal of habitat features to facilitate the downriver transport of logs), and flow alteration. Prior alterations have permanently changed some of the river habitat from a fast, cold-water habitat to a slow, warm-water habitat within certain reaches. Deposition of sediments derived from agriculture has filled in pools and caused the wetted channel to become wider and shallower than its natural form. These habitat changes have resulted in alterations to the aquatic community, particularly a decline in diadromous fish species and an increase in non-native generalist species, such as smallmouth bass, that do not require strict thermal limits or structured habitats with variable features (USACE 2011).

In 2015, a watershed-based management plan for the Meduxnekeag River Watershed was prepared under Section 319 of the Clean Water Act (SASWCD 2015) to address the causes of water quality impairments throughout the watershed. The purpose of this management plan was to "*document the sources of water pollution and present a strategic plan of actions needed to improve water quality*." To the extent that water quality is critical to the survival and spawning success of both diadromous and native fish species, successful implementation of the water quality projects outlined in the plan are critical to the ultimate success in restoring diadromous fish runs and aquatic habitat.

2.6.1 State of Maine Water Quality Classifications

The State has four classes for freshwater rivers (AA, A, B, C). In accordance with the State of Maine regulations, standards for water quality are different under the different classifications. In Class AA waters (the highest classification), waste discharges and impoundments are prohibited, and there is a high expectation to achieve natural conditions without degradation. Class A waters (the second highest classification after Class AA), are suitable for a number of uses, including (for the purposes of this plan), providing habitats for fishes and other aquatic life. Class B waters are the third highest classification and are suitable for fish habitats that are categorized as unimpaired. Class C waters have the least restrictive uses, and the lowest water quality criteria. A full summary of the Class A and Class B standards relevant to this plan can be found at Maine Revised Statues, Title 38: Waters and Navigation §465 (Maine DEP 2018).

The majority of the rivers, streams, and ponds in the Meduxnekeag watershed are designated as Class B by the State of Maine. The entire mainstem of the Meduxnekeag River from the outlet of Meduxnekeag Lake to the Canadian border is categorized as Class B. The tributaries to the Meduxnekeag River are Class B with the exception of the following four streams/rivers (and their tributaries), which are Class A. None of the waterbodies in the Meduxnekeag River Watershed are designated as Class AA or Class C:

- North Branch of the Meduxnekeag River and its tributaries above the Town of Monticello boundary with the unorganized territory of TC R2 WELS;
- Moose Brook and its tributaries, upstream of Ludlow Road in Ludlow;
- South Branch of the Meduxnekeag River and its tributaries, upstream of Oliver Road in Cary; and
- B Stream and its tributaries upstream of the Burnt Brow Bridge in Hammond.

The designated uses of the North and South Branches of the Meduxnekeag under the Class A and Class B standards are partially met, according to the Maine DEP 2016 Integrated Water Quality Monitoring and Assessment Report; this report indicates that there is insufficient information to determine attainment of some uses, specifically, within the mainstem between Meduxnekeag Lake and the confluence with the South Branch (Maine DEP 2016).

2.6.2 Pollutant Loading

Below the South Branch confluence with the mainstem of the Meduxnekeag River to the Canadian border, a Total Maximum Daily Load (TMDL) assessment has been approved for phosphorus (Maine DEP 2000). According to Maine DEP (2016), there have been ongoing low DO problems in the upper five miles of this segment (from the confluence of the mainstem of the Meduxnekeag River with the South Branch to the biomonitoring station S-364, located approximately 500 ft downstream from the Houlton Wastewater Treatment Facility (Figure 1-2). All freshwater fishes in the state of Maine are under a fish consumption advisory due to mercury, with an additional limitation of two fish meals per month from the Meduxnekeag River because of potentially high levels of Dioxins, legacy polychlorinated biphenyl (PCB), and legacy dichloro-diphenyl-trichloroethane (DDT) (Maine DEP 2016).

The impacts of nutrient enrichment and warming of the Meduxnekeag River have been documented by HBMI for many years (HBMI 2017). High temperatures, benthic algal growth, low DO concentrations, and fluctuating pH have all led to a reduction in the amount and quality of habitat for aquatic organisms and native and anadromous fishes. These issues are discussed in greater detail below. In general, water quality problems associated with nutrient enrichment are greater in downstream sections than in upstream sections (HBMI 2017).

Of particular importance to diadromous fishes is the prevalence of low DO concentrations related to a diurnal pattern of low oxygen concentrations at night (when plants and algae use more oxygen than they produce) and higher concentrations during the day (when plants and algae produce more oxygen than they use). These diurnal “swings” are attributed to excessive algal growth fueled by phosphorus, which has been documented in the South Branch of the Meduxnekeag River. Phosphorus control is identified as the primary mechanism for addressing low DO concentrations. The mainstem Meduxnekeag to the Canadian border, Oliver Brook, and tributaries to lower Pearce Brook have been identified as impacted by nutrient enrichment (Maine DEP 2016), stormwater runoff, and effluent from the Houlton wastewater treatment plant (Fretwell 2006)

In addition to nutrient inputs from agriculture, the river receives effluent from the Tate & Lyle Starch plant, which is regulated by the United States Environmental Protection Agency (US EPA) under the National Pollutant Discharge Elimination System (NPDES) permit number ME0002216. This facility is authorized to discharge 40,000 gallons per day of boiler blowdown and process wastewater, and 50,000 gallons per day of non-contact cooling water to the Meduxnekeag River at two outfalls located near the confluence of Moose Brook (Maine DEP 2008). However, such discharges are prohibited when the river flow is less than 15 cfs. The facility is required to monitor DO and restrict discharge when DO concentrations are less than certain thresholds. The facility’s NPDES permit allows for a daily maximum effluent temperature of 90°F with a pH range limitation of 6.0 to 9.0, a total Phosphorous monthly average limit of 0.5 milligrams per liter (mg/L), and a total suspended solids monthly average limit of 284 mg/L. Maine DEP, the permitting agency, has determined that the discharge from this facility will not lower the quality of any classified body of water below existing water quality standards (Maine DEP 2008).

2.6.3 Water Quality Monitoring

As shown in Table 2-4, extensive water quality monitoring efforts have been implemented by HBMI and other partners since 1995, primarily in response to the conditions described above and to monitor potential problem areas over time.

Table 2-4. Water Quality Monitoring History in the Meduxnekeag River

Water Quality Parameter	Years Covered	Locations	Frequency	Organizations
Algae	2003 - present	Mainstem, selected tributaries	Biennially	HBMI, with occasional DEP support
Turbidity	2014 - present	Mainstem, Smith Brook, Suitter Brook	Annually, using dataloggers (May to October)	
pH	1995 - present	Mainstem, selected tributaries		
Dissolved Oxygen				
Specific Conductance				
Temperature				
Nutrients (Nitrogen, Phosphorus)	2009 - present		Periodically	

Source: HBMI 2017

Water Quality parameters (temperature, dissolved oxygen, pH, specific conductance, and turbidity) are measured in the mainstem of the Meduxnekeag River by HBMI, using a continuous datalogging sonde (Yellow Springs Instruments, Model Number 6920) at the Lowery Rd. USGS gaging station (#01018035). These data are included as part of the water quality dataset reported by the USGS for this gaging station (HBMI 2017; USGS 2018). Recent data are shown in Table 2-5 for 2018, as representative of current conditions.

Table 2-5. Water Quality Parameters Measured in the Mainstem of the Meduxnekeag River during May to September 2018

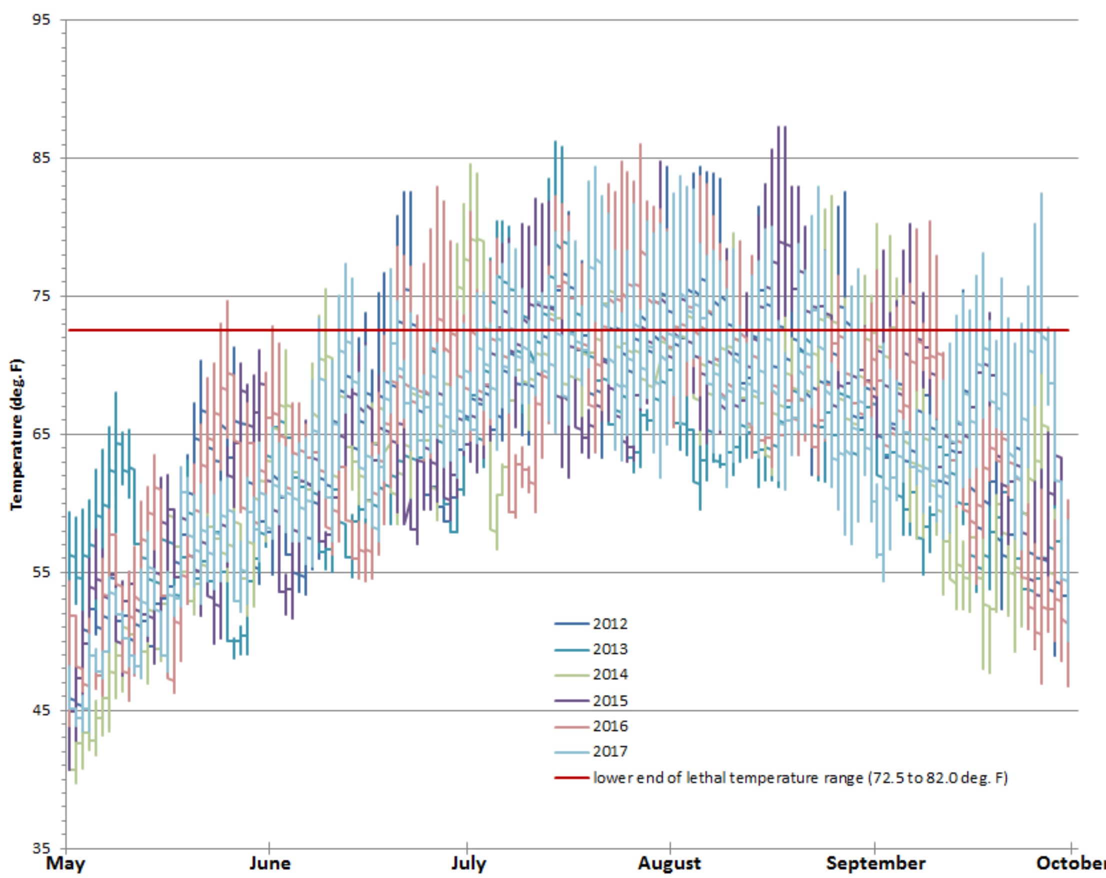
Water Quality Parameter (1 May to 30 Sept. 2018)	**USGS Data** (Lowery Rd. gaging station)	**Atlantic Salmon Water Quality Physiological Requirements[1]**
Water Temperature (°F)	Mean = 65.2°F Range = 48.2 to 88.4°F	Temperature preference between 59.0 to 66.2°F Upper lethal range = 72.5 to 82.0°F
Specific Conductance (µS/cm)	Mean = 257.4 Range = 148.0 to 455.0	No upper or lower limit, since various lifestages of Atlantic salmon can tolerate a full range of specific conductances, from dilute streams to full-strength seawater.
Dissolved Oxygen (DO) (mg/L)	Mean = 9.37 Range = 6.50 to 13.00	DO > 8 mg/L
pH	Mean = 8.13 Range = 7.5 to 8.9	5.4 to 8.5
Turbidity (NTU)	Mean = 0.94 Range = -0.6 to 24.2	< 60 NTU

Source: USGS 2018
Note: NTU = Nephelometric Turbidity Units
[1]Kircheis and Liebich 2007

In addition, HBMI has been monitoring water quality using continuous datalogging sondes (YSI 6920) placed within semi-permanent sites distributed along the mainstem of the Meduxnekeag, as well as selected tributary streams. Parameters measured include water temperature, dissolved oxygen, specific conductance, and pH (HBMI 2017). Data from the USGS gaging station and the HBMI sites are discussed in Sections 2.6.3.1 through 2.6.3.3.

2.6.3.1 Water Temperature

Water temperature is an important factor for salmonid species, such as brook trout (*Salvelinus fontinalis*) and Atlantic salmon, occupying the Meduxnekeag River. Warm water has negative impacts on fecundity, egg survival, larval growth rates, and feeding abilities (McCullough 1999). During the summer months, a critical period for salmonids, the water temperatures may exceed their physiological tolerances. Atlantic salmon parr prefer temperatures between 59.0 to 66.2°F and mortality can occur at temperatures exceeding 72.5 to 82.0°F, or greater (Kircheis and Liebich 2007). Atlantic salmon mortalities have been documented in the Penobscot River at daily average temperatures of 79 to 81°F (Kircheis and Liebich 2007). The Committee on the Status of Endangered Wildlife in Canada (COSEWIC), estimated 82°F as a lethal temperature and temperatures greater than 72°F are reported as unsuitable for feeding (COSEWIC 2010). Figure 2-9 provides a 6-year snapshot of water temperature conditions during the summer months, from 2012 to 2017, monitored at the Lowery Road gaging station (#01018035) within the mainstem of the Meduxnekeag River, adjacent to HBMI Tribal Land.



Source: USGS 2018

Figure 2-9. Water Temperature in the Mainstem of the Meduxnekeag River During Summer Months (2012 to 2017).

During 2017, hourly water temperatures exceeded 72°F for a total of 88 days, with observed hourly temperatures often dropping below this threshold at night (HBMI 2017). Despite the water temperatures ranging above this low end of lethal tolerance for Atlantic salmon, there are several tributary streams that provide important thermal refuge during such conditions. Atlantic salmon generally move to colder waters when temperatures rise above their preferred temperature tolerances, provided they have access to those cooler-water habitats (Kircheis and Liebich 2007). One such site is the deep pool along the east bank at Lowery Bridge, which is fed by a consistent groundwater seep and, therefore, maintains cooler water temperatures than the main channel. Other important tributaries that provide thermal refugia include Suitter Brook, Pearce Brook, Smith Brook, Cook Brook, B Stream, and Big Brook (HBMI 2017).

2.6.3.2 Dissolved Oxygen

All lifestages of Atlantic salmon require high levels of DO to maintain growth, development, and survival (Spence et al. 1996). Reported physiological requirements for DO vary for Atlantic salmon during embryonic development and hatching. DO concentrations greater than 7 mg/L are generally suitable in the redd for egg development, but in general DO levels of greater than 8.0 mg/L are associated with high quality Atlantic salmon habitat (Kircheis and Liebich 2007). Since DO decreases with increasing water temperatures, the warm water conditions observed in the mainstem of the Meduxnekeag River can be a concern for Atlantic salmon survival. Throughout the summer, DO typically remains above 8.0 mg/L except in the upper portion of the watershed (at the monitoring site located 9.1 miles below the Meduxnekeag Lake outlet) where periodic low DO concentrations have been observed during late July and the entire month of August. Additionally, diurnal fluctuations in DO of 1 to 3 mg/L are typical and most likely tied to variations in water temperature and respiration activity throughout the day (HBMI 2017), as described in Section 2.6.2 (Pollutant Loading).

2.6.3.3 pH

The pH of a river has a substantial influence on its ability to sustain salmonid populations. Many watersheds in the northeastern U.S. exhibit low pH due to soils with naturally low buffering capacity, as well as acidic deposition; these factors have negative effects on salmonids. Freshwater stages of Atlantic salmon are unaffected when the pH is greater than 5.4, but substantial mortality of fry (19 to 71%) and to a lesser extent in smolts (1 to 5%) occurs when the pH is less than 5.0. Mortality of parr and smolts is relatively high (72 to 100%) when pH values decline to the 4.6 to 4.7 range. Eggs and alevins begin to experience lethal effects at pH levels less than 4.8. Levels of pH ≤ 5.0 also interfere with the smoltification process and seawater adaptation (COSEWIC 2010).

Parr undergoing parr/smolt transformation become more sensitive to acidic water; therefore, water chemistry that is not normally regarded as toxic to other salmonids may be toxic to Atlantic salmon smolts (Staurnes et al. 1993 and 1995). This is true even in rivers that are not chronically acidic and not normally considered to be in danger of acidification (Staurnes et al. 1993; Staurnes et al. 1995). Atlantic salmon smolts are most vulnerable to low pH in combination with elevated levels of monomeric labile species of aluminum (aluminum capable of being absorbed across the gill membrane) and low calcium (Rosseland and Skogheim 1984; Rosseland et al. 1990; Kroglund and Staurnes 1999). These factors have a significant impact on the conservation of the species because Atlantic salmon smolts exposed to acidic waters (pH levels less than 6.0) can lose sea water tolerance, which can result in direct mortality or indirect mortality from altered behavior and fitness.

In contrast, the Meduxnekeag River exhibits relatively high pH, compared to other watersheds in Maine, with pH values typically greater than 7.0. The pH data observed at all monitoring stations in the Meduxnekeag River and its tributary streams were all well above the low pH threshold values for salmonids. In contrast, when pH values are too high, salmonids can also experience negative effects. Values of pH measured at several monitoring sites on the mainstem of the Meduxnekeag River generally range between 7.4 and 8.6, which is within the physiological requirements of Atlantic salmon (Kircheis and Liebich 2007). Wilkie and Wood (1995) found that a pH greater than 9.6 was lethal to salmonids and that a pH greater than 8.5 could cause chronic stress and exhaustion. High pH can also lead to ammonia toxicity when combined with high temperatures and low DO (which are factors of concern at some locations within the Meduxnekeag River). Values of pH recorded in the Meduxnekeag River during 2017 (HBMI 2017) were occasionally greater than the upper pH threshold value for salmonids.

2.7 Fish Resources and Habitat

As discussed in Section 1.2, the purpose of this WAS/Plan is to support the recovery of Atlantic salmon by restoring the Meduxnekeag River, riparian habitat, and watershed. The need for the recovery of Atlantic salmon is to support HBMI's cultural practices and to ensure that the species is available for future generations of U.S. citizens to enjoy. This section presents the fish species native to the Meduxnekeag River Watershed and their habitat, with additional detail on the diadromous species (particularly Atlantic salmon) found within the watershed, as well as non-native species.

2.7.1 Native Species

The Saint John River Watershed, downstream of the Mactaquac Dam, has the greatest natural diversity of freshwater fishes in Maine and Atlantic Canada (CRI 2011). Prior to the construction of the Mactaquac and other dams on the Saint John River, most migratory fishes could ascend to Grand Falls, located in northern New Brunswick, Canada (CRI 2011). According to CRI, historical records indicated the presence of anadromous salmon as far as the Saint John River's Beechwood Dam (located in Beechwood, NB, upstream of the Meduxnekeag River's confluence with the Saint John River). Other reaches of the river typically have fewer than ten common species (CRI 2011).

Table 2-6 includes a list of fish species known to occur in the Saint John River and Meduxnekeag River Watersheds, 30 of which occur within the Meduxnekeag Watershed (Baum 1982; MDIFW 2008; DFO Canada 2018a). as well as relative abundances for the Meduxnekeag River Watershed, based on electrofishing data collected by U.S. and Canadian agencies.

Table 2-6. Freshwater and Migratory Fish Species Occurrences in the Saint John River and Meduxnekeag River Watersheds

Common Name	Species	Saint John River (Canada)[1] *Between Mactaquac Dam and Hargrove Dam*	Meduxnekeag River (U.S and Canada)[2, 3]	Relative Abundance in Meduxnekeag River Watershed[4] (U.S only)
Alewife[5]	*Alosa pseudoharengus*	✓	✓	--
American eel[5]	*Anguilla rostrata*	✓	✓	--
American shad[5]	*Alosa sapidissima*	✓*	--	--
Atlantic salmon[5]	*Salmo salar*	✓	✓	< 0.1% (landlocked)
Banded killifish	*Fundulus diaphanus*	✓	✓	--
Blacknose dace	*Rhinichthys atratulus*	✓*	✓	41.9%
Blacknose shiner	*Notropis heterolepis*	✓*	✓	0.1%
Blueback herring[5]	*Alosa aestivalis*	✓*	✓	--
Brook trout	*Salvelinus fontinalis*	✓	✓	22.6%
Brown bullhead	*Ameiurus nebulosus*	✓	✓	0.1%
Brown trout	*Salmo trutta*	✓	✓	0.2%
Burbot (Cusk)	*Lota lota*	✓*	--	--
Chain pickerel	*Esox niger*	✓	✓	< 0.1%
Common shiner	*Luxilus cornutus*	✓	✓	5.7%
Creek chub	*Semotilus atromaculatus*	✓	✓	12.6%
Fallfish	*Semotilus corporalis*	✓	✓	0.2%
Fathead minnow	*Pimephales promelas*	✓*	✓	0.6%
Finescale dace	*Chrosomus neogaeus*	✓*	✓	2.8%

Common Name	Species	Saint John River (Canada)[1] *Between Mactaquac Dam and Hargrove Dam*	Meduxnekeag River (U.S and Canada)[2, 3]	Relative Abundance in Meduxnekeag River Watershed[4] (U.S only)
Golden shiner	*Notemigonus crysoleucas*	✓	✓	--
Lake chub	*Couesius plumbeus*	✓	✓	0.8%
Lake trout	*Salvelinus namaycush*	✓	--	--
Lake whitefish	*Coregonus clupeaformis*	✓*	--	--
Longnose sucker	*Catostomus catostomus*	✓*	--	--
Muskellunge[6]	*Esox masquinongy*	✓	--	--
Ninespine stickleback	*Pungitius pungitius*	✓	✓	0.2%
Northern redbelly dace	*Chrosomus eos*	✓	✓	1.0%
Pearl dace	*Margariscus margarita*	✓*	✓	< 0.1%
Pumpkinseed sunfish	*Lepomis gibbosus*	✓	✓	0.4%
Rainbow smelt	*Osmerus mordax*	✓*	✓	--
Rainbow trout[6]	*Oncorhynchus mykiss*	✓	--	--
Redbreast sunfish	*Lepomis auritus*	✓*	✓*	--
Sea lamprey[5]	*Petromyzon marinus*	✓*	--	--
Slimy sculpin	*Cottus cognatus*	✓*	✓	3.0%
Smallmouth bass[6]	*Micropterus dolomieu*	✓	✓	0.4%
Striped bass[5]	*Morone saxatilis*	✓*	--	--
Threespine stickleback	*Gasterosteus aculeatus*	✓	✓*	--
White perch[5]	*Morone americana*	✓	✓	--
White sucker	*Catostomus commersonii*	✓	✓	7.5%
Yellow perch	*Perca flavescens*	✓	✓	--

Sources: [1]CRI 2011; [2]Baum 1982; [3]MRWA 2015; [4]MDIFW 2008
[5]diadromous
[6]non-native
*Historical records only
Note: Electrofishing data (MDIFW 2008) collected throughout the Meduxnekeag River Watershed during 2007-2008, including the mainstem of the Meduxnekeag River, North Branch, and South Branch of the Meduxnekeag River and the following tributaries: B Stream, Bither Brook, Dead Stream, Meduxnekeag Lake, Mill Brook, Moose Brook, and South Brook

2.7.2 Fish Habitat

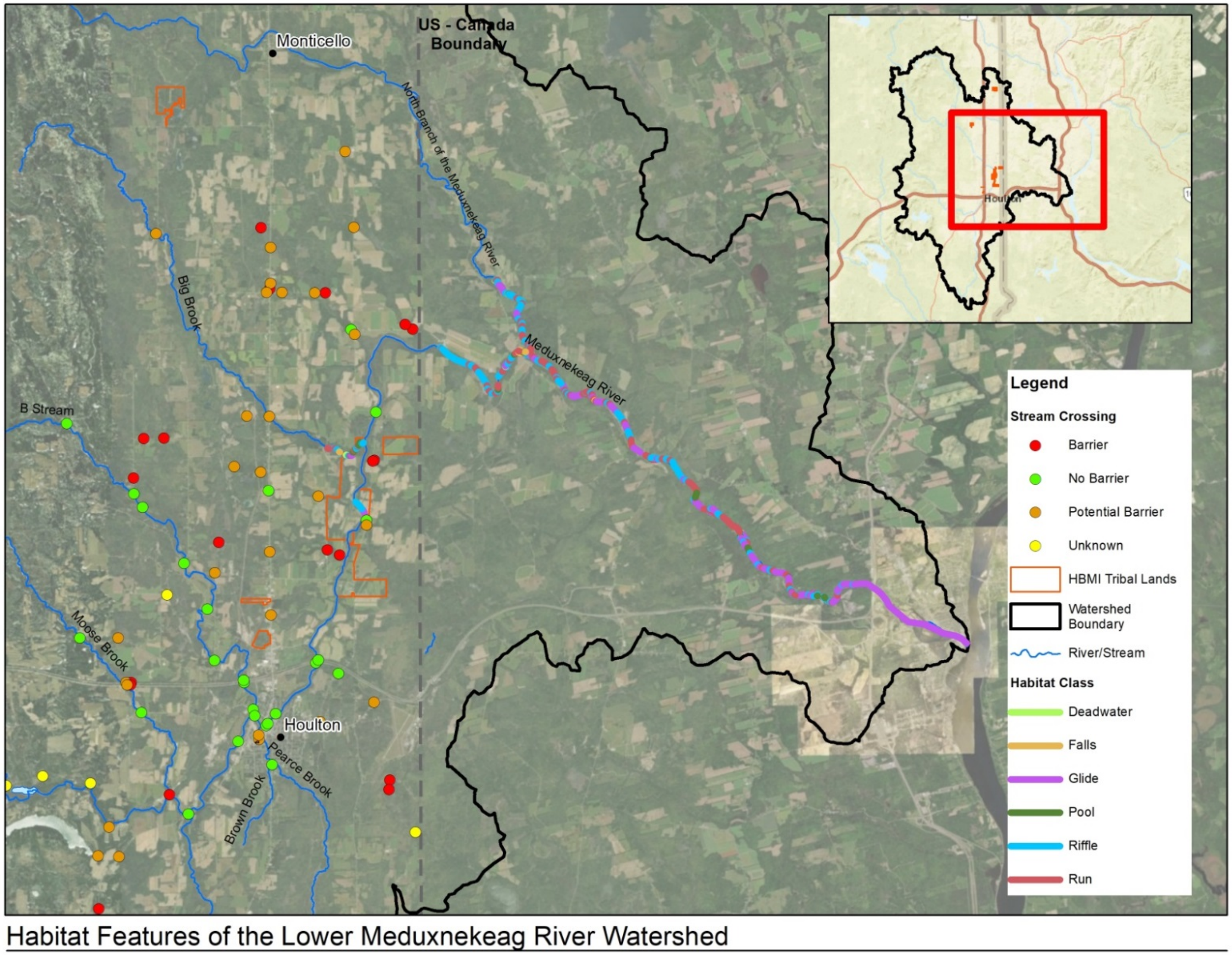
The upper portion of the Meduxnekeag River, and its major tributaries, are characterized by low-gradient riffle-run/glide, and "deadwater" sections (very low velocity), with occasional deeper pools. Overall, the lower portion of the river (from Houlton, through HBMI tribal lands and into Canada), lacks structured habitat features that are important to all salmonid populations in the river. HBMI's recent efforts to introduce structured habitat, such as root wads or boulders, within the channel have enhanced the complexity of this section of the river resulting in more suitable habitats for diadromous fish species. HBMI has implemented a 2-mile segment of instream restoration work to introduce large, woody debris and boulders to improve habitat complexity in the river channel and restore the natural, fluvial geomorphologic characteristics of the river (Field 2010) see also, Section 3.3.3.

The primary stream substrate type throughout the Meduxnekeag River is gravel mixed with cobbles, ledge (bedrock), and boulders. Sand and finer sediment make up the remaining substrate types. The smaller tributaries can be categorized into two stream types: 1) those with higher gradients, higher water velocities, and, consequently, larger substrate sizes; and 2) those with lower gradients, slower velocity rates, and a higher percentage of fine material in the substrate (MRWA 2015).

Fish habitat surveys on the Meduxnekeag River were completed during three efforts that took place across three separate years, as follows:

- 2001, by the MDIFW and USFWS (MDIFW 2001);
- 2006, by HBMI and John Field (Field 2010); and
- 2015, by HBMI and USACE (USACE 2017).

These surveys utilized quantitative and semi-quantitative methods to assess fish habitat characteristics within the mainstem of the Meduxnekeag and the lower portion of the North Branch of the Meduxnekeag River in New Brunswick, as well as between the covered bridge to Lowery Rd, including the lower portion of Big Brook in Maine, as shown in Figure 2-10.



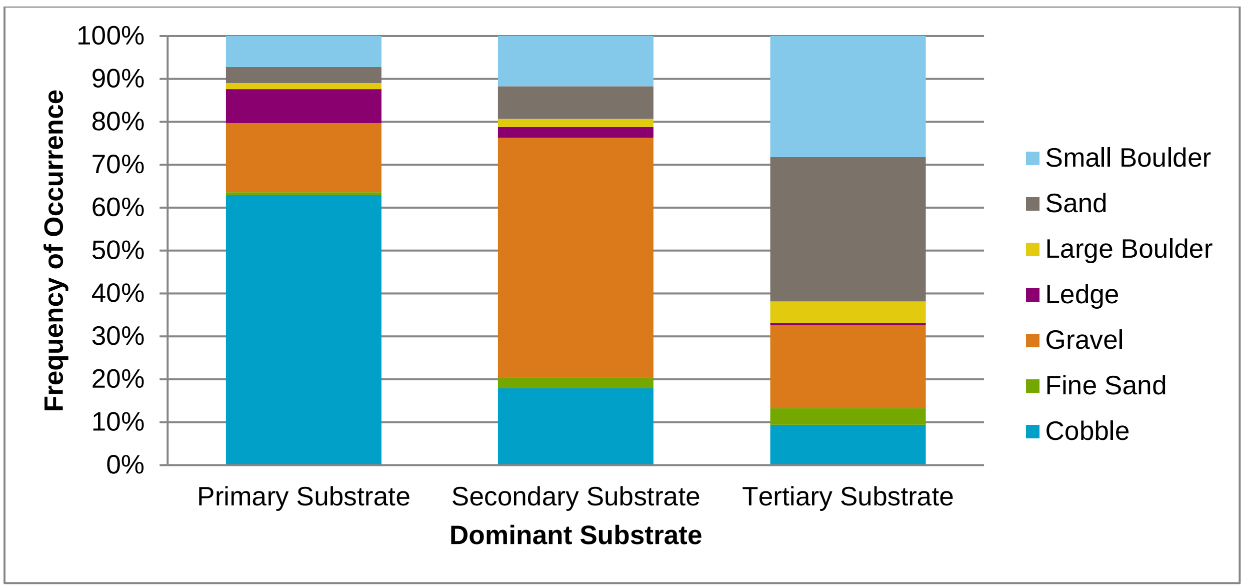
Source: MDIFW 2001; Field 2010; USACE 2017; Maine DMR 2018

Figure 2-10. Location of Fish Habitat Data Collected to-date within the Meduxnekeag River Watershed.

During the USACE/HBMI habitat survey (USACE 2017), 294 habitat features (riffle, run, glide, pool, falls, and deadwater) were inventoried. Within each of those habitat features, the following parameters were collected:

- Substrate type (primary, secondary, and tertiary);
- Average depth;
- Minimum depth;
- Maximum depth;
- Length;
- Width;
- Number of pieces of large, woody debris;
- Pool width; and
- Atlantic salmon spawning/rearing habitat.

Among the habitats surveyed, glides/runs were the most abundant type, accounting for approximately 48% of the total habitat, followed by riffles (37%), pools (8%), and falls (7%). The average water depth during low-flow conditions was 1.3 ft, ranging from 0.3 ft in areas of wide riffles to 16.4 ft in areas with deeper pools. Cobble was the dominant primary substrate type, accounting for approximately 63% of the primary substrate types, followed by gravel (16%), ledge (8%), small boulder (7%), and sand (6%). Gravel was the dominant secondary substrate, accounting for approximately 56%. Detailed relative abundances for primary, secondary, and tertiary sediment types are shown in Figure 2-11. The average number of pieces of large, woody debris was 6.9 pieces per reach, with a range of 0 to 100 pieces, depending on the available sources within the riparian zone. In the surveyed reaches, a total of 79,556 ft^2 (1.83 acres) of Atlantic salmon spawning habitat was identified, with approximately 79% of that area classified as "high quality", 10% classified as "medium quality", and 11% classified as "low quality" spawning habitat.



Source: USACE 2017

Figure 2-11. Frequency of Occurrence for Dominant Substrates within the Surveyed Reaches of the Meduxnekeag River

2.7.3 Diadromous Species

Diadromous fish species within the Saint John River Watershed include the anadromous Atlantic salmon, Atlantic sturgeon, shortnose sturgeon, river herring or gaspereau (alewife and blueback herring), striped bass, white perch, sea lamprey, and the catadromous American eel. Since the construction of the Mactaquac Dam on the Saint John River at Fredericton in New Brunswick, Canada in 1968, most diadromous fish populations have declined within the Saint John River and its tributaries (including the Meduxnekeag River) upstream of this dam.

Of these diadromous species, only the alewife, American eel, and Atlantic salmon are known to occur in the U.S. or Canadian portions of the Meduxnekeag River. However, it is rare that alewife or Atlantic salmon are found within the U.S. portion (or HBMI portion) of the river (CRI 2011; MDIFW 2008) because of fish passage constraints in the Saint John River. These diadromous species are discussed further in the subsections below.

2.7.3.1 River Herring

River herring (or gaspereau) collectively refers to alewife (*Alosa pseudoharengus*) and blueback herring (*Alosa aestivalis*); these species are anadromous and are native to the Saint John River Watershed. Both species exhibit similar life history patterns spending the majority of their life at sea and returning to freshwater ponds, lakes, and rivers to spawn (Werner 2004). River herring that migrate into the Saint John River are captured in the fish lift at Mactaquac Dam and then trucked to the headpond where they are released; however, specific numbers of river herring that are captured in the fish lift at the Mactaquac Dam are not monitored. The former rapids at the site of the Mactaquac Dam may have impeded their historical upstream limit (CRI 2011); therefore, the presence of river herring in the Meduxnekeag may have been limited. However, Tribal elders note that alewives historically occurred further upstream in the Saint John River than the present location of the Mactaquac Dam.

2.7.3.2 American Eel

American eel (*Anguilla rostrata*) are catadromous; they spawn in the ocean and migrate to coastal estuaries and rivers as larvae (elvers), disperse to freshwater rivers, streams, and lakes where they grow to adults, and then migrate back to the ocean (Sargasso Sea) to spawn. The eel population in the Saint John River Watershed, below the Mactaquac Dam, appears to be healthy compared to the Saint Lawrence River populations, which have been in decline (CRI 2011). American eel are capable of accessing barriers, including small dams and culverts that would otherwise prevent access to those upstream habitats. Similar to river herring, American eel are also captured in the fish lift at Mactaquac Dam and then trucked to the headpond where they are released; however, specific numbers of eel that are captured in the fish lift at the Mactaquac Dam are not monitored. HBMI has noted that eel populations in the headwaters of the Meduxnekeag River (Meduxnekeag Lake) have declined in recent decades, based on observation of recreational catches.

2.7.3.3 Atlantic salmon

Details regarding the Atlantic salmon populations (including historical and current populations, and habitat requirements) within the Meduxnekeag River Watershed are further described below. HBMI's long-term goal is salmon restoration in the river. However, fish passage above the Mactaquac Dam, including direct upstream salmon passage to the mouth of the Meduxnekeag River, remains a challenge. As noted in Section 2.5.1, a trap and truck system is currently employed for Atlantic salmon at the Mactaquac Dam.

2.7.3.3.1 Regulatory Summary

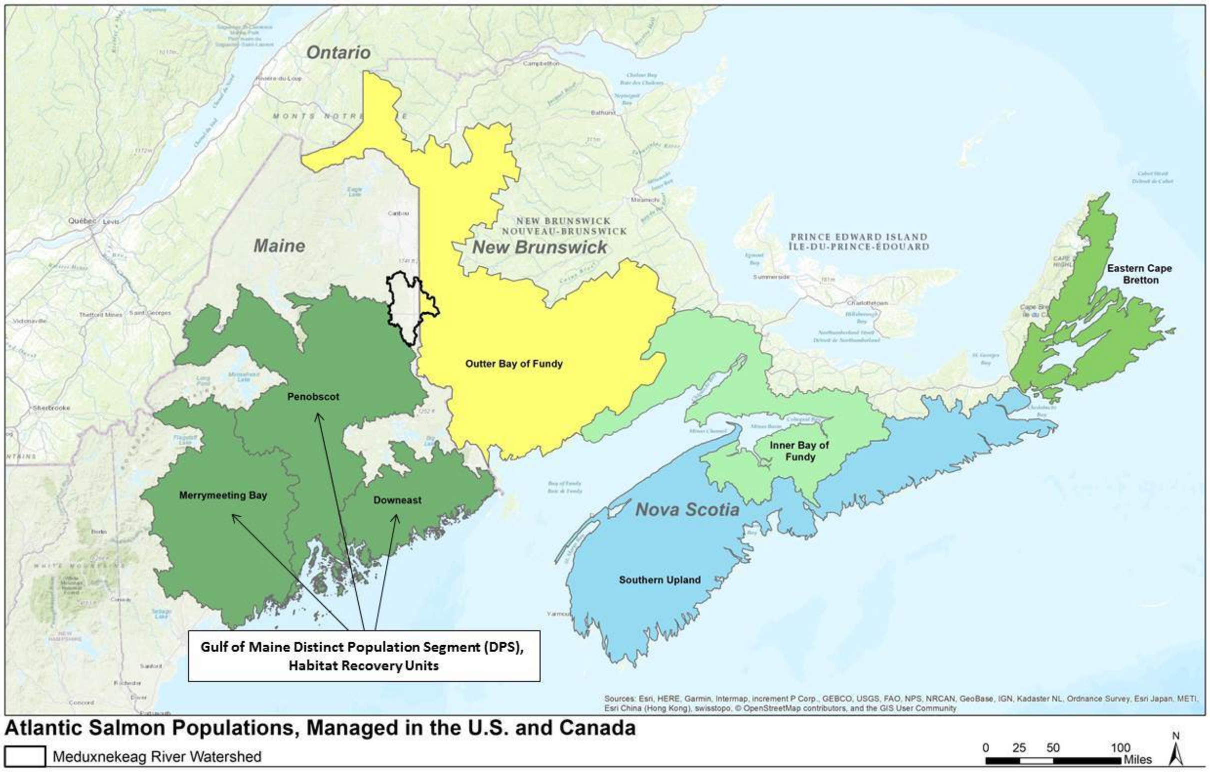
The Meduxnekeag River is considered a historical Atlantic Salmon River by the regulatory agencies that manage Atlantic salmon resources in Maine. Therefore, it is no longer managed for Atlantic salmon populations and there are no current state or federal stocking or restoration programs in place within the U.S. portion of the Meduxnekeag River Watershed. Outside of the U.S. portion of the Meduxnekeag River Watershed, Atlantic salmon populations are managed by various state, federal, and provincial agencies, as described below.

In the United States, the Gulf of Maine Distinct Population Segment (DPS) of Atlantic salmon (located outside of the Meduxnekeag River Watershed) is jointly managed by the United States Fish and Wildlife Service (USFWS) and the National Oceanographic and Atmospheric Administration (NOAA), National Marine Fisheries Service (NOAA Fisheries). The Gulf of Maine DPS was originally listed as endangered in 2000, with an expanded listing and designation of Critical Habitat in 2009 (NOAA Fisheries 2009a; 2009b). In Canada, Atlantic salmon are managed as several different populations or designatable units, with the Inner Bay of Fundy (IBOF) population and the Outer Bay of Fundy (OBOF) designatable unit, being the most relevant of the Canadian Atlantic salmon populations to the geographic context of this document. The IBOF population is currently listed as endangered under Canada's Species at Risk Act (SARA) and the OBOF designatable unit is not currently listed as endangered under SARA; the OBOF designatable unit is however, considered endangered under COSEWIC (DFO Canada 2018b and 2018c). Only the U.S. Gulf of Maine DPS, OBOF, and IBOF are relevant to the geographic context of this document and are further described in Table 2-7. The Atlantic salmon occurring in the Meduxnekeag River Watershed, are part of the OBOF population, outside of the U.S.-listed entity Gulf of Maine DPS, as shown in Figure 2-12.

Table 2-7. Atlantic Salmon Populations, as Regulated in the U.S. and Canada

	United States	**Canada**	
	Gulf of Maine Distinct Population Segment (DPS) of Atlantic Salmon	***Atlantic Salmon, Inner Bay of Fundy (IBOF) Population***	***Atlantic Salmon, Outer Bay of Fundy (OBOF) Designatable Unit***
Endangered Species Status*	DPS listed as ***Endangered***, under the Endangered Species Act (ESA)	Listed as ***Endangered***, under SARA. Considered to be ***Endangered*** under COSEWIC	***No Status***, under the Species at Risk Act (SARA). Considered to be ***Endangered*** as a Designatable Unit, under the Committee on the Status of Endangered Wildlife in Canada (COSEWIC)
Geographic extent of the listed entity	The DPS is limited to three Habitat Recovery Units - Merrymeeting Bay, Penobscot, and Downeast (inclusive of the Androscoggin River Watershed through the Dennys River Watershed). ***Does not include*** the Meduxnekeag River Watershed.	50 rivers draining into the Inner Bay of Fundy starting with the Mispec River (northeast of the Saint John River) in New Brunswick, around the Inner Bay to the Pereaux River (in the Minas Basin northeast of the Annapolis River) in Nova Scotia. ***Does not include*** the Meduxnekeag River Watershed.	New Brunswick rivers (from the Maine/New Brunswick border, along the Bay of Fundy up to and including the Saint John River) ***Includes*** the Meduxnekeag River Watershed.
Unique Features	• DPS represents the remaining wild (naturally spawning) population of Atlantic salmon in the U.S. • Adults return to freshwater to spawn, typically after 1 to 3 years at sea.	• Genetically different from the OBOF designatable unit. • High proportion of individuals that mature as grilse (only one winter at sea). • Migrations generally confined to the IBOF.	• Genetically different from adjacent populations (IBOF and Gulf of Maine DPS). • Adults usually return to freshwater to spawn after one to three years at sea. • Offshore migration patterns, similar to the Gulf of Maine DPS.

*The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) is an independent body of experts responsible for identifying and assessing wildlife species considered to be at risk, but this classification does not imply formal listing status under the Species at Risk Act (SARA).
DPS = Distinct Population Segment
ESA = Endangered Species Act
IBOF = Inner Bay of Fundy
OBOF = Outer Bay of Fundy
Sources: NOAA 2009a; DFO Canada 2018b; DFO Canada 2018c



Sources: Adapted from NOAA 2009a; COSEWIC 2010

Figure 2-12. Location of the Meduxnekeag River Watershed, within the Outer Bay of Fundy Designatable Unit, in Relation to the other Canadian Populations and the U.S. Gulf of Maine DPS

The OBOF designatable unit was classified as endangered by COSEWIC in November 2010 but since that time, a formal listing of this designatable unit has not been made under SARA (COSEWIC 2010). The primary reason COSEWIC classified the OBOF designatable unit as endangered was an observed net decline of mature individuals by about 64% over three generations. Historical declines due to dams that have impeded spawning migrations, aquaculture escapements, and poor marine survival were also cited (COSEWIC 2010). A formal recovery potential assessment process has been developed by DFO Canada to provide the information and scientific advice required to meet the various requirements of SARA, to determine if the OBOF designatable unit is warranted under SARA. This assessment, underway since 2013, provides a summary of the scientific data and analyses available to assess the recovery potential of OBOF Atlantic Salmon (DFO Canada 2014).

2.7.3.3.2 Historical Populations

The Meduxnekeag River is considered a historical Atlantic Salmon River. The Meduxnekeag River once held self-sustaining populations, as confirmed by Tribal accounts, oral history, and published documentation (Kendall 1935; Baum 1982; Baum 1997). One historical perspective summarizing the state of Atlantic salmon in the Meduxnekeag River is provided by Kendall (1935):

> "*Meduxnekeag River -- Authentic records show that during the early part of the (19th) century salmon entered this river in abundance, more especially in the vicinity of Houlton, Maine, where they continued plentiful until shut out by dams about 1832. During some years, however, it is reported that a few salmon still find their way into the lower part of the river …. There is no recent available information concerning this river*."

Atlantic salmon stocking of the Meduxnekeag River dates back to 1926 when 92,000 fry were stocked. However, all stocking of Atlantic salmon was discontinued in 1980 (Baum 1997); records, by year, are summarized in Table 2-8.

Table 2-8. Atlantic Salmon Stocking Records for the Meduxnekeag River

Year	Fry	Parr	Smolts	Stock Origin
1926	92,000	0	0	Saguenay River, Quebec
1927	92,000	0	0	
1929	0	40,000	0	
1931	0	50,000	0	Miramichi River, New Brunswick
1979	0	2,100	0	Penobscot River, Maine
1980	0	0	2,730	Union River, Maine

Source: Baum 1997

2.7.3.3.3 Current Populations

In Canada, the Saint John River Atlantic salmon population is assessed annually from data collected at the Mactaquac Dam, as well as from the Tobique and Nashwaak Rivers, the largest salmon-producing tributaries upstream and downstream, respectively, of the Mactaquac Dam (Jones et al. 2010). The CRI reports that the majority of modern Atlantic salmon spawning and production of young for the entire basin occurred in the Tobique River upstream of the Mactaquac Dam (CRI 2011).

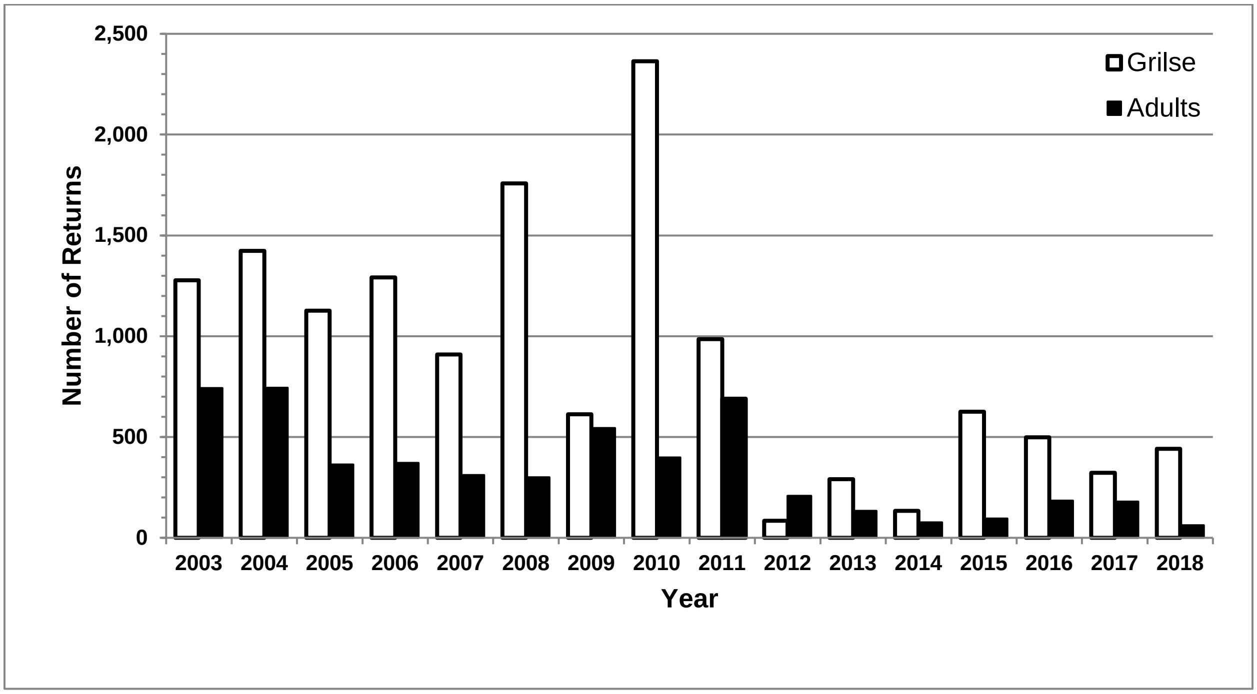
Atlantic salmon returns in the Saint John River are tracked as the number of grilse (individuals with only one sea-winter that may or may not have reached reproductive maturity) and the number of adults (individuals with two or more sea-winters that have reached reproductive maturity). The number of adult Atlantic salmon returns reported in the Saint John River declined from approximately 18,000-30,000 (estimated from capture fisheries) prior to 1960, to only a few hundred in the 1960s as the Mactaquac Dam was completed (CRI 2011). The number of adult returns appeared to be recovering in the 1970s during a period of intensive stocking associated with compensation of losses from the construction of dams (CRI 2011).

In more recent years, the number of grilse and adult salmon returns documented at the Mactaquac Dam have been in decline since the mid-1990s, with 4-year average returns shown in Table 2-9, and annual returns from 2003 to 2018 shown in more detail in Figure 2-13 (DFO Canada 2018d). The annual numbers for 2018 are current as of 30 November 2018 (fish lift ceased operations for the year on 05 November 2018), as reported by DFO Canada (2018a).

Table 2-9. Average Number of Adult Atlantic Salmon Returns at the Mactaquac Dam since 1995

Date Range	4-year Average Returns	
	Grilse (1 sea-winter)	Adults (multi sea-winter)
1995 to 1999	4,459	1,994
2000 to 2004	1,936	732
2005 to 2009	1,140	378
2010 to 2014	772	302
2015 to 2018	472	130

Source: DFO Canada 2018d



Source: DFO Canada 2018d

Figure 2-13. Number of Atlantic Salmon Returns in the Saint John River at the Mactaquac Dam, 2003 to 2018.

Natural reproduction primarily occurs downstream of the Mactaquac Dam. Stocked individuals and offspring from parents transported by DFO Canada to specific locations, or stocked and managed land-locked and trans-located populations (in places such as Nictau Lake and the Tobique River, upstream of the Mactaquac Dam) are also components in the Saint John River system salmon population (CRI 2011). The estimated abundance of adult Atlantic salmon on the Saint John River upriver of the Mactaquac Dam and on the Nashwaak River was reported at 5 and 23% of their respective conservation requirements in a 2010 report (Jones et al. 2010). Estimated egg deposition in these areas decreased by over 65% between 1993 and 2008 (Jones et al. 2010).

In recent years, DFO Canada (2018b) has reported Atlantic salmon parr at several locations within the Meduxnekeag River as well as several tributaries in the vicinity of Jackson Falls, approximately 3 river miles downstream from the U.S. border. It is notable that the mouth of the Meduxnekeag River is close to the Saint John River location where returning adults trapped at the Mactaquac Dam are released upstream of the dam and above the influence of the headpond. As such, it is possible that natural spawning is occurring within the Meduxnekeag River (or its tributaries), and/or that juveniles are dispersing to suitable habitats for spawning within the Meduxnekeag River Watershed.

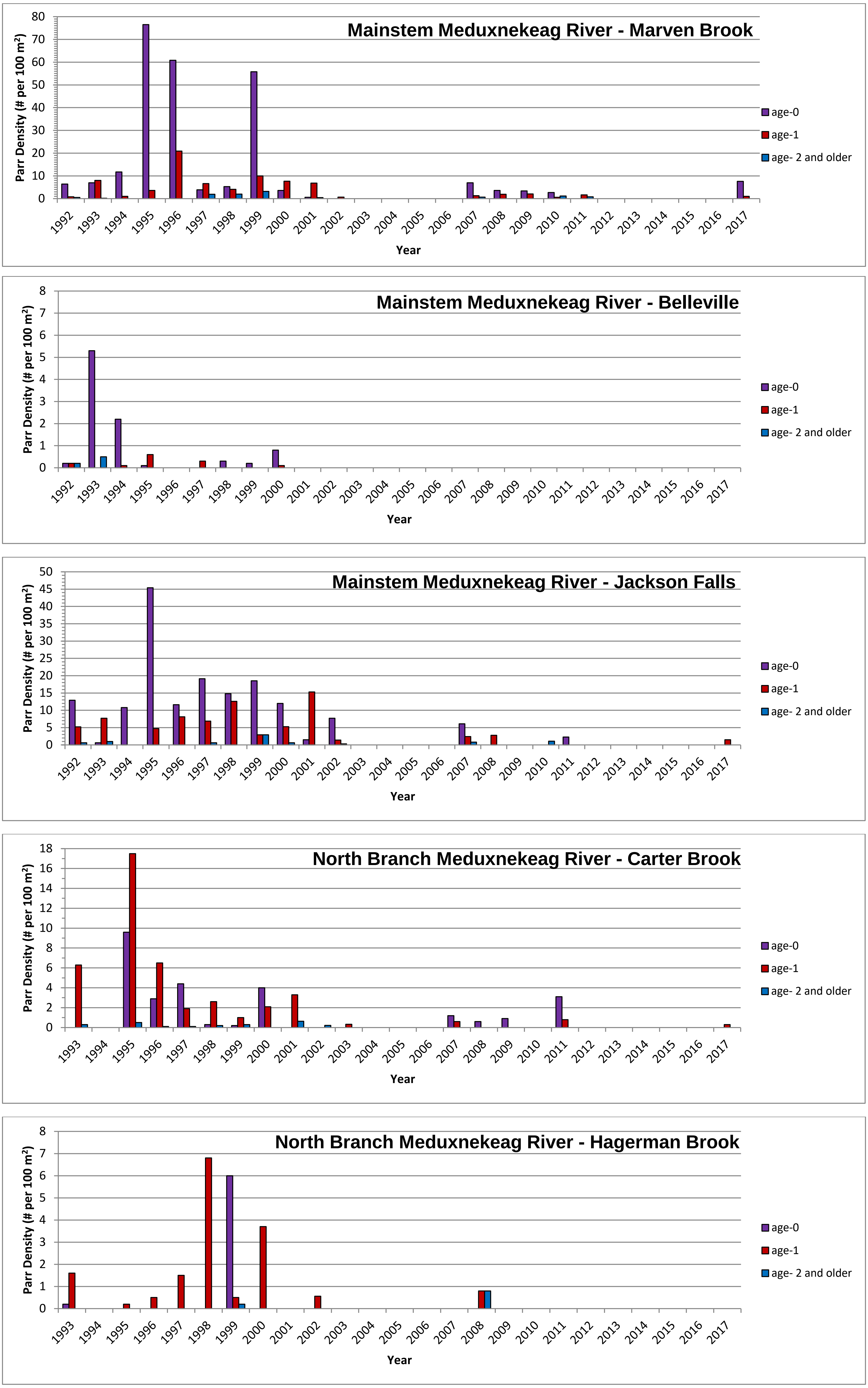
Reference sites were electrofished annually between 1997 and 2011, and again in 2017. While parr were not present at all sites during all years, the most recent data (2017) indicated that Marven Brook contained age 0+ parr in densities up to 7.6 parr/100m^2 and age 1+ parr in densities up to 1.5 parr/100 m^2 in the Mainstem Meduxnekeag River at Jackson Falls; note that data reported in metric units to align with source data (DFO Canada 2018a). Table 2-10 presents the Atlantic salmon density data from DFO Canada within the Meduxnekeag River Watershed. Figure 2-14 presents the range of observed juvenile Atlantic salmon densities for each age group within the Meduxnekeag River and its Tributaries.

Table 2-10. Range of Atlantic Salmon Densities in the Meduxnekeag River and Tributaries

Location	**Years**	**Density** (# of parr/100m^2)		
		Age-0	***Age-1***	***Age-2+***
Main Stem Meduxnekeag River (Belleville)	1992-2000	0.0 to 5.3	0.0 to 1.0	0.0 to 0.5
Marven Brook	1992-2011; 2017	0.0 to 55.8	0.0 to 10.0	0.0 to 3.2
North Branch (below the Briggs Mill site)	1992-2011; 2017	0.0 to 45.4	0.0 to 15.3	0.0 to 2.9
Hagerman Brook	1993-2011; 2017	0.0 to 6.0	0.0 to 3.7	0.0 to 0.8
Carter Brook	1993-2011; 2017	0.0 to 4.4	0.0 to 17.5	0.0 to 0.5

Note: Data reported in metric units to align with source data.

Source: DFO Canada 2018a



Note: Different scales are used to show detail within each location. Data reported in metric to align with source data. Source: DFO Canada 2018a

Figure 2-14. Juvenile Atlantic Salmon Densities, Sampled in the Mainstem of the Meduxnekeag River (Marven Brook, Belleville, Jackson Falls), and the North Branch of the Meduxnekeag River (Carter Brook and Hagerman Brook)

Baum (1982) reported that the Meduxnekeag River Watershed has 118 acres of available salmon spawning habitat and 251 acres of available nursery habitat. Based on this available habitat, Baum estimated that the Meduxnekeag River Watershed could potentially produce a run of 440-733 adult salmon to the Outer Bay of Fundy population. Assuming that this spawning habitat is still intact within the Meduxnekeag River Watershed (and perhaps even more would be available as a result of existing/future restoration efforts), the number of returning adults may be considered the maximum potential output of a future population of Atlantic salmon within the Meduxnekeag River (including tributaries). More recently, at the 2017 meeting of the U.S. Atlantic Salmon Assessment Committee, updated conservation limits were presented for Maine rivers, including the Meduxnekeag River with a conservation limit of 200,400 eggs, resulting in an estimated population size of 56 adult Atlantic salmon capable of occupying the Meduxnekeag River (U.S. Atlantic Salmon Assessment Committee 2017).

2.7.3.3.4 Habitat Requirements by Life Stage

As an anadromous species, Atlantic salmon pass through several phases identified by specific changes in behavior, physiology, morphology, coloration, and habitat requirements that are necessary during their development (Kircheis and Liebich 2007). While the habitat requirements for each life stage overlap, there are habitat characteristics that are distinct for each life stage. Life history characteristics and habitat requirements for Atlantic salmon are summarized in Table 2-11.

Table 2-11. Life Stage Habitat Characteristics for Outer Bay of Fundy Atlantic Salmon Populations

Life Stage	Habitat Utilization	Description
Spawning Adults	Riverine migratory pathways from the ocean to freshwater spawning habitats. Water temperatures 57 to 68 °F	• Outer Bay of Fundy populations typically mature after either one or two winters at sea. • Spawning adults (typically age 1-4 years) return to rivers from the sea to migrate to their natal streams. Average generation time for the Outer Bay of Fundy designatable unit is 4 years. • Spawning does not occur until late fall, but the majority of Atlantic salmon enter freshwater between May and November, with the peak influx occurring in June. Some runs can begin as early as March and April. • Timing of the migration run varies by river, sea age, year, and hydrological conditions • During migration, adult salmon require holding and resting areas. Holding areas are necessary below temporary seasonal migration barriers such as those created by flow or temperature and temporary obstructions such as falls/cascades, debris dams, and other passable obstructions. • Adult salmon can become fatigued when ascending high velocity riffles or falls and need resting areas near these places. Returning salmon also need cool water refuges such as deep pools, springs, and mouths of smaller tributaries during the summer months. • Female salmon use their caudal fins to excavate a redd where they deposit eggs to be fertilized. After spawning, a small portion (20%) return to the sea immediately after spawning, while the majority over-winter in the river and return to the sea the following spring. • If a salmon then survives another one to two years at sea, it will return to its natal river as a repeat spawner (approximately 3% of spawning adults).
Egg	Over-wintering in cobble/gravel	• Spawning occurs during October through November. • Optimum temperature for egg fertilization and incubation is approximately 43°F. • Eggs hatch after 175-195 days, typically in April.
Larvae (fry)	Headwater streams with structured habitats	• Newly hatched salmon are called larval fry, alevin, or sac fry and after hatching, they remain in the redd for about six weeks, nourished by their yolk sac. • After this period, they emerge from the gravel and begin active feeding in mid-May to early June when they are then called fry. • The estimated rate of survival from egg to fry is 15-35%.

Life Stage	Habitat Utilization	Description
Juvenile (parr)	Headwater streams and river channels with structured habitats	• Within a few days of emerging from the redd, the fry enter the parr stage (which is indicated by vertical bars visible on their sides) at a total length of approximately 1.6 in. • Preferred or optional summer stream temperature for the growth and survivorship of salmon is approximately 63°F, while the upper lethal temperature is approximately 82°F. • Parr generally remain in the river for two to four (and up to eight) years before undergoing smoltification, the process in which they undergo physiological changes in order to transition from a freshwater environment to a saltwater, marine environment.
Juvenile (smolt)	River channels and estuaries	• Most smolts enter the sea during April through June. • Overall the rate of survival from the egg to the smolt stage is estimated from 0.13 to 6.09%.
Adult	Pelagic ocean waters	• Oceanic adults spend 1 to 4 years at sea during which they migrate as far north as the Labrador Sea and the west coast of Greenland. • Adults are found in pelagic waters and are subject to numerous sources of mortality (natural and fishing) before they mature to return to their natal rivers as spawning adults.

Sources: Kircheis and Liebich 2007; COSEWIC 2010; DFO Canada 2018c

2.7.4 Non-Native and Invasive Species

Historically, in freshwater, Atlantic salmon coexisted with abundant populations of other native diadromous fishes and native resident species (Kircheis and Liebich 2007). They are preyed upon at various life stages by many avian, terrestrial, and aquatic predators. Introduced, non-native species that prey on Atlantic salmon in freshwaters include smallmouth bass, largemouth bass, chain pickerel, brown trout, splake, and northern pike (Kircheis and Liebich 2007). The two most important native fish predators of Atlantic salmon in freshwaters are likely brook trout and American eel (Fay et al. 2006). American eel populations are relatively low in the Meduxnekeag Watershed; however, native brook trout populations are relatively well represented (~14%). Avian predators, such as the double-crested cormorant, are also known to prey on out-migrating Atlantic salmon smolts. Overall predation on juvenile Atlantic salmon by native fishes in freshwater habitats is low, compared with predation in the estuarine and marine environment (Fay et al. 2006). Non-native species, particularly smallmouth bass, feed on fry, parr, and smolts. While little quantitative information exists regarding the extent of Atlantic salmon predation by smallmouth bass, smolt consumption could be as high as 10 smolts per bass per day (Van den Ende 1993).

The smallmouth bass, a non-native species, was introduced to the Saint John River Watershed in the 1800's and early 1900's (CRI 2011). Currently, in the Saint John River Watershed, smallmouth bass are found in the Tobique River and upstream of Grand Falls, where they are expanding their range upstream into Maine. Smallmouth bass can occupy the same habitats as brook trout and Atlantic salmon, and therefore may displace and/or eliminate these native species (CRI 2011). Smallmouth bass account for approximately 22% of the targeted recreational catch in the Saint John River Watershed.

Muskellunge (*Esox masquinongy*) were introduced into a headwater lake of the Saint John River as part of a planned management exercise; however, this introduction resulted in the unintended expansion of this species outside of the lake (CRI 2011). Muskellunge are now present in the Saint John River in Maine and New Brunswick (from Glazier and Baker Lakes to Jemseg River) and are expanding downstream. Muskellunge are unlikely to consume a significant number of young salmon in the Saint John River, but no additional studies have assessed this potential (CRI 2011).

Rainbow trout (*Oncorhynchus mykiss*) were introduced to the Saint John River through escapes from private aquaculture facilities (CRI 2011). Currently, rainbow trout are widely distributed and self-sustaining from Grand Falls to Woodstock and upstream of Grand Falls. The species is more tolerant of warmer temperatures than other salmonids, and typically out-competes native brook trout and Atlantic salmon in these conditions (CRI 2011). Rainbow trout account for approximately 12% of the recreational fish harvest in the Saint John River Watershed (CRI 2011).

Brown trout (*Salmo trutta*) are self-sustaining in the Meduxnekeag River, following their release from a federal hatchery into Nickerson Lake in the 1900s (Frost 2002). Brown trout are more tolerant of warmer temperatures and sediment and may out-compete native brook trout and Atlantic salmon in these conditions (CRI 2011). Brown trout account for approximately 5% of the recreational fish harvest in the Saint John River Watershed.

2.8 Cultural Resources

HBMI is a federally recognized Tribe located in the Meduxnekeag watershed with over 900 acres of reservation/trust land along the lower section of the Meduxnekeag River. HBMI are part of the Maliseet Nation that extends into Canada and includes the six recognized Maliseet First Nation Tribes. The Maliseets rely heavily on fishing, trapping, hunting, and gathering in the waters and floodplains; therefore, they are very concerned with the river's water quality (SASWCD 2015). The river is a critical link in preserving tribal practices, traditions, and history (Field 2010). Before contact with Europeans, the Maliseets occupied much of what is now considered the eastern border of the U.S. (Maine) and Canada in northern New England. After the Jay Treaty in 1794, the Maliseets obtained free border crossing rights between the two countries because their villages spanned both countries.

HBMI currently consist of 1,804 members who live along Meduxnekeag River, in both the U.S. and Canada. The Tribe was federally recognized as a governing body in 1980. One of the Maliseet traditions is basket-making, using the wood of ash trees to fashion different styles of baskets. This traditional craft provides both supplemental income (to some) and continuity of the cultural heritage.

Seven prehistoric Native American sites are now known within the watershed area, including; Smith Bridge, Maliseet Housing, B Stream, Moose Brook, Hagan, Royal, and Gardiner, were first identified in the process of model development and testing undertaken by the NRCS (Putnam et al. 1995).

2.9 Recreation and Tourism

For many years, the Meduxnekeag River Watershed community has placed a high value on the fishing resources in the Meduxnekeag River and its tributaries. Recreation is the primary use of the Meduxnekeag River and canoeing and fishing are the predominant recreational activities for the local population as well as tourists/visitors. The Meduxnekeag River has a popular wild brown trout and brook trout sport fishery (Frost 2002). Brown trout is non-native to Maine and, as noted above, became established in the watershed during stocking of Nickerson lake from 1959 to 1952 (Frost 2002). Pearce Brook has been designated as "fishing restricted to persons 16 years of age and younger" since the late 1950s. Big Brook in Littleton, another large cold water tributary to the Meduxnekeag, is well-known locally for brook and brown trout fishing (Frost 2002).

Spring canoeing and kayaking are popular pastimes on the Meduxnekeag River with an annual canoe race to benefit local charities. The Monticello Fish and Game Club, located along the North Branch of the Meduxnekeag, is the only fish and game club in the watershed; the river is used for many different club and public functions, including canoe races. In the lower Meduxnekeag, canoeists put in below Jackson Falls during the spring and at Red Bridge later in the summer when water levels drop. The main stem of the river is navigable by canoe or kayak only under certain flow conditions (typically in the spring). In Canada, smallmouth bass tournaments are held annually within the Meduxnekeag and Saint John Rivers (Mactaquac in late May and Woodstock in September), bringing a substantial number of anglers to the lower Meduxnekeag River, near the confluence with the Saint John River. Recreational angling for brown trout and brook trout also occurs throughout the watershed.

3. Restoration Plan

Background regarding the potential restoration projects is presented in Sections 3.1 through 3.3. Section 3.4 presents recommended actions for restoring native fish habitat and populations to the Meduxnekeag River Watershed. As described in Section 1.5, the restoration of Atlantic salmon populations to the Meduxnekeag River Watershed is a primary goal of the Tribe. Therefore this section focuses on the restoration of Atlantic salmon populations and habitats, within the context of diadromous populations and habitats. In general, improvements made to the fish habitat of the Meduxnekeag River Watershed will benefit all native diadromous species.

3.1 Restoration Goals and Objectives

Section 2.1 presented an overview of the existing watershed conditions and a list of problems and restoration opportunities identified by HBMI. While not all of these problems can be completely remedied through this WAS/Plan, this section attempts to provide an initial screening/evaluation of potential projects and a roadmap for how HBMI and/or the USACE might achieve improvements for each of these problems; it also includes metrics for determining success (where possible). The restoration goals identified by HBMI and USACE for the Meduxnekeag River Watershed are as follows:

- Improve native fish habitat;
- Improve native fish passage (both upstream and downstream);
- Restore native salmon and other diadromous fish populations; and,
- Improve water quality.

Table 3-1 lists the identified watershed problems, the potential opportunities related to each of the problems, and an indication of how each of the watershed problems and opportunities are addressed by the respective restoration goals.

Table 3-1. Meduxnekeag Watershed Anadromous Fish Restoration Problems and Opportunities

Watershed Problem	Watershed Opportunity	Alignment with Restoration Goals			
		Fish Habitat	***Fish Passage***	***Diadromous Fish Restoration***	***Water Quality***
Reduced diadromous fish populations and salmon returns.	Preserve the cultural and ecological role of diadromous fishes in the Meduxnekeag River Watershed, and increase the number of salmon returns to the watershed.	✓	✓	✓	✓
Lack of river connectivity via dams, culverts, or other barriers.	Improve river connectivity and open new habitat to diadromous fishes	✓	✓	✓	
Altered flow regime and channelization.	Restore a more natural flow regime to promote habitat diversity within the river.	✓		✓	
Loss of Atlantic salmon from the U.S. portion of the watershed and diadromous fish spawning/rearing habitat.	Improve aquatic habitat quality and restore a self-sustaining population of Atlantic salmon.	✓	✓	✓	✓

Watershed Problem	Watershed Opportunity	Alignment with Restoration Goals			
		Fish Habitat	***Fish Passage***	***Diadromous Fish Restoration***	***Water Quality***
Poor or declining water quality, including water temperature, dissolved oxygen, and sedimentation.	Protection, conservation, and restoration of the Meduxnekeag watershed. Implementation of the 2015 watershed plan.	✓		✓	✓
Riparian habitat degradation resulting in poor instream habitat, streambank and channel instability and temperature increases.	Restore riparian buffers and encourage bioengineered approaches to streambank stabilization using natural materials and native plants.	✓		✓	✓
Non-native and invasive fish species.	Reduce predation, competition, and fishing pressure.	✓		✓	
Genetic alteration of remaining wild Atlantic salmon.	Protect and preserve the watershed-specific genetics of salmon stocks. Provide scientific data and information to support a comprehensive watershed fisheries plan.			✓	
Incidental catch of Atlantic salmon by anglers.	Increase fisheries management efficiency.			✓	

Source: SASWCD 2015; USACE 2016a

3.2 Restoration Project Screening

The potential Meduxnekeag River Watershed restoration projects described herein are focused opportunities intended to address components of the watershed problems listed in the previous sections. Restoration project options include the following categories that are explored and screened in this section:

- Instream habitat structure enhancements;
- Upgrades to culverts in order to enhance fish passage;
- Water quality and land use improvements; and
- Population enhancements for native diadromous fish species.

In order to begin to prioritize potential restoration activities that are aligned with these goals, a matrix was developed which scores restoration alternatives based on seven criteria. Each criterion is described below and points are assigned. Alternatives with the highest score are considered to be higher priority for implementation, while those scoring fewer points are considered to be lower priority. The results of the analysis are shown in Table 3-2. The following criteria were assessed:

1. Direct benefit to native and anadromous fishes. This criterion describes whether the proposed action would have a direct benefit to populations or habitat (high ranking), a secondary benefit (medium ranking), or little to no benefit (low ranking).
2. Technical feasibility. This criterion scores each action based on whether it is highly feasible with current technology (high ranking), difficult but possible (medium ranking), or not likely to be possible with current technology (low ranking).
3. Regulatory feasibility. This describes the ability to implement the action, based on the current regulatory requirements. It includes both of the following factors: the feasibility of obtaining the appropriate permits for the project; and an indication of whether the regulatory coordination is

currently in place to implement the action (high ranking). An alternative with a medium ranking might have cross-border coordination considerations or no clear regulatory pathway. Options with low rankings would include projects for which permits would not be attainable, or those that are prohibited by policy or law.

4. Available partners. Projects receive high rankings within this criterion if there are a large number of governmental, non-governmental, and/or private entities that would be willing partners as a part of their current mission. A medium ranking would include fewer potential partners with no clear nexus between their mission and the project. A low-ranking project would have few potential partners or no clear lead partner.
5. Water Quality supports effectiveness. This criterion determines whether the current water quality supports (high ranking) or severely limits (low ranking) the effectiveness of the proposed measure. As an example, an alternative that restores high-quality rearing habitat in an area that exhibits high water temperatures or high nutrient concentrations would be ranked low with respect to this criterion.
6. Cost Under this criterion, a project with a low cost would receive more points than a project with high cost.
7. Funding sources available. Under this criterion, actions that could be funded under current programs with sufficient funding would be ranked high while those actions with no established program or a program with no current funding would be ranked low.

The numerical scores presented in Table 3-2 can be used to categorize projects by priority.

- Projects scoring ***between 18 and 21*** are considered to be high-priority projects with a high potential for success;
- Projects scoring ***between 14 and 17*** are considered to be medium-priority projects with a medium potential for success; and,
- Projects scoring ***13 or below*** are considered to be low-priority projects with a low potential for success.

Table 3-2 lists potential restoration projects, for screening purposes, to determine feasibility of implementation, benefit to the watershed, benefit to the resource, benefit to the stakeholders/rightsholders, relative cost, and other factors.

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Table 3-2. Restoration Project Screening Within the Meduxnekeag River Watershed, Listed in Order of Total Score

Potential Project	Key Stakeholders/ Rightsholders	Alignment with Restoration Goals				Currently Underway?	Mechanism to Implement	Direct Benefit To Native and Anadromous Fishes		Technical Feasibility		Regulatory Feasibility		Available Partners		Water Quality Supports Effectiveness		Relative Cost		Funding Sources Available		Potential for Success (Qualitative)	Total Project Score (Quantitative)	Metrics to Measure Success	Notes
		Fish Habitat	Fish Passage	Diadromous Fish Rest.	Water Quality			Class L,M,H	Points1,2,3	Class L,M,H	Points1,2,3	Class L,M,H	Points1,2,3	Class L,M,H	Points1,2,3	Class L,M,H	Points1,2,3	Class L,M,H	Points1,2,3	Class L,M,H	Points1,2,3				
Cross-Boundary Fish Passage Coordination (improved coordination of restoration efforts)	HBMI, USFWS, MDIFW, DFO Canada, MNCC, MRWA, WWF	✓	✓	✓[1,2,3,4]		No	Coordination with Canadian agencies (federal & provincial) and NGOs (Meduxnekeag River Watershed Association, WWF, TNC, others)	High	3	High	3	High	3	High	3	High	3	Low	3	Med.	2	**High**	**20**	Establishment of shared database as a clearinghouse of data for the Meduxnekeag River Watershed and greater Saint John River Watershed.	Existing and planned restoration efforts on the U.S. portion of the Meduxnekeag River Watershed could be a model for the Canadian portion and, by extension, for the greater Saint John River Watershed. Improved coordination of those efforts may improve the success rate of those projects.
eDNA survey to confirm presence of Atlantic salmon	HBMI, DFO Canada			✓[1]		Yes	Sampling plan is in-place, but funding secured for preliminary survey (Atlantic salmon only)	Med.	2	High	3	High	3	High	3	High	3	low	3	Med.	2	**High**	**19**	If Atlantic salmon genetic material is detected, follow-up with additional targeted surveys.	Atlantic salmon parr documented in the Meduxnekeag River, just a few miles from the U.S. border
Expansion of instream physical habitat enhancements	HBMI, DFO Canada	✓		✓		Partially	Guidance for implementation is prescribed in the Field (2010) Report	High	3	High	3	High	3	High	3	Med.	2	Low	3	Med.	2	**High**	**19**	Number of structures placed River miles of habitat improved Native fish utilization, follow-up with fisheries monitoring.	Dozens of structures already placed within three river miles - one mile in the North Branch and two miles in the Mainstem of the Meduxnekeag River.
Best management practices (BMPs) to minimize sedimentation & nutrient loading	HBMI, NRCS, Maine DEP, US EPA, Aroostook County Soil & Water Conservation District	✓		✓[1,2,3,4]	✓	Yes	Coordination with Southern Aroostook County Soil & Water Conservation District	High	3	High	3	Med.	2	High	3	High	3	Low	3	Med.	2	**High**	**19**	Water quality monitoring (turbidity, TSS, nutrients) Sedimentation index	Water quality improvement goals consistent with US EPA and Maine DEP goals for the watershed.
Instream Atlantic salmon egg planting	HBMI, USFWS, MDIFW, DFO Canada			✓[1]		No	Guidance for implementation is prescribed by Maine DMR	High	3	High	3	Med.	2	Med.	2	High	3	Low	3	Med.	2	**High**	**18**	Monitoring of spawning sites to determine spawning success (fertilized eggs), hatching success (fry/larvae), out-migrating recruitment (tag and count smolts), and returning adults (# of Meduxnekeag River origin adults)	Maine DMR and other agencies have successfully implemented this in the Androscoggin River Watershed and other locations in Maine. Success is dependent upon fish passage upgrades at Mactaquac
Moose Brook culvert replacement	HBMI, TNC	✓	✓	✓[1,2,3,4]		Yes – planning stage only	Habitat connectivity design standards	High	3	High	3	High	3	High	3	High	3	High	1	Med.	2	**High**	**18**	Native fish utilization upstream of culvert. # of stream miles accessible	Ongoing discussions with property owner (Tate & Lyle Starch) and TNC, with final culvert design.
Restoration of river herring (alewife and blueback) to Meduxnekeag Lake	HBMI, USFWS, MDIFW			✓[3]		Yes	Hatchery-based stocking program; USFWS.	Low	1	High	3	High	3	High	3	Low	1	Low	3	High	3	**Med.**	**17**	Monitoring of population levels within the lake and effects to the forage-base of native species. If a sea-run alewife population is targeted, counts of returning adults at expected threshold level to the lake would determine success.	Not clear if river herring were historically present in the Meduxnekeag. If not, this should proceed with caution.

Potential Project	Key Stakeholders/ Rightsholders	Alignment with Restoration Goals				Currently Underway?	Mechanism to Implement	Direct Benefit To Native and Anadromous Fishes		Technical Feasibility		Regulatory Feasibility		Available Partners		Water Quality Supports Effectiveness		Relative Cost		Funding Sources Available		Potential for Success (Qualitative)	Total Project Score (Quantitative)	Metrics to Measure Success	Notes
		Fish Habitat	Fish Passage	Diadromous Fish Rest.	Water Quality			Class L,M,H	Points1,2,3	Class L,M,H	Points1,2,3	Class L,M,H	Points1,2,3	Class L,M,H	Points1,2,3	Class L,M,H	Points1,2,3	Class L,M,H	Points1,2,3	Class L,M,H	Points1,2,3				
Capture incoming Atlantic salmon spawning adults below Mactaquac Dam; transplant to Meduxnekeag River	HBMI, USFWS, MDIFW, DFO Canada		✓	✓[1]		Partially; limited to Saint John River (Canada -only)	Existing program at Mactaquac Biodiversity Facility. Transportation from Canada to U.S., or release at border.	High	3	High	3	Med.	2	Med.	2	Med.	2	Low	3	Med.	2	**Med.**	**17**	Monitoring of transplanted spawning sites to determine spawning success (fertilized eggs), outmigrating recruitment (tag and count smolts), and returning adults (# of Meduxnekeag River origin adults)	Success is dependent upon fish passage upgrades at the Mactaquac Dam. Would require cross-boundary cooperation/agreements. Expansion/offshoot of the existing New Brunswick Power (NBP) "trap & truck" program at the Mactaquac Dam.
Streamside incubation of Atlantic salmon eggs	HBMI, USFWS, MDIFW, DFO Canada			✓[1]		No	Guidance for implementation is prescribed by Maine DMR, MDIFW, and NOAA Fisheries	High	3	Med.	2	Med.	2	Med.	2	High	3	Med.	2	Med.	2	**Med.**	**16**	Monitoring of spawning sites to determine spawning success (fertilized eggs), hatching success (fry/larvae), outmigrating recruitment (tag and count smolts), and returning adults (# of Meduxnekeag River origin adults)	Success is dependent upon fish passage upgrades at the Mactaquac Dam
Fish passage improvements at the Mactaquac Dam	HBMI, USFWS, MDIFW, DFO Canada	✓	✓	✓[1,2,3,4]		Yes	New Brunswick Power (NBP) considering improvements to fish passage (up/down) facilities as part of the dam refurbishment currently underway	High	3	Med.	2	Med.	2	Med.	2	High	3	High	1	Low	1	**Med.**	**14**	Monitoring of transplanted spawning sites to determine spawning success (fertilized eggs), outmigrating recruitment (tag and count smolts), and returning adults (# of Meduxnekeag River origin adults)	Not within the control of HBMI or USACE. Success of all fish restoration projects above depend on fish passage improvements at the Mactaquac Dam
Capture outmigrating Atlantic salmon smolts (from the Meduxnekeag River); grow-out in Mactaquac Biodiversity Facility, then transplant spawning adults to Meduxnekeag River	HBMI, USFWS, MDIFW, DFO Canada			✓[1]		Partially (Canada -only)	Existing program at Mactaquac Biodiversity Facility. Transportation from Canada to U.S., or release at border	High	3	Med	2	Low	1	Med.	2	Med.	2	Med.	2	Low	1	**Low**	**13**	Monitoring of transplanted spawning sites to determine spawning success (fertilized eggs), outmigrating recruitment (tag and count smolts), and returning adults (# of Meduxnekeag River origin adults)	This aligns with what NBP is currently doing for their Mactaquac program. Success is dependent upon fish passage upgrades at the Mactaquac Dam. Would require cross-boundary cooperation/agreements.
Capture outmigrating Atlantic salmon smolts; grow-out in commercial sea pens, then transplant spawning adults to Meduxnekeag River	HBMI, USFWS, MDIFW, Maine DMR, DFO Canada, Cooke Aquaculture			✓[1]		Partially (Canada -only)	Existing program at Mactaquac Biodiversity Facility. Existing program with Cooke Aquaculture. Transportation from Canada to U.S., or release at border	High	3	Low	1	Med.	2	Med.	2	Med.	2	Med.	2	Low	1	**Low**	**13**	Monitoring of transplanted spawning sites to determine spawning success (fertilized eggs), outmigrating recruitment (tag and count smolts), and returning adults (# of Meduxnekeag River origin adults)	Project in Nova Scotia has shown positive results/returns. Success is dependent upon fish passage upgrades at Mactaquac. Would require cross-boundary cooperation/agreements. Would require cooperation with an existing commercial salmon operation.
Restoration of historical sea-run brook trout populations	HBMI, USFWS, MDIFW, DFO Canada	✓	✓	✓[2]		No		High	3	Low	1	Med.	2	Med.	2	Med.	2	Med.	2	Low	1	**Low**	**13**	Counts of individuals migrating out/in the Saint John River, near the mouth, at expected threshold levels would determine success.	Sea-run brook trout within lower Saint John River only; not within the Meduxnekeag River.

Potential Project	Key Stakeholders/ Rightsholders	Alignment with Restoration Goals				Currently Underway?	Mechanism to Implement	Direct Benefit To Native and Anadromous Fishes		Technical Feasibility		Regulatory Feasibility		Available Partners		Water Quality Supports Effectiveness		Relative Cost		Funding Sources Available		Potential for Success (Qualitative)	Total Project Score (Quantitative)	Metrics to Measure Success	Notes
		Fish Habitat	Fish Passage	Diadromous Fish Rest.	Water Quality			Class L,M,H	Points1,2,3	Class L,M,H	Points1,2,3	Class L,M,H	Points1,2,3	Class L,M,H	Points1,2,3	Class L,M,H	Points1,2,3	Class L,M,H	Points1,2,3	Class L,M,H	Points1,2,3				
Pearce Brook culvert/trestle replacements, habitat enhancements, and water quality improvements	HBMI	✓	✓	✓[1,2]	✓	Partially	Guidance for implementation is prescribed in the Field (2010) Report Habitat connectivity design standards Maine water quality standards	High	3	Low	1	Med.	2	Med.	2	Med.	2	High	1	Low	1	Low	12	Native fish utilization upstream of culverts. # of stream miles accessible Water quality monitoring	Formerly contaminated sites with residual concerns. Impaired riparian area. Many stakeholders/rightsholders involved. Water quality improvement goals consistent with US EPA and Maine DEP goals for the watershed.

NOTES: Projects scored between 18 and 21 are considered high-priority projects with a high potential for success, Projects scored between 14 and 17 are considered to be medium-priority projects, while projects scored 13 or below are considered to be low priority. Inclusion in this table does not imply endorsement by USACE or other agencies or cooperating partners. Implementation of any project listed here would require additional analysis, beyond this WAS/Plan.

[1] Atlantic salmon; [2] Brook trout; [3] River herring; [4] American eel

BMP = best management practice
DEP = Department of Environmental Protection
DFO = Department of Fisheries & Oceans
DMR = Department of Marine Resources
DOT = Department of Transportation
eDNA = Environmental DNA
HBMI = Houlton Band of Maliseet Indians
MDIFW = Maine Department of Inland Fisheries & Wildlife
MNCC = Maliseet Nation Conservation Council
MRWA = Meduxnekeag River Watershed Association
NBP = New Brunswick Power
NGO = non-governmental organization
NOAA = National Oceanographic and Atmospheric Administration
NRCS = Natural Resource Conservation Service
TNC = The Nature Conservancy
U.S. = United States
USACE = United States Army Corps of Engineers
US EPA = United States Environmental Protection Agency
USFWS = United States Fish and Wildlife Service
WWF = World Wildlife Federation

3.3 Potential Restoration Projects

Potential restoration projects were screened, ranked, and prioritized as described in Section 3.2. Ten of the projects, ranked as having a medium to high feasibility of implementation and a medium to high potential for success, are described further in this section. The screening criteria included: potential direct impact of the project; technical feasibility; regulatory feasibility; access to project partners; influence of other factors, such as water quality; relative cost; and availability of funding. Project descriptions based on criteria were summarized in Table 3-2. Each categorical ranking was assigned a numerical score to provide a preliminary priority list for projects, as described in Section 3.2. This document and Table 3-2 should be updated when projects are implemented and new challenges arise.

3.3.1 Cross-Boundary Fish Passage Coordination

Potential for Success = High; Project Score = 20

The Meduxnekeag River Watershed includes land in both the United States and Canada; this is also true of the larger Saint John River Watershed, which encompasses the Meduxnekeag River Watershed. The trans-boundary nature of this watershed presents unique challenges to watershed management and aquatic resource management.

While several different stakeholders, rightsholders, and organizations are involved and have an interest in fish passage, water quality, and habitat conservation efforts within the Meduxnekeag River Watershed and greater Saint John River Watershed, the transboundary nature of the watershed presents limitations. Informally, the stakeholders and rightsholders involved routinely share data and coordinate on projects that have mutual interest. These groups include HBMI, DFO Canada, TNC, World Wildlife Federation (WWF), MNCC, MRWA, USACE, and others. For example, members of HBMI natural resources staff have assisted with parr tissue sample collection and adult Atlantic salmon surveys conducted by DFO Canada. Similarly, the USACE has performed fish habitat characterization surveys within the Canadian portion of the watershed.

There are existing efforts to better align these agencies, stakeholders, and rightsholders through events such as the Saint John River Watershed International Cross-Boundary Summit, held biennially (most recently, in November 2018). This type of forum could be expanded on, perhaps with more focused technical group that could establish a single data-sharing portal accessible by interested agencies, stakeholders, and rightsholders, to better facilitate data-sharing between those groups with a common interest. Establishing a shared database as a clearinghouse of data for the Meduxnekeag River Watershed and greater Saint John River would be a first step at improving cross-boundary fish passage coordination.

Existing and planned restoration efforts on the U.S. portion of the Meduxnekeag River Watershed could be a model for the Canadian portion of the Meduxnekeag River Watershed, and by extension to the greater Saint John River Watershed. Improved coordination of those efforts may improve the success rate of those projects.

Table 3-2 ranks this alternative as high with respect to direct benefits to native and anadromous fishes, technical feasibility, regulatory feasibility, availability of project partners, and water quality support. The costs for these types of projects are typically low, relative to other applied watershed restoration projects.

3.3.2 eDNA Survey to Confirm Presence of Atlantic Salmon

Potential for Success = High; Project Score = 19

The Meduxnekeag River Watershed historically supported self-sustaining Atlantic salmon and other diadromous fish populations. There is evidence of some salmon using the Meduxnekeag River Watershed in recent years (see Section 2.7.3.3.3). However, it is unclear if these salmon are vestigial populations of the historical Meduxnekeag runs or if they are related to individuals spawned in other rivers that are returning to non-natal rivers or moving to the Meduxnekeag as juveniles (after being spawned elsewhere in the Saint John system).

The first step in this evaluation is to determine where the Atlantic salmon currently exist in the Meduxnekeag system. Once this information is obtained, it can be used to guide restoration efforts going forward. Environmental DNA (eDNA) provides a low-cost method for determining the presence of Atlantic salmon in a waterbody (Atkinson et al. 2017). Positive eDNA results can be confirmed with conventional fisheries capture techniques, such as electrofishing or acoustic surveys, to determine the size and age structure of the population(s) in a specific area(s). Required state or federal sampling permits from U.S. and Canadian resource management agencies would need to be obtained prior to executing any biological field surveys. Restoration alternatives could also potentially be implemented to benefit these populations and life stages.

Figure 3-1 depicts one type of eDNA test kit for Atlantic salmon. Table 3-2 ranks this alternative as high with respect to impact to direct benefit to native diadromous fishes, technical feasibility, regulatory feasibility, availability of project partners, and water quality support. The cost of this type of project is low relative to other more intensive stream restoration projects.

During September 2018, HBMI completed an initial round of eDNA sampling, which resulted in no Atlantic salmon detections in U.S. waters of the sampled portions of the Meduxnekeag River Watershed (with the exception of a likely false-positive attributed to a landlocked strain from Meduxnekeag Lake). Atlantic salmon were detected at Marven Brook in Canadian waters, where parr have been previously documented (see Section 2.7.3.3.3).

Photo Credit: Smith-Root

Figure 3-1. Field Test Kit for Atlantic Salmon eDNA

3.3.3 Expansion of Instream Physical Habitat Enhancements

Potential for Success = High; Project Score = 19

The geomorphology of the Meduxnekeag River Watershed and several of its tributaries has been evaluated in detail (Frost 2002; Field 2010). General conclusions of the report suggest that the river, in many locations, is overly straight, shallow, and wide due to historical logging and agricultural activities. In addition, the streambed is fairly homogeneous and provides relatively poor substrate for spawning and rearing of salmon and native riverine fishes. The shallow channel likely contributes to higher than optimal water temperatures for Atlantic salmon. Solutions to improve habitats in the watershed are presented in Field (2013) and several stream reaches, such as those shown in Figure 3-2, have already benefited from the implementation of the proposed solutions. Over time, these features will result in a diversity of habitats including scour pools and bars, and deposits of well-sorted gravels suitable for spawning.

Figure 3-2 shows a reach of the Meduxnekeag River that has already been enhanced by the placement of large, woody debris and boulders. The overriding concept is to place the structures in the stream and let the stream adjust in response through meanders, scour, and deposition. A number of additional candidate sites for instream physical habitat enhancements, including sites at B Stream, South Branch of the Meduxnekeag River, North Branch of the Meduxnekeag River (at the Canadian Border), and the mainstem of the Meduxnekeag River at Houlton are presented in Field (2010). These sites should be considered as first priority sites, if this alternative is implemented, but this concept could potentially be applied to as much river channel as possible where habitat complexity has been impacted by prior instream alterations. Also, this type of in-stream habitat improvement should include the installation of riparian buffers to ensure adequate habitat structure, shading, overhanging banks, and access to floodplain/floodwater storage.

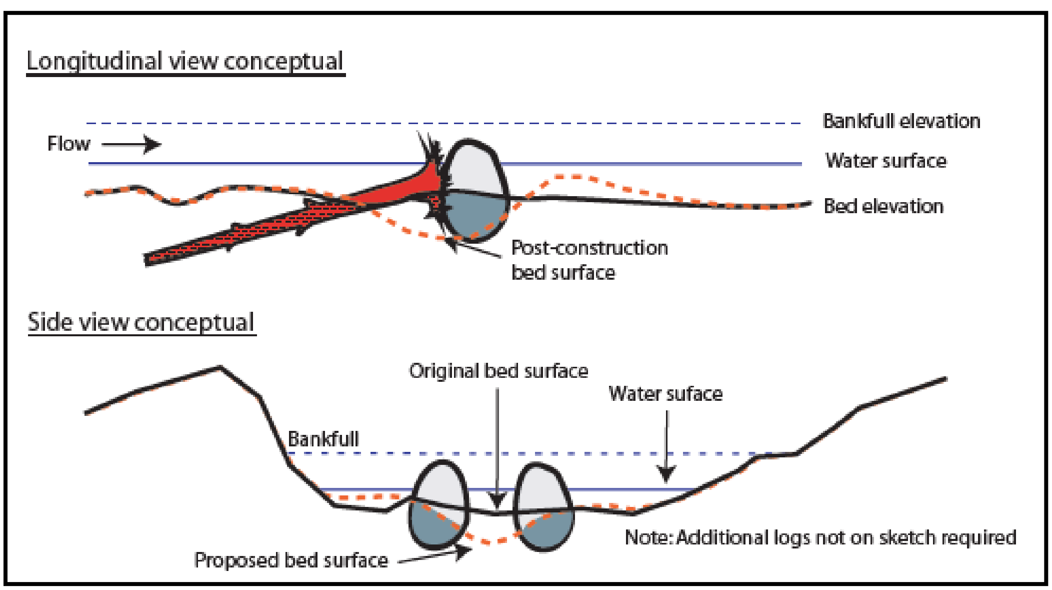
Low-Flow Conditions

High-Flow Conditions

Photo credit: AECOM

Figure 3-2. Placement of Woody Debris and Boulders in the Stream Channel

Figure 3-3 shows a conceptual view of one type of root wad and boulder placement. Additional conceptual designs are presented in Field (2013). Water quality, particularly temperature, does not fully support salmonids in some potential candidate reaches; however, in general, implementation of this type of project should result in a narrower, deeper stream channel that will be less vulnerable to elevated summer temperatures than the current shallow broad channel. In addition, the formation of bars at the meanders may result in vegetation growth near the stream that can provide shade and further reduce temperatures.



Source: Field 2013

Figure 3-3. Conceptual View of Large, Woody Debris and Boulder Placement

Table 3-2 ranks this alternative as high with respect to impact to direct benefit to native diadromous fishes, technical feasibility, regulatory feasibility, and availability of project partners. The cost of this type of project is low relative to other more intensive stream restoration projects.

3.3.4 BMPs to Minimize Sedimentation and Nutrient Loading

Potential for Success = High; Project Score = 19

In recent years, water quality has been evaluated throughout the Meduxnekeag River Watershed by several groups (HBMI 2017). The data collected has led to the conclusion that several reaches of the Meduxnekeag River are currently not supporting their designated uses (Maine DEP 2016); those reaches that are currently not supporting aquatic life uses are important to Atlantic salmon and other anadromous fish restoration efforts. Data emerging from these water quality evaluations/monitoring efforts have led to several planning documents intended to address the use impairments (SASWCD 2012; SASWCD 2015).

Nutrient loading management and reduction is critical to the restoration of Atlantic salmon to the Meduxnekeag River Watershed, since excessive nutrient enrichment has been identified as the primary cause of low DO concentrations and the proliferation of attached benthic algae in some reaches (Maine DEP 2016). Likewise, erosion throughout the watershed, primarily attributable to agricultural activities (but also to forestry activities, streambank erosion, and urban stormwater), adds substantial sediment loading to the Meduxnekeag River and its tributaries. Potato farming and other agricultural practices are common within the watershed, as depicted in Figure 3-4.

Sediment runoff from these activities degrades available spawning and rearing habitats by becoming embedded in spawning gravels and covering eggs. Water quality restoration alternatives are presented and discussed in detail in SASWCD 2015; implementation of the plan outlined in the SASWCD 2015 report is critical to the ultimate success of the Atlantic salmon restoration efforts throughout the Meduxnekeag River Watershed.

Some of the more prominent solutions offered in SASWCD 2015 include cropland erosion control, livestock nutrient management, streambank stabilization, forestry best-management practices, riparian buffer restoration, and reduction of urban sources. The plan also offers a range of potential funding options for implementation of the plan.

Table 3-2 ranks this alternative as high with respect to direct benefits to native and anadromous fishes, technical feasibility, availability of project partners, and water quality support. The costs for these types of projects are typically low, relative to other more intensive stream modification projects.

Photo Credit: SASWCD 2015

Figure 3-4. Erosion and Nutrient Export from Potato Field

3.3.5 Instream Atlantic Salmon Egg Planting

Potential for Success = High; Project Score = 18

The Maine Department of Marine Resources (Maine DMR) is currently operating an instream egg-planting project in an effort to enhance Atlantic salmon recruitment within specific watersheds of the Gulf of Maine DPS. This experimental project began in 2002 using surplus eggs from the Green Lake National Fish Hatchery to implant within the Sandy River and its tributaries, including Orbeton Stream located in Franklin County. In 2010, the observed fry hatching rate was within an approximate range of 40-47% at four of the nine monitored locations (Mitchell 2013). An adaptive management approach has been implemented to improve on-site selection and methodology, which is anticipated to improve the hatching rate.

The high-percentage hatching rates have yielded direct results in returns of spawning adults. By 2006, for the first time in more than 150 years, four spawning adults returned to the Sandy River. This program has had continued success, yielding eight consecutive years of returning salmon, with the highest returns of 43 individuals in 2011 (Mitchell 2013).

This method is far less labor intensive than the streamside incubation method described in Section 3.3.9. Once the eggs are planted within the streambed, there is no monitoring needed until hatching occurs. A simple egg implantation device is relatively inexpensive to assemble. Figure 3-5 provides photographs of the egg planting process.

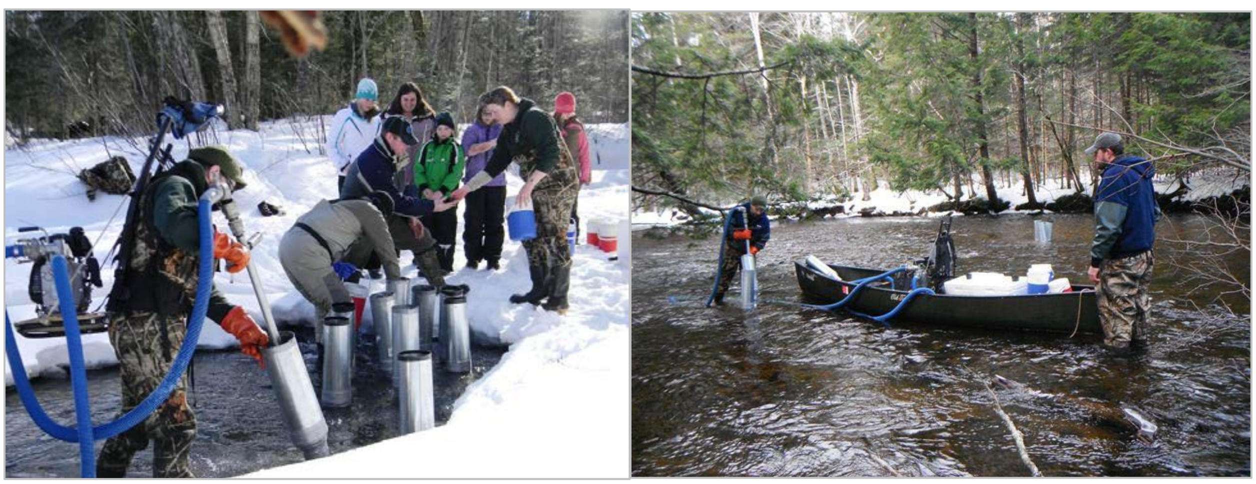


Photo credit: Maine DMR

Figure 3-5. Instream Egg Planting Using Hydraulic Methods

A trapping program, which requires daily visits, is typically conducted in the spring to monitor the success of the project. However, once a site has demonstrated success, future planting is all that would be necessary, eliminating the need for labor-intensive surveys. Currently, a field team of three to four people can plant about 200,000 eggs per day. This rate may also improve as information is gained from the program. Program costs for this restoration option have not been evaluated for application within the Meduxnekeag River Watershed; however, Maine DMR could be consulted to determine ballpark cost estimates, based on their application of this method within other Maine watersheds.

The Mactaquac Biodiversity Facility (MBF), located at the Mactaquac Dam near Fredericton, New Brunswick, operates several hatchery-based programs aimed at conserving and restoring populations of Atlantic salmon within the Saint John River Watershed. The MBF would be the logical potential source of eggs for a Meduxnekeag River Watershed planting or incubation program. This facility already has a captive rearing program for OBOF populations (specifically for the Tobique River). The opportunity to obtain OBOF-specific eggs maintained at this facility, and use them for instream egg planting operations could be further investigated as a potential restoration option within the Meduxnekeag River Watershed.

This facility also has established a live gene bank (LGB) program that captive-breeds and rears individuals from the IBOF populations of Atlantic salmon listed as endangered in Canada. While the Meduxnekeag River Watershed lies outside of the IBOF population of Atlantic salmon, the same type of LGB approach could be considered and applied, if feasible, using a similar LBG program, specific to OBOF Atlantic salmon recovery efforts, within the Meduxnekeag River Watershed. Eggs from the MBF, as part of the Tobique River program, could be candidates for transfer into the Meduxnekeag River Watershed, since both are part of the OBOF population. Appropriate permits would need to be obtained from U.S. and Canadian resource management agencies prior to implementing such a program.

Table 3-2 ranks this alternative as high with respect to impact to direct benefit to native diadromous fishes and technical feasibility. The cost of this type of project is low relative to other more intensive stream restoration projects.

3.3.6 Moose Brook Culvert Replacement

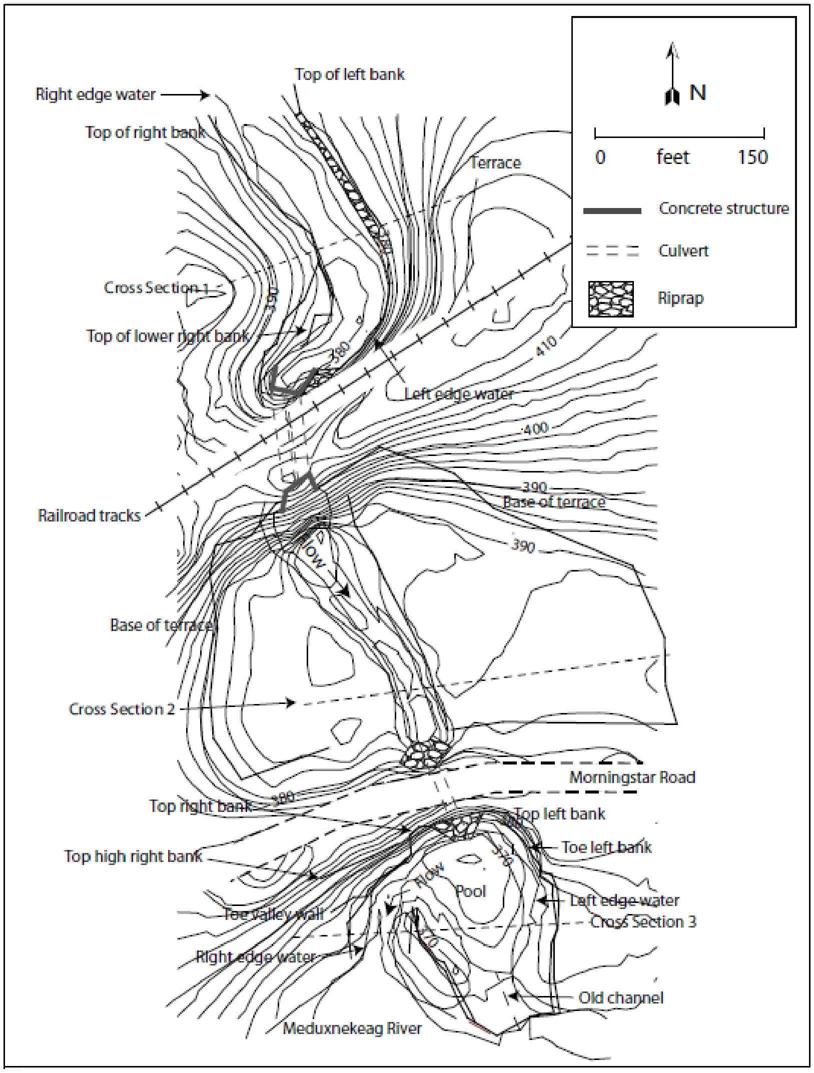
Potential for Success = High; Project Score = 18

Stream crossings were identified as a potential barrier to fish passage in Section 2.5.2. Of the 208 documented stream crossings in the Meduxnekeag River Watershed, only 27% have been classified as known barriers to fish migration, as shown in Figure 2-5. As discussed in section 2.5.2, some of these barriers to fish migration occur higher up in a tributary stream, such that a migrating fish could still potentially access much of the available habitats within that stream. Moose Brook, a major tributary to the mainstem of the Meduxnekeag River, is considered a high-quality stream with cool water temperatures. The primary barrier to fish migration is a perched culvert at its confluence with the Meduxnekeag River, which prevents access to this high-quality habitat under most flow conditions. For this reason, Moose Brook has been identified as a high-priority restoration site for upgrading the existing culverts and enhancing fish passage.

Moose Brook enters the Meduxnekeag River approximately 0.62 river miles west of the confluence of the South Branch and the Meduxnekeag River, in Houlton ME. Moose Brook is considered a “Class-A” waterbody upstream of Ludlow Road. Morningstar Road crosses Moose Brook over a corrugated steel culvert immediately upstream from its confluence with the Meduxnekeag River. This perched culvert restricts fish passage into Moose Brook during most flow conditions; during low-flow conditions, it includes an approximate drop of 2 ft into the scour pool below. The scour pool created from the culvert outflow has altered the natural flow regime where Moose Brook enters the Meduxnekeag River, with substantial sediment buildup that has created a large sandbar. The series of culverts, as well as the plunge pool and sandbar, have resulted in a flow pattern that circulates upriver before entering the Meduxnekeag River channel, as shown in Figures 3-6 and 3-7.

Photo credit: AECOM

Figure 3-6. Moose Brook Outlet at Morningstar Road Culvert During Low-Flow Conditions



Source: Field 2010

Figure 3-7. Arrangement of Morningstar Road Culvert and Railroad Culvert

Moose Brook contains high-quality spawning/rearing habitats and appropriately cold temperatures required to support Atlantic salmon and other diadromous species (HBMI 2017). Water temperatures in Moose Brook are monitored by HBMI staff each summer and the observed water temperatures typically remain lower than the 72.5°F critical threshold for salmonids (in contrast with the higher temperatures of the mainstem Meduxnekeag River) (HBMI 2017). Currently, this high-quality habitat in Moose Brook cannot be easily accessed by diadromous fishes from the Meduxnekeag River because of the inadequate passage at the Morningstar Road culvert.

Since 2015, TNC and HBMI have been exploring options for replacing the perched culvert with a more “fish friendly” design. These options include the use of an open-bottom box culvert, using stream simulation methods inside the culvert; and restoring the natural stream alignment and slope of the stream gradient upstream and downstream of the culvert to permanently remove this migration barrier from the watershed. The single landowner (Tate & Lyle Starch) that occupies the land adjacent to Moose Brook at Morningstar Road is generally receptive to the concept of this approach to improve the culvert, provided that the restoration will not impose restrictions on their operations. Morningstar Road is owned by the Town of Houlton and the Houlton Department of Public Works agrees with this potential replacement approach (which is consistent with their budgetary requirements). To date, all of the stakeholders and rightsholders have been involved in the approach for this potential restoration project and TNC has developed two conceptual project designs, as described in Table 3-3.

Table 3-3. Conceptual Restoration Options for the Morningstar Road Culvert on Moose Brook.

Restoration Option	Description
Concept A – Replace Culvert with Fish Passage	Replacement of existing culvert with new 12’ tall x 20’ wide pre-cast box culvert. Grade and alignment would be similar to the existing streambed. Installation of denil-style concrete fishway at the outlet of the culvert to provide fish passage under most flow conditions.
Concept B – Restore Historical Stream Alignment and Morphology	Replacement of existing culvert with new 12’ tall x 40’ wide open-bottom pre-cast box (or arch) culvert. Grade and alignment would be restored. Incorporation of “stream simulation” methods to span 1.2 x the bankfull width, restoring a more natural streambed condition within and outside of the culvert. Placement of a series of stone weirs and step-pools within the restored channel alignment between Morningstar Road and the railroad crossing (approximately 275’ upstream) to ensure passable conditions through the railroad crossing.

Source: TNC 2015

Figure 3-8 provides examples of what “Concept B” (Restore Historical Stream Alignment and Morphology) might look like, based on similar projects completed in other watersheds that have utilized a 1.2x bankfull width approach and “stream simulation” design principles. These standards typically provide long-term solutions to hanging/perched culverts that restrict fish passage by restoring the slope of the streambed and re-introducing a natural streambed composition inside the culvert; these measures result in successful fish passage under most flow conditions. The State of Maine Department of Transportation (DOT) has recently adopted such design principles for all state-maintained stream crossings within designated critical habitat for the Gulf of Maine Distinct Population Segment of Atlantic Salmon (Maine DOT 2017).

Photo credits: Left - Maine DOT; Middle - Maine DOT; Right - AECOM

Figure 3-8. Culvert Replacement Projects in Northern Maine Utilizing a 1.2x Bankfull Width Approach and “Stream Simulation” Design Principles

Given the limited availability of high-quality salmonid spawning/rearing habitat within the Meduxnekeag River Watershed, improving fish passage into a high-quality tributary stream, such as Moose Brook, would benefit existing salmonids, including brook trout and native diadromous species within the watershed. If this project was combined with a population-enhancement project for Atlantic salmon, access to Moose Brook would be an important feature to the success of restoring Atlantic salmon to the watershed by providing access to spawning/rearing habitat, as well as potential locations for direct population enhancements such as egg planting, or other similar methods under consideration. Appropriate permits would need to be obtained from U.S. and Canadian resource management agencies prior to implementing such a program.

Table 3-2 ranks this alternative as high with respect to impact to direct benefit to native diadromous fishes, technical feasibility, regulatory feasibility, availability of project partners, and water quality support. The cost of this type of project is high relative to other less intensive stream restoration projects.

3.3.7 Restoration of River Herring to Meduxnekeag Lake

Potential for Success = Medium; Project Score = 17

Meduxnekeag Lake (also known as Drew's Lake) has been discussed as a candidate for river herring (collectively alewife and blueback herring) restoration by USFWS. The program would involve stocking adult river herring in the lake prior to their spawning. While it is possible that the resultant population may become landlocked, some or all of the juvenile population may out-migrate downstream. The primary benefits of this restoration effort would be the provision of forage species to the resident landlocked salmon population in Meduxnekeag Lake. However, there may be some forage-base benefit for non-landlocked Atlantic salmon in the Meduxnekeag and Saint John Rivers as herring migrate out of Meduxnekeag Lake to the ocean via the Meduxnekeag River. Section 2.5.3 described a potential natural barrier to upstream migration of river herring beyond Jackson Falls, in Canada. If this falls functions as a barrier to river herring, then river herring were not likely part of the native fish community in Meduxnekeag Lake; therefore, the restoration of "sea-run" river herring may not be warranted this high up in the watershed, if that is the goal. Appropriate permits would need to be obtained from U.S. and Canadian resource management agencies prior to implementing such a program.

Table 3-2 ranks this alternative as low with respect to direct benefits to native and anadromous fishes in the Meduxnekeag River Watershed. It is ranked high with respect to technical feasibility, regulatory feasibility, availability of project partners, and availability of funding sources. The cost for this program would likely be low as long as a local source of stocked individuals of the appropriate lifestages could be secured for transport and stocking.

3.3.8 Capture Incoming Atlantic Salmon Adults Below Mactaquac Dam and Transplant to the Meduxnekeag River

Potential for Success = Medium; Project Score = 17

The MBF, located at the Mactaquac Dam near Fredericton, New Brunswick, operates several hatchery-based programs aimed at conserving and restoring populations of Atlantic salmon within the Saint John River Watershed, specifically within the Tobique River (a tributary of the Saint John River). The Mactaquac Dam has a fish lift designed to collect fishes returning to the dam, where they have historically been trucked and released upriver. In recent years, this activity has expanded to include a fish culture facility to spawn and grow Salmon for stocking in captivity to compensate for production losses upriver of the dam. The facility is capable of rearing more than two million eggs and up to one million individuals of various life stages, annually (DFO Canada 2017).

For the "trap & truck" program, the MBF collects migrating adult salmon at the fish lift and then trucks and releases them upriver of the Mactaquac Dam headpond. Release locations for relocated adults are generally near Woodstock, NB, so that migrating adults can be released upriver of the influence of the dam's headpond and continue their upriver migration. Given the release location is already near the confluence of the Meduxnekeag River with the Saint John River, it may be feasible to release a portion of the spawning adults within the Meduxnekeag River itself (near the U.S. border), assuming that those individuals would continue their migration upriver and into spawning habitats available within the Meduxnekeag River Watershed. This approach would require some level of monitoring, such as acoustic telemetry, of adults as they move upriver, as well as locating and monitoring redds to determine spawning and hatching success. If those initial reproductive stages are successful, then a smolt trap could be used to quantify the reproductive output of the Meduxnekeag River, in terms of smolt production. This information could then be compared to other known systems with high-quality spawning habitats within the Saint John River Watershed, such as the Tobique River. The presence of parr in the lower portion of the Meduxnekeag River in recent years suggests that spawning success could be feasible in this system.

However, it is also possible that the observed parr could have spawned elsewhere and may be using the lower Meduxnekeag River Watershed as rearing habitat only.

The MBF also maintains a LGB program to support recovery of the endangered IBOF Atlantic salmon population. This program involves rearing captured wild juvenile Salmon from the Big Salmon River through to the adult stage followed by hatchery spawning and the release of juveniles. All individuals are subjected to DNA analysis for stock origin and family grouping, so that mating of siblings is avoided and family representation is optimized. In this manner, the genetic integrity of the IBOF population is optimized. While the Meduxnekeag River Watershed lies outside of the IBOF population of Atlantic salmon, the same type of LGB approach could be considered and applied, if feasible, by establishing an LBG program, specific to OBOF Atlantic salmon recovery efforts. The LGB program could also be an integral component of the instream egg planting or streamside incubation projects described in Sections 3.3.5 and 3.3.9, respectively. Appropriate permits would need to be obtained from U.S. and Canadian resource management agencies prior to implementing such a program.

In addition to maintaining the LGB program, the MBF also participates in a program that applies a novel approach to fish stocking. In the Fundy Salmon Recovery Project, rather than stocking fish as juveniles, outgoing IBOF smolts are trapped at the dam and grown-out to spawning adults in the MBF or in commercial sea pens; this project has seen great success in Fundy National Park by removing the at-sea mortality element from the life history of these individuals (Parks Canada 2018). This program has potential for application in the Meduxnekeag River Watershed, using OBOF smolts. However, a logical first step would be to further evaluate the feasibility of relocating spawning adults at the dam to sites within or adjacent to the Meduxnekeag River in order to evaluate the potential success of this or other related programs. Potential issues with this approach would be the transfer of adult salmon across international borders and the uncertainty associated with transferring fish that were destined to a stream that's not the natal stream to those spawning adults. There would be potential impacts to the natal streams that those individuals were otherwise destined for. Substantial coordination would be required among the rightsholders, stakeholders, and various agencies to implement this project. Table 3-2 ranks this alternative as high with respect to impact to direct benefit to native diadromous fishes and technical feasibility. The cost of this type of project is high relative to other less intensive stream restoration projects.

3.3.9 Streamside Incubation of Atlantic Salmon Eggs

Potential for Success = Medium; Project Score = 16

The Maine Department of Marine Resources has implemented streamside incubation of Atlantic salmon in the Kennebec and Sandy Rivers. The results from this program indicate some success and have been used to estimate potential benefits and costs for the implementation of similar efforts within the Meduxnekeag River Watershed.

The Craig Brook National Fish Hatchery in Maine, established in 1889, spawns Atlantic salmon broodstock from the Penobscot River to produce up to three million eggs per year. A portion of these eggs are transferred to another hatchery (Green Lake National Fish Hatchery) for smolt production and the rest are raised at Craig Brook and then released as fry. At this hatchery, captured juveniles from the Penobscot and six other DPS rivers are reared to reproductive maturity; they spawn and produce fry which are then released to their respective rivers of origin. Excess eggs are provided free to the State of Maine to support its experimental streamside and instream incubation programs. The Mactaquac Hatchery could presumably provide OBOF eggs for a similar program along the Meduxnekeag River but would likely require financial compensation.

During the winter of 2002-2003, the Atlantic Salmon Commission tested streamside incubation at three sites on two tributaries to the Sandy River in Maine. Old refrigerators were used as incubators and placed streamside with water flow-through systems (Figure 3-9). Eggs from hatcheries were raised in the incubators and the fry were released in the spring. Hatching success was 90%; however, maintenance demands for the incubators were high. In this method, building the incubators is time consuming, the incubator systems are prone to freezing, and the number of incubators and people available to maintain the systems limit the number of eggs and possible hatchings. Several visits to the incubators – up to two to three times per week – are required to ensure that the systems are running properly and during the hatching period, daily visits are required.

Photo credit: Maine DMR

Figure 3-9. Streamside Atlantic Salmon Incubator Using Old Refrigerators as Incubation Chambers

Assuming old refrigerators are donated, costs for this program would include supplies such as pumps, electricity and labor associated with building the incubators, monitoring and maintenance. In addition to these direct costs, labor would be required to build an incubator and two to three visits per week are required for a two person crew for four to five months to maintain, monitor the system and release the fry. One refrigerator can house approximately 25,000 eggs. Using the hatch rate from the 2008 Atlantic Salmon Assessment Committee Annual Report (75%) and a return rate of 0.013%, five incubators could produce 12 adult returns. Program costs for this restoration option have not been evaluated for application within the Meduxnekeag River Watershed; however, Maine DMR could be consulted to determine ballpark cost estimates, based on their application of this method within other Maine watersheds.

The MBF would be a logical potential source of eggs for a Meduxnekeag River Watershed planting or incubation program. This facility uses native Saint John River salmon stocks. This facility has also established a LGB program that captive-breeds and rears individuals from the IBOF populations of Atlantic salmon listed as endangered in Canada. While the Meduxnekeag River Watershed lies outside of the IBOF population of Atlantic salmon, the same type of LGB approach could be considered and applied, if feasible, using a similar hatchery-based or LBG program, specific to OBOF Atlantic salmon recovery efforts, within the Meduxnekeag River Watershed. Eggs from the MBF, as part of the Tobique River program, could be candidates for transfer into the Meduxnekeag River Watershed, since both are part of the OBOF population. Appropriate permits would need to be obtained from U.S. and Canadian resource management agencies prior to implementing such a program.

Table 3-2 ranks this alternative as high with respect to impact to direct benefit to native diadromous fishes and water quality support. The cost of this type of project is moderate relative to other more intensive stream restoration projects.

3.3.10 Fish Passage Improvements at the Mactaquac Dam

Potential for Success = Medium; Project Score = 14

The Mactaquac Generating Station, owned and operated by New Brunswick Power (NB Power) since 1968, is a run-of–the-river hydropower facility with an installed generation capacity of 660 megawatts (MW), supplying about 12% of electricity needs for the province of New Brunswick, Canada (NB Power 2016). As described in Section 2.5.1, the Mactaquac Dam is the primary barrier to migratory diadromous species attempting to reach the Meduxnekeag River. A total of 11 diadromous species, including Atlantic salmon, are known to occur at the Mactaquac Dam, with historical runs occurring upriver to Grand Falls and various tributaries; including the Meduxnekeag River (NB Power 2016).

Atlantic salmon are currently managed for upstream migration at the Mactaquac Dam (Figure 3-10) by corralling fishes into collection facilities on the downstream side of the powerhouse and transporting them upstream by truck. The dam currently has no infrastructure for the downstream movement of fishes from the headpond past the dam. In order to successfully navigate downstream, outmigrating fishes must move through a series of turbines, spillways, or over the diversion sluiceway, which is only accessible during periods of high water (NB Power 2016).

Source: Linnansaari et al. 2015

Figure 3-10. Schematic Representation of the Existing Mactaquac Dam

In recent years, maintenance issues have been noted at the dam. Specifically, the facility has been affected by an alkali-aggregate reaction which causes the concrete to swell and crack, requiring substantial annual maintenance and repairs. NB Power is proposing a project to ensure continued, safe operation of the concrete dam through modification of its maintenance schedule (NB Power 2016).

NB Power anticipated a potential early retirement of the station due to the alkali-aggregate reaction and in 2013, it began to consult with engineers, scientists, stakeholders, rightsholders, the public, and First Nations on potential future options for the dam site. These options included:

1. Building a new station;
2. Removing all of the structures, except for the earthen dam; or
3. Removing all of the structures and restoring the Saint John River to its natural flow.

In December 2016, NB Power recommended a fourth option, which was to maintain the station to achieve its original intended lifespan (through approximately 2068) by employing various means of rehabilitation – this became known as the “Life Achievement” approach (NB Power 2016). This decision requires NB Power to balance environmental, social and technical, and cost considerations. As part of this “Life Achievement” approach, NB Power agreed to install multi-species fish passage. However, the specific details of the fish passage design and goals have not yet been determined.

NB Power has agreed to continue working with CRI and DFO (DFO Canada 2017) to achieve targeted fish passage goals on the Saint John River as informed by science, ongoing studies, input from stakeholders, First Nations rightsholders, and future regulatory requirements (NB Power 2016).

This Life Achievement option requires the addition of multi-species fish passage to the existing dam, informed by best available science from ongoing research by CRI, including fish behavior studies and environmental flow studies to optimize the success of potential fish passage improvement projects. NB Power has allocated funding for the installation of adequate multi-species fish passage at the Mactaquac Dam (NB Power 2016).

Currently, upstream fish passage is entirely “trap & truck” to locations above the headpond, which results in fishes being placed near Woodstock, NB (in the vicinity of the confluence of the Meduxnekeag River with the Saint John River). Improvements to the upstream passage at the dam would likely enhance the numbers of fishes re-located upriver of the dam and would eliminate or reduce the need for an active trap-and-haul management scenario.

For downstream passage, funding has already been spent on construction of a bypass sluice. This bypass sluice redirects out-migrating smolts (and adult American eel) into a sluiceway where a portion of the salmon are kept in the Mactaquac Biodiversity Facility, grow to adults, and are subsequently transferred to upriver locations for optimal spawning potential in natural conditions (NB Power 2016).

Fish passage options at the Mactaquac Dam have been debated for many years, with increasing attention given to this topic in recent years. A workshop for fish passage experts was held in 2014, which explored and evaluated fish passage options at the Mactaquac Dam. Linnansaari et al. 2015 summarized the workshop and provided the following preliminary list of conceptual fish passage options for Mactaquac Dam (note that the list does not consider the feasibility of any particular option):

- Locate hydraulic structures near the shore and in one section of the river to concentrate river flow;
- Fish lift and hopper;
- Fish collection facilities (trap & truck);
- Fishways (fish ladders);
- Fish ramps;
- Fish-friendly turbines;
- Angling of the powerhouse as much as possible to the axis of flow;
- Downstream by-pass structures;
- Top-opening gates in one or two main spillway gates;
- Downstream guidance structures; and
- Flexible tube pressure-differential fish passage.

The implementation of one or more of these options at the Mactaquac Dam may be considered as part of the “Life Achievement” approach to provide improved fish passage.

Another important component of a successful fish passage restoration program at the Mactaquac Dam is the LGB program at the Mactaquac Biodiversity Facility, which yields about 500,000 eggs per year for re-population of IBOF rivers, producing next-generation juveniles and, ultimately, broodstock (DFO Canada 2017). By growing-out these fish to spawning adults, this program circumvents the poor levels of marine survival (cited as an important factor in the decline of Atlantic salmon populations in North America) and maximizes their potential for recovery by avoiding exposure to sources of marine mortality (DFO Canada 2017). While the Meduxnekeag River Watershed lies outside of the IBOF population of Atlantic salmon, the same type of LGB approach could be considered and applied, if feasible, using a similar LBG program, specific to OBOF Atlantic salmon recovery efforts, within the Meduxnekeag River Watershed.

Since the Mactaquac Dam is the primary barrier to migration to/from the Meduxnekeag River, it is imperative that HBMI engages with NB Power as a stakeholder to ensure that NB’s stated fish passage goals (and, consequently, diadromous species restoration goals) for the Saint John River Watershed are consistent with HBMI’s restoration goals for the Meduxnekeag River Watershed. Various First Nations communities and organizations (including all six Maliseet and nine Mi’kmaq communities in New Brunswick) have already engaged with NB Power to evaluate the future of the Mactaquac Dam (NB Power 2016). Under this approach, NB Power must recognize the Maliseet Nation Tribes, and HBMI by extension, as important rightsholders in their engagement of First Nations as part of the “Life Achievement” project. To ensure that HBMI participates and is recognized during this stakeholder/rightsholder engagement, it may be productive to maintain a high-level of coordination with the natural resource managers of the various Maliseet Nation Tribes within the Saint John River Watershed in New Brunswick. An organization such as the MNCC would be a logical partner to coordinate with HBMI, since HBMI's restoration goals for the Meduxnekeag River Watershed are closely aligned with MNCC's watershed goals for the Saint John River Watershed (MNCC 2018).

Finally, active engagement with the greater Maliseet Nation to bring fish passage issues to light can be facilitated by staying active in regional events, such as the Saint John River Watershed International Cross-Boundary Summit that was last held at the Tobique First Nation in April 2018. In this manner, HBMI could take a pro-active approach to implement appropriate fish passage design at the Mactaquac Dam. Once implemented, this approach would ensure the highest level of probability of Atlantic salmon migration into the Meduxnekeag River.

Table 3-2 ranks this alternative as high with respect to impact to direct benefit to native diadromous fishes. However, the cost of this type of project is high relative to other less intensive stream restoration projects.

3.3.11 Low-Priority Projects

As described earlier in this section, the ten projects described here are included because they ranked as having a medium to high feasibility of implementation and a medium to high potential for success. The remaining four projects had a low feasibility of implementation and a low potential for success; therefore they are not described further in this document. It is possible that the scorings/rankings of feasibility of implementation or potential for success could change over time as more information is obtained and as other projects are implemented, potentially making those projects more feasible. Therefore, it is important to revisit Table 3-2 and re-evaluate each of these projects over time, or any additional new projects, as appropriate.

3.4 Recommended Actions

3.4.1 Implementation

An adaptive management approach is highly recommended for implementation of this plan. Adaptive management enables stakeholders and rightsholders to conduct restoration activities in an iterative manner; this provides opportunities to efficiently use available resources. Stakeholders and rightsholders can evaluate the effectiveness of one set of restoration actions and either adopt or modify the activities before implementing the next round of restoration. It also allows the stakeholders and rightsholders to react to technical advances as well as regulatory and funding changes within the confines of this plan.

This plan should be considered a living document that will be continually updated as restoration activities are completed or conditions change. The adaptive management approach recognizes that the entire watershed cannot be restored with a single restoration action or within a short time frame. Instead, adaptive management establishes an ongoing program that provides adequate funding, stakeholder/rightsholder guidance, and efficient coordination of restoration activities. Implementation of this approach ensures that appropriate restoration actions are taken and that populations and habitats are monitored to document restoration over an extended time period. The adaptive management components for future implementation efforts should include the following measures:

- ***Establish an implementation committee***. This committee should include all relevant stakeholders and rightsholders across the watershed and state and federal agencies. This committee is charged with ensuring that the plan is up-to-date, progress is being made, and opportunities for action are fully exploited.
- ***Develop a plan for sustainable funding***. Lack of funding or insufficient funding can often slow or stop the implementation of a watershed plan. Funding should rely on multiple

revenue streams to maintain momentum in the event that one or more source of revenue declines or is eliminated.

- ***Continue public outreach***. Public outreach throughout implementation is critical to maintaining support for restoration efforts. Publicizing successes may lead directly to opportunities for expansion of existing efforts or new projects elsewhere in the watershed.
- ***Develop a long-term monitoring program***. Documenting improvements over time is essential to maintaining momentum in implementation. This may include direct measures, such as documenting fish populations, or indirect measures, such as documenting water quality improvements or increases in habitat quality over time. This documentation forms the foundation of outreach efforts and directly impacts the ability to attract additional funding to support restoration.
- ***Establish measurable milestones***. A schedule for implementation is critical to maintaining the forward momentum of the restoration project. A list of action items and target dates for completion is an essential part of the restoration plan.

3.4.2 Expected Future Condition/Outcome

The ultimate outcome of the restoration plan is to restore the habitats within the Meduxnekeag River Watershed to support native fish communities, including diadromous fishes – particularly, Atlantic salmon. The restoration projects outlined in this document are intended to improve the available habitat for spawning/rearing within the watershed, so that Atlantic salmon and other diadromous fishes can be restored through direct measures such as stocking, planting, or relocating, or through natural recruitment and migration from adjacent spawning populations within the Canadian portion of the river. To ensure that adequate fish passage exists, it is imperative that restoration projects implemented within the U.S. portion of the watershed include some level of coordination with the Canadian portion of the watershed.

To facilitate changing the status of the Meduxnekeag River from a “historical” salmon river, to an “occupied” salmon river, certain aspects or habitat parameters of the watershed must be changed/restored to a different (improved) condition, as shown in Table 3-4. Projects implemented to restore Meduxnekeag River Atlantic salmon habitat and populations would aim to exhibit the characteristics listed in Table 3-4.

Table 3-4. Existing and Desired Habitat Conditions Relevant to Enhancing Outer Bay of Fundy Atlantic Salmon Populations

Parameter	Existing Condition	Desired Future Condition
Water Quality	> 72°F max water temperature < 7 mg/L min. DO > 8.5 max. pH excess nutrients fuel excessive algae growth	All waterbodies meet water quality standards and support designated uses which include native and anadromous fish spawning and rearing.
Flow Regime/Channelization and Structured Habitat	Uniform flow/depth exists in non-restored locations with minimal structure.	In-stream structure placement creates structured habitats with variable flow/depth regimes.
Substrate	Areas of stream/river bed experience sedimentation from agricultural runoff within historical spawning habitat.	Sediment sources are eliminated/reduced and variable flow regime allows sediment to move through the stream/river bed.
Accessibility	Major dam in lower watershed, with minimal fish passage Culverts restrict access to tributaries containing spawning habitat	Major dam in lower watershed, with improved fish passage Improved culverts using habitat connectivity design (HCD) provide unrestricted access to tributaries containing spawning habitat

Parameter	Existing Condition	Desired Future Condition
Spawning Habitat	An unknown portion of 118 acres of historical spawning habitat is available/accessible	All 118 acres (100%) of historical spawning habitat available/accessible 2.4 eggs per m^2 of productive habitat, based on OBOF conservation egg requirements and abundance targets
Rearing Habitat	An unknown portion of 251 acres of historical rearing habitat is available/accessible	All 251 acres (100%) of historical rearing habitat is available/accessible
Atlantic salmon population size in the Meduxnekeag River Watershed	Egg production = unknown Parr density = 0.0 to 17.5 parr/100m^2 Annual returns = unknown	Egg production = 2.4 eggs per m^2 Parr Density = 9.3 to 28.0 parr per 100 m^2 Adult population size = 56 individuals based on estimates from OBOF conservation limits of egg production and parr density Adult returns = 440-733, based on estimates of historical runs.

Note: Data reported in metric units to align with source data.

Sources: Baum 1982; Baum 1997; COSEWIC 2010; DFO Canada 2014; U.S. Atlantic Salmon Assessment Committee 2017; DFO Canada 2018a; Gibson et al. 2016; DFO Canada 2018d

Atlantic salmon require very specific habitat parameters during their life history. Since a major focus of the desired restoration within the Meduxnekeag River Watershed is specific to Atlantic salmon restoration, particular attention is given to habitat requirements for spawning adults and rearing habitats for eggs, larvae, and juveniles (parr), although these habitat features also benefit other native diadromous fish species.

The Meduxnekeag River Watershed, and greater Saint John River Watershed, have gone through many changes that have resulted in impacts to the availability of, and access to, spawning and rearing habitats for Atlantic salmon. Baum (1997) estimated that the Meduxnekeag River Watershed once had 118 acres of spawning habitat and 251 acres of rearing habitat for Atlantic salmon. Recent habitat surveys conducted between 1997 and 2015 (USACE 2017) identified only 1.83 acres of spawning habitat within the mainstem of the Meduxnekeag River. A more comprehensive habitat survey would be required to fully quantify the total acreage of spawning and rearing habitat within the watershed. Such a survey should include major tributaries as well, since it is likely that much of the currently available spawning habitat lies within tributaries to the Meduxnekeag River. The available spawning and rearing habitat can be used as a metric to estimate the number of outmigrating smolts that could be expected to result from a restored Meduxnekeag River Watershed, within the context of estimated historical runs of 440 to 733 annual adult returns (Baum 1997). For comparison, the 4-year average annual returns at the Mactaquac Dam between 2015 and 2018 was 130 multi sea-winter adults and 472 grilse (DFO Canada 2018d)

NOAA Fisheries identified Primary Constituent Elements (PCE) as part of designating critical habitat for the Endangered Species Act (ESA)-listed Atlantic salmon in the Gulf of Maine Distinct Population Segment (DPS) in Maine (NOAA 2009b). The Meduxnekeag River is outside of the regulatory DPS; however, the same habitat requirements (identified in Table 3-5) that are essential to the conservation of each lifestage within the DPS rivers (NOAA 2009b), are also essential to the conservation and restoration goals aligned with each lifestage within the Meduxnekeag River Watershed and the greater Saint John River Watershed. Restoration efforts aimed at one, or several, lifestages should use these essential features as guidelines for habitat needs and required improvements to existing habitats to create positive outcomes in restoring Atlantic salmon populations.

Table 3-5. Atlantic Salmon Habitat Features to Achieve Restoration Goals (Adapted from Kircheis and Liebich 2007)

Essential Feature	Fully Functioning	Limited Functioning	Not Properly Functioning
Spawning Adults (October 1 to December 14) (April 15 to December 14 for migrating adults)			
Passage	Unrestricted upstream passage of adults to optimal spawning habitat.	Partial barriers limit access of adults to suitable spawning habitat.	Barriers eliminate access of adults to suitable spawning habitat.
Substrate	Nearly 100% gravel/cobble (0.47 to 3.9 in)	40-60% cobble; 40-50% gravel; 10-15% coarse sand; < 3% fine sand	> 20% sand; 0% gravel/cobble
Depth	15.0 in	6.7 to 30.0 in	< 6.7 in
Velocity	1.00 to 1.50 ft/second (sec)	0.92 to 2.75 ft/sec	< 1.67 ft/sec and > 2.58 ft/sec
Temperature	44.6 to 50 °F	< 44.6 °F and > 50 °F	
pH	> 5.5	< 5.5	< 5.0
Cover	Pools 5.9 to 11.8 ft deep with large boulders, overhanging trees, instream wood, undercut banks.	Habitat contains partial cover requirements.	Habitat contains none of the cover requirements.
Egg/Larvae Development (October 1 to April 14)			
Temperature	32.9 to 44.9°F	44.9 to 50°F	50+ °F
DO	> 8.0 mg/L	5.9 to 8.0 mg/L	< 5.9 mg/L
pH	> 6.8	> 5.0 and < 6.8	< 5.0
Depth	14.9 in	6.7 to 29.9 in	< 6.7 in
Velocity	1.00 to 1.50 ft/sec	0.92 to 2.75 ft/sec	< 1.17 ft/sec and > 2.58 ft/sec
Parr Development (Year-Round)			
Substrate	Cobble diameter = 2.5 to 20.2 in, gravel diameter = 0.63 to 2.5 in, boulder diameter = 11.8 in	Cobble diameter <2.5 in, gravel diameter < 0.63 in, boulder diameter < 11.8 in	
Depth	3.9 to 5.9 in (small parr) > 11.8 in (large parr)	< 3.9 in (small parr) < 11.8 in (large parr)	
Velocity	0.23 to 0.49 ft/sec (small parr) 0.33 to 0.65 ft/sec (large parr)	< 0.23 ft/sec and > 0.49 ft/sec (small parr) < 0.33 ft/sec and > 0.65 ft/sec (large parr)	
Temperature	59 to 66.2°F	66.2 to 71.6°F	Upper lethal temperature ranges from 72.5 to 82.0°F 100% mortality at 82.4 to 86°F

Essential Feature	Fully Functioning	Limited Functioning	Not Properly Functioning
DO	> 8 mg/L	2.85 to 7.99 mg/L	< 2.85 mg/L
Food	Adequate invertebrate drift (mayflies, stoneflies, chironomids, caddisflies, blackflies, and other invertebrates). Larger parr shift to larger food sources such as small fishes, annelids, and invertebrates.	Inadequate supplies of invertebrate drift.	
Smolt Migration (April 15 to June 14)			
Temperature	41 to 50°F	< 41°F	
pH	> 5.8	< 5.8	
Passage	Sufficient flow and lack of downstream barriers to move quickly through the estuary within a few days.	Downstream barriers that delay downstream migration and reduce estuarine survival.	Downstream barriers that prohibit downstream migration.

Source: Kircheis and Liebich 2007; COSEWIC 2010; DFO Canada 2014; Gibson et al. 2016.
Note: Dates reflect approximate seasonal periods for Gulf of Maine and inner Bay of Fundy Atlantic salmon populations in Maine and New Brunswick for each lifestage specified. Depth, velocity, and temperature measurements are converted from metric to English units for consistency with this report.

The habitat features listed in Table 3-5 encompass a diversity of complex structured habitats containing variations in flow (pool-run-riffle), in which Atlantic salmon and other diadromous fish species thrive. Large, woody debris in a river may increase channel complexity and create high-quality pools and riffles that provide feeding and cover habitats for juvenile and adult salmon and areas for rearing juveniles. Higher densities of large, woody debris in a stream channel are often correlated with higher densities of salmonids (Kircheis and Liebich 2007). Boulders may cause localized eddies or backwaters that create scour holes on the boulders' downstream sides; these areas can be used by salmonids for resting, shelter, and feeding and may be particularly important for over-wintering individuals (Kircheis and Liebich 2007). These habitats can be enhanced through restoration activities, as demonstrated on the Meduxnekeag River and other watersheds within Maine, as discussed in Section 3.3.

3.4.3 Stakeholder and Rightsholder Outreach

The primary stakeholders and rightsholders in the successful outcome of implementing this WAS/Plan are the USACE and HBMI, respectively. In addition, other cooperating agencies/partners and non-governmental organizations (NGOs) are actively involved with watershed restoration and fish restoration efforts within the Meduxnekeag River Watershed (on both the U.S. and Canadian sides); these entities, along with their respective watershed roles and involvement in current/potential restoration projects, are listed in Table 3-6.

Table 3-6. Stakeholders/Rightsholders, Cooperating Agencies/Partners, and NGOs Involved in Watershed Restoration in the U.S. and Canada

Stakeholder/Rightsholder	Role in Watershed	Involvement in Current/Potential Restoration Projects
Houlton Band of Maliseet Indians (HBMI)	Landowner, resource manager	Lead or teaming partner in multiple projects listed in Table 3-2
United States Army Corps of Engineers (USACE)	Federal Agency/Regulatory, resource manager	Lead or teaming partner in multiple projects listed in Table 3-2. Potential funding source
Town of Houlton	Local government	Teaming partner for Moose Brook Culvert Replacement
Natural Resource Conservation Service (NRCS)	Federal Agency/Regulatory	Potential funding source
United States Fish and Wildlife Service (USFWS)	Federal Agency/Regulatory	Lead in the river herring restoration project listed in Table 3-2
Maine Department of Inland Fisheries and Wildlife (MDIFW)	State Agency, resource manager	Baseline fish population characterization and monitoring
The Nature Conservancy (TNC)	Landowner, resource manager	Teaming partner for Moose Brook Culvert Replacement
Department of Fisheries and Oceans (DFO Canada)	Federal Agency/Regulatory	Teaming partner for multiple projects listed in Table 3-2
Maliseet Nation Conservation Council (MNCC)	Conservation Organization	Teaming partner for multiple projects listed in Table 3-2
Meduxnekeag River Watershed Association (MRWA)	Conservation Organization	Teaming partner for multiple projects listed in Table 3-2

HBMI has been actively involved in restoration activities for several years and has been engaged with tribal, community, and agency stakeholders/rightsholders throughout the process. The primary goals of stakeholder/rightsholder outreach within the context of this WAS/Plan are as follows:

- Provide information about the Meduxnekeag WAS/Plan to interested HBMI members;
- Gather and share feedback from interested HBMI members with WAS/Plan development decision makers;
- Consider (where appropriate and feasible) incorporating HBMI member input into Plan-development decisions.

An important step toward meeting these goals included a June 2018 scoping event to identify potential issues and concerns that could arise as members became engaged in the process. This event was held at HBMl's annual Health Fair in Houlton, Maine. The HBMI Natural Resources Department (NRD) staffed a booth and provided flyers with WAS/Plan information. Questions were accepted and verbal comments were documented by attending staff. A large poster was laid out on a table with a map, markers, and space to provide written comments. This event was well-attended by HBMI members living in Aroostook County and the greater Meduxnekeag River Watershed area. Similar annual scoping events will be planned for the implementation and development years of this WAS/Plan.

Additional scoping activities, outlined as follows, have informed (and will continue to inform) the tribal membership throughout the development and implementation of the WAS/Plan:

- All HBMI members were informed of the WAS/Plan progress, via NRD's newsletter "Skitkomiq" and Facebook Page, and were notified of opportunities for direct involvement in the planning process, beginning with the Summer 2018 Newsletter.
- Membership response to a previously published invitation allowed HBMI to engage members who seek more information and are interested in providing input.
- The invitation to participate described two ways for the members to engage - by direct email communication, or via the NRD Facebook page. In addition:
  - Both methods of engagement will occur at least quarterly throughout the planning process and will coincide with the mailing of the seasonal newsletter (“Skitkomiq”), when feasible. NRD staff will respond directly to questions and concerns or request written responses from USACE when necessary.
  - HBMI does not anticipate holding physical meetings as part of the Public Involvement Strategy unless it is requested by interested tribal members or HBMI leadership.
- NRD staff will document, summarize, and share the questions, concerns, and comments provided by HBMI members throughout the development and implementation of the WAS/Plan.

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