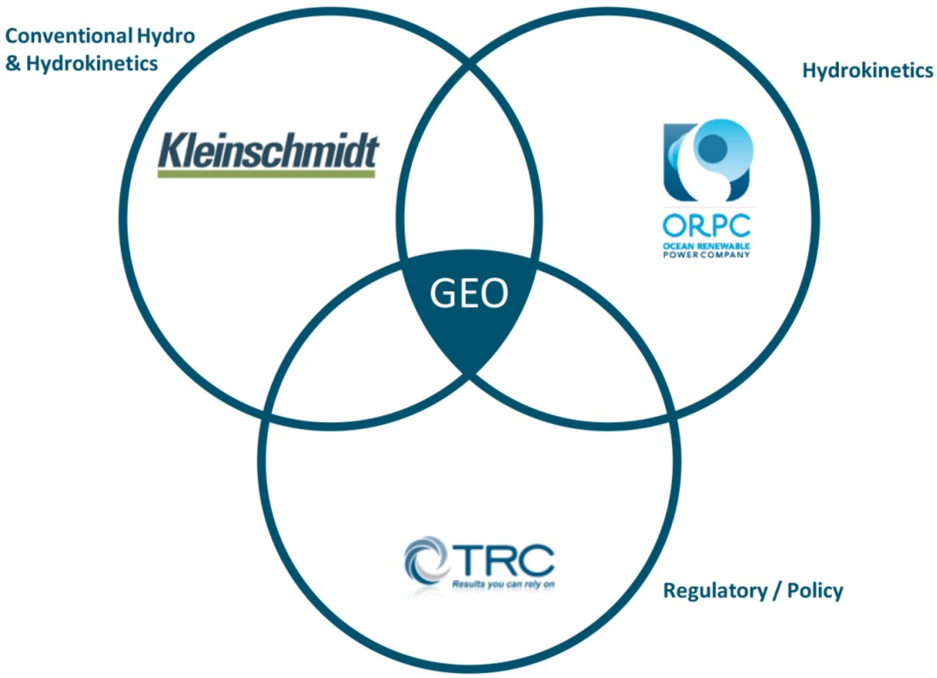
MAINE HYDROPOWER STUDY



Prepared for:

Maine Governor's Energy Office
Augusta, Maine

Prepared by:

Kleinschmidt

Pittsfield, Maine
www.KleinschmidtGroup.com

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EXECUTIVE SUMMARY

The primary goals of Maine Hydropower Study were twofold: (1) develop an inventory of existing and potential hydropower resources, and (2) identify potential regulatory changes to facilitate development of these resources.

INVENTORY OF POTENTIAL HYDROPOWER

An inventory of **Conventional Hydropower Development** at existing powered and unpowered dam sites in Maine was made. The screening analysis identified 110 total sites at powered and non-powered dams with potential for installation of 193 MW of additional capacity. As a result of limitations of the screening analysis, these estimates are considered an upper limit of development and generation potential. Application of estimated development cost and potential revenue data to these sites indicates that while many existing dam sites have hydroelectric development potential, these opportunities do not appear economic under current market conditions. In addition, when environmental and regulatory considerations are taken into account, 47 sites with 56 MW of potential capacity showed significant development potential for conventional hydropower development.

Based on the results of the conventional hydropower inventory, the following additional investigations are recommended for consideration:

- Identify potential for conduit hydropower development;
- Identify potential of adding minimum flow units at existing hydropower sites;
- Analyze the commercial viability of emerging hydropower technologies; and
- Analyze the role of grid interconnection as a potential barrier to future hydropower development.

The inventory of **Hydrokinetic Sites** conducted as part of this study was limited by a lack of consistent data necessary to fully evaluate site potential, and a process and funding should be developed to properly assess priority tidal and river sites. Nonetheless, review of available information indicates the State's resources are conducive to marine and hydrokinetic development. Maine is well positioned to play a leadership role in the development of the national marine and hydrokinetic industry based on proven industry/academic partnerships and an existing supply chain. The following recommendations for further investigation include:

- Develop consistent data in order to fully evaluate hydrokinetic sites;
- Identify marine and hydrokinetic sites in proximity to Maine communities with high cost of power, which could allow for high power costs to be reduced while offering opportunities for market entry by technology developers;
- Identify infrastructure projects at or in the vicinity of marine hydrokinetic resources, which could offer the opportunity for reduced installation and maintenance costs;
- Identify existing conventional hydropower that could incorporate new hydrokinetic units; and
- Use the Adaptive Management Plan process governing the Cobscook Bay Tidal Energy Project's licensing requirements as a model for other MHK projects.

REGULATORY REVIEW

Hydropower is capital intensive and has a long payback period, making the economics of most new projects marginal. A survey of hydropower developers found that the three greatest hurdles to hydropower development in Maine are perceived to be (1) project permitting/licensing, (2) project financing, and (3) infrastructure limitations.

Project Permitting/Licensing: The length, cost, and uncertainty associated with permitting a new project (or, for that matter, relicensing an existing project) were cited as major hurdles to new development. These concerns encompassed both federal and state regulatory processes. Recommendations from the respondents for improving this included:

- **Establish a "Hydropower Coordinator"** for all of the state agencies on hydropower licensing and related regulatory reviews, to ensure consistency with the State's policy goals of balancing hydropower and non-hydropower uses of Maine's waters. To be effective, the hydropower coordinator would need to be empowered to make final decisions on the State's positions related to the project licensing and permitting.
- **Conduct an in-depth review of Maine's 401 water quality standards** and the criteria used to evaluate whether hydropower projects meet those standards, including both

numeric and narrative standards, as well as designated uses. As part of the review the State should examine the open-ended timeline associated with 401 certification; as currently implemented this practice adds considerable uncertainty to project licensing and permitting.

Project Financing: While the State cannot directly affect the price of power, respondents had several suggested ways that Maine could affect the value of hydropower generation:

- **Review and revise the Maine RPS** and eligibility requirements such that more new conventional hydropower development, if not all hydropower development, is classified as a Class 1 renewable;
- Consider **legislation that allows for the Public Utilities Commission to solicit pricing for long-term contracts** for existing and new hydro facilities, and if the price is deemed prudent, to direct the utilities to enter into agreements for this power;
- **Develop a State-sponsored hydropower project financing authority and funding mechanism** to attract new hydropower technologies to the State;
- **Modify Maine's existing capital investment programs** to better support the capital and financing needs of the private sector, in addition to municipalities; and
- **Amend Chapter 329**, which provides incentives for the development of "community based" renewable projects, to remove the 51% resident ownership requirement–allowing more projects to qualify for the program.

InfrastructureLimitations: Grid interconnection was identified as a significant potential hurdle to hydropower development in Maine. Some of the issues associated with grid connection are related to the cost associated with lack of consistency in grid tie-in requirements, depending on the location and ownership of the transmission facilities. In Maine, a potentially bigger problem associated with grid connection is the remoteness of potential project sites and the lack of existing transmission within the immediate vicinity of these sites.

MAINE HYDROPOWER STUDY
MAINE GOVERNOR'S ENERGY OFFICE
AUGUSTA, MAINE

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DEFINITIONS OF TERMS, ACRONYMS, AND ABBREVIATIONS

ACHP	Advisory Council on Historic Preservation
ADCP	Acoustic Doppler Current Profiler
af	Acre-foot, the amount of water needed to cover one acre to a depth of one foot
APE	Area of Potential Effect as pertaining to Section 106 of the National Historic Preservation Act
CEII	Critical Energy Infrastructure Information
CFR	Code of Federal Regulations
cfs	cubic feet per second
Commission	Federal Energy Regulatory Commission
CWA	Clean Water Act
DO	dissolved oxygen
DOE	U.S. Department of Energy
DOI	U.S. Department of Interior
DOT FHA	Department of Transportation Federal Highway Administration
EA	Environmental Assessment
EAP	Emergency Action Plan
EFH	Essential Fish Habitat
EIA	U.S. Energy Information Agency
EIS	Environmental Impact Statement
EL	Elevation
EPRI	Electric Power Research Institute
ESA	Endangered Species Act
FEMA	Federal Emergency Management Agency
FERC	Federal Energy Regulatory Commission
FPA	Federal Power Act
FVCOM	Unstructured Finite Volume Coastal Ocean Model
FWCA	Fish and Wildlife Coordination Act
GEO	State of Maine Governor's Energy Office
GIS	Geographic Information Systems
GOMDPS	Gulf of Maine Distinct Population Segment
GWh	Gigawatt-hour (equals one million kilowatt-hours)
Hp	Horsepower
Hz	hertz (cycles per second)
Installed Capacity	The nameplate MW rating of a generator or group of generators
kV	Kilovolts
KVA	Kilovolt amperes

kW	kilowatt
kWh	kilowatt-hour
License Application	Application for New License submitted to FERC no less than two years in advance of expiration of an existing license.
LIHI	Low Impact Hydropower Institute
LUPC	Maine Land Use Protection Commission
MDACF	Maine Department of Agriculture, Conservation, and Forestry
MDEP	Maine Department of Environmental Protection
MDIFW	Maine Department of Inland Fisheries and Wildlife
MDMR	Maine Department of Marine Resources
MEMA	Maine Emergency Management Agency
MESA	Maine Endangered Species Act
MHK	marine and hydrokinetic
MHPC	Maine Historic Preservation Commission
MPUC	Maine Public Utilities Commission
MW	megawatt
MWh	megawatt-hour
MWDCA	Maine Waterway Development and Conservation Act
MOU	Memorandum of Understanding
NEPA	National Environmental Policy Act
NERACOOS	Northeastern Regional Association of Coastal and Ocean Observing Systems
NGO	non-governmental organization
NMFS	National Marine Fisheries Services, same as NOAA Fisheries
NOAA Fisheries	NOAA National Marine Fisheries Service, same as NMFS
NPDES	National Pollutant Discharge Elimination System
NPS	National Park Service
NREL	National Renewable Energy Laboratory
NRPA	Maine Natural Resources Protection Act
NWI	National Wetlands Inventory
ORNL	U.S. Department of Energy's Oak Ridge National Laboratory
PNNL	Pacific Northwest National Laboratory
Peaking	Operation of generating facilities to maximize generation during a given time frame, generally drawing down a reservoir.
Penstock	A pressurized pipe through which water flows from a forebay or tunnel to the powerhouse turbine
PM&E	Protection, Mitigation and Enhancement Measures
PPA	Power purchase agreement
Project Area	The area within the FERC Project Boundary

Project Boundary	The boundary line defined in the Project license issued by FERC that surrounds those areas needed for operation of the Project.
Project Impoundment	Body of water retained by a dam or similar structure
Relicensing	The process of acquiring a new FERC license for an existing hydroelectric Project upon expiration of the existing FERC license
RM	River mile
RPS	Renewable portfolio standard
Run-of-river	A hydroelectric Project that uses the flow of a stream with little or no reservoir capacity for storing water. Such projects can still have substantial reservoirs as long as outflow equals inflow.
SHPO	State Historic Preservation Officer
Tailrace	Channel through which water is discharged from the powerhouse turbines
T&E Species	Threatened and endangered species
THPO	Tribal Historic Preservation Officer
TU	Trout Unlimited
UMaine	University of Maine
USACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
USEIA	U.S. Energy Information Administration
USEPA	U.S. Environmental Protection Agency
USFS	U.S. Forest Service
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
WQC	Water Quality Certificate

1.0 INTRODUCTION

Hydropower has played a long and important role in the history of Maine. Small, water-powered saw- and grist-mills were essential to the establishment and economic growth of towns along many of Maine's rivers. Initial hydroelectric projects were vital to industrial development and rural electrification, and brought economical and reliable power to all corners of the State. As environmental awareness increased throughout the twentieth century, the hydropower industry adapted to ensure protection of the State's resources. With the renewed interest in hydro, there has been a renaissance of new ideas and technologies, including hydrokinetic and micro-hydro, that could be economical at sites that were not developed during the last major phase of hydro expansion in the 1980s.

The State of Maine Governor's Energy Office (GEO) contracted with a team led by Kleinschmidt Associates to develop an updated inventory of Maine's existing and potential hydropower resources, based on current technologies and regulatory environment, as well as recommendations for regulatory changes needed to allow and encourage cost-effective expansion of the resource. Kleinschmidt, based in Pittsfield, has a nearly 50-year long history of conventional hydroelectric power expertise, which was used in the assessment of conventional hydro potential. The study team included two other Maine-based firms that played a vital role in the development of this report. ORPC Solutions, a wholly owned subsidiary of Ocean Renewable Power Company (collectively, ORPC), are pioneers in the hydrokinetic industry and brought their expertise to the assessment of marine and hydrokinetic potential. TRC is a national firm with deep hydro policy/regulatory experience, and used this experience to assess the regulatory environment in Maine and develop recommendations for potential regulatory reform.

1.1 STUDY GOALS AND OBJECTIVES

The State has not assessed its hydropower resources since the early 1990s, when the vision of hydropower development still included the construction of significant new hydro dams. Since that time, new technologies have been developed that could open up new opportunities for additional hydropower production, using unconventional resources. The primary goals of this study were twofold: (1) develop an inventory of existing and potential hydropower resources, and (2) identify potential regulatory changes to facilitate development of these resources.

The inventory developed for this study identifies potential sites for small and micro facilities at existing unpowered dams, untapped potential at existing hydropower sites, and hydrokinetic resources (energy produced from river flows, waves, tides, and currents).

The study also evaluated the existing regulatory environment for hydropower and has identified current obstacles to new investment, and provides recommendations to encourage further development.

1.2 HYDRO IN MAINE

Hydropower continues to play an important role in electricity generation in the state. Maine produces more hydropower per capita than any other state east of the Mississippi (U.S. Energy Information Administration, 2013). Based on data derived from the U.S. Energy Information Administration, Form EIA-923, "Power Plant Operations Report" in 2012 hydroelectric generation was estimated at approximately 3,732 GWh, or 26% of the total energy generated in Maine.

Maine has an abundance of water throughout the state and a large number of dams. For this study, the Maine Emergency Management Agency (MEMA) provided data that listed 891 different dams in the state. The vast majority of these dams, of course, do not have hydroelectric generation and were built instead for other purposes such as hydromechanical power, flood control, water supply, recreation, or industrial withdrawals.

Using the MEMA dataset as a base, existing dams in Maine can be divided into two broad groups: (1) dams with existing hydroelectric generation, and (2) non-powered dams. This study looked both at the potential for adding additional generating capacity to existing stations as well as adding completely new generation to non-powered sites.

Of the dams with existing hydroelectric generation, most of these are under the jurisdiction of the Federal Energy Regulatory Commission (FERC), which is the independent federal agency that regulates most non-federal dams in the United States. The authority to regulate hydroelectric facilities stems from the Federal Power Act (FPA), which was enacted in 1920. (A more detailed discussion of the regulatory framework is provided in Section 3.2.)

FERC-jurisdictional projects are subdivided into two broad categories: licensed and exempt projects. All projects that are jurisdictional require licensing or exemption from licensing by the FERC. Any project that is located on a navigable waterway, has post-1935 construction or affects interstate commerce (as defined by the FPA, as well as FERC and court decisions) is within FERC's licensing jurisdiction. Exempt projects require a FERC-review process and authorization to proceed just as licensed projects do. See Sections 1.2.1 and 1.2.2.

1.2.1 LICENSED PROJECTS

Projects that are jurisdictional, but that are not eligible for exemptions, must obtain long term operating licenses from the FERC. The licensing process generally requires 3–5 years to complete, though large and complex projects may take even longer to complete the process. Under the FPA FERC can issue operating licenses for 30 to 50 year periods. In practice, FERC generally issues licenses for 30 years upon relicensing or for projects where no new construction is required. License terms of 50 years are reserved for projects that are newly constructed, or that require substantial new construction, or which propose additional capacity or extensive environmental enhancements upon relicensing. Licensees must file applications for new licenses two years prior to the expiration of the existing license.

As shown in Table 1-1, as of December 2014 there are 69 FERC licensed projects[1] with a total of over 723 MW of installed capacity. In this study and in FERC parlance a hydro "project" means the complete "unit of development" that is encompassed by a single FERC license (and which is assigned a project number). A project is comprised of one or more "developments," each of which may include any combination of the following: dam, impoundment, water conveyance facilities (canal, penstock, flume), generating equipment, and other appurtenant facilities. Not all projects/developments have dams or impoundments and not all projects/developments have generating equipment. Storage projects, for example, are non-generating dams generally placed

[1] The FERC list of licenses includes three additional projects that are part of the Penobscot River Restoration Agreement—Great Works (FERC No. 2312), Veazie (FERC No. 2403), and Howland (FERC No. 2721)—and have either been decommissioned or in the process of being decommissioned.

in the upper portions of watersheds. They store excess water during high flow periods in order to augment downstream flows during low-flow periods.

TABLE 1-1. FERC LICENSED PROJECTS IN MAINE

FERC No.	PROJECT NAME	NO. OF DEVELOPMENTS	LICENSE EXPIRATION	AUTHORIZED CAPACITY (KW)	RIVER
2142	Indian Pond	1	10/31/36	76,400	Kennebec
2194	Bar Mills	1	07/31/48	4,000	Saco
2283	Gulf Island - Deer Rips	2	12/31/48	37,232	Androscoggin
2284	Brunswick	1	02/28/29	19,000	Androscoggin
2302	Lewiston Falls	6	08/31/26	36,354	Androscoggin
2322	Shawmut	2	01/31/21	8,740	Kennebec
2325	Weston	1	10/31/36	15,980	Kennebec
2329	Wyman	1	10/31/36	83,700	Kennebec
2333	Rumford Falls	2	09/30/24	44,500	Androscoggin
2335	Williams	1	12/31/17	13,000	Kennebec
2364	Abenaki	1	04/30/54	18,800	Kennebec
2365	Anson	1	04/30/54	9,000	Kennebec
2367	Aroostook River	2	12/31/43	800	Millinocket Stream
2368	Squa Pan	1	12/03/21	1,500	Squa Pan Stream
2375	Riley-Jay-Livermore	3	09/15/48	19,725	Androscoggin
2458	Penobscot Mills	5	09/30/26	70,810	West Branch Penobscot
2492	Vanceboro (Storage)	1	03/01/16	-	East Branch St. Croix
2519	North Gorham	1	12/31/34	2,190	Presumpscot
2520	Mattaceunk	1	08/31/18	19,200	Penobscot
2527	Skelton	1	01/31/38	21,600	Saco
2528	Cataract	3	11/30/29	6,650	Saco
2529	Bonny Eagle	1	01/31/38	7,200	Saco
2530	Hiram	1	11/30/22	10,500	Saco
2531	West Buxton	2	12/31/17	7,812	Saco
2534	Milford	2	03/31/38	8,000	Stillwater
2555	Automatic	1	06/30/36	800	Messalonskee Stream
2556	Messalonskee	4	06/30/36	5,900	Messalonskee Stream
2572	Ripogenus	1	09/30/26	37,530	West Branch Penobscot
2574	Lockwood	1	10/31/36	6,915	Kennebec
2600	West Enfield	1	05/31/24	13,000	Penobscot
2611	Hydro-Kennebec	1	09/30/36	15,433	Kennebec
2612	Flagstaff Storage	1	02/29/36	-	Dead
2615	Brassua	1	03/31/12	4,180	Moose
2618	West Branch (Storage)	2	09/29/00	-	West Branch St. Croix
2634	Storage	9	11/30/54	-	West Branch Penobscot
2660	Forest City (Storage)	1	08/31/00	-	East Branch St. Croix
2666	Medway	1	03/31/29	3,440	West Branch Penobscot
2671	Moosehead Lake (Storage)	1	10/31/36	-	Kennebec
2710	Orono	1	03/31/48	6,518	Stillwater Branch Penobscot
2712	Stillwater	1	03/31/48	1,950	Stillwater Branch Penobscot
2727	Ellsworth Graham	2	12/31/17	8,900	Union
2804	Goose River	5	02/29/20	375	Goose
2808	Barker's Mill	1	01/31/19	1,500	Little Androscoggin

FERC No.	Project Name	No. of Developments	License Expiration	Authorized Capacity (kW)	River
2809	American Tissue	1	04/30/19	1,000	Cobbosseecontee Stream
2897	Saccarappa	1	09/30/43	1,350	Presumpscot
2931	Gambo	1	09/30/43	1,900	Presumpscot
2932	Mallison Falls	1	09/30/43	800	Presumpscot
2941	Little Falls	1	09/30/43	1,000	Presumpscot
2942	Dundee	1	09/30/43	2,400	Presumpscot
2984	Eel Weir	1	03/31/04	1,800	Presumpscot
3428	Worumbo	1	11/30/25	19,100	Androscoggin
3562	Barker Mill Upper	1	07/31/23	950	Little Androscoggin
4026	Aziscohos	1	03/31/25	5,311	Magalloway
4202	Lowell Tannery	1	09/30/23	1,000	Passadumkeag
4784	Pejepscot	1	08/31/22	13,880	Androscoggin
5073	Benton Falls	1	02/28/34	4,330	Sebasticook
5362	Lower Mousam	3	03/31/22	600	Mousam
6398	Hackett Mills	1	08/31/24	485	Little Androscoggin
7189	Green Lake	1	03/31/24	500	Reeds Brook
8277	Otis	1	09/15/48	10,350	Androscoggin
9340	Kezar Falls Lower	2	09/30/30	1,000	Ossipee
11006	Upper Androscoggin	1	08/31/26	1,695	Androscoggin
11132	Eustis	1	11/30/26	250	North Branch Dead
11163	South Berwick	1	11/30/37	1,200	Salmon Falls River
11472	Burnham	1	10/31/36	1,050	Sebasticook
11482	Marcal	1	06/30/37	1,310	Little Androscoggin
11566	Damariscotta Mills	1	11/30/33	460	Damariscotta
11834	Upper & Middle Dams Storage	2	11/30/52	-	Rapid
12711	Cobscook Bay Tidal Energy	1	01/31/20	300	Cobscook
TOTAL	69 projects	109		723,155	

Source: FERC 2014, MDEP 2010

1.2.2 Exempted Projects

Jurisdictional projects may obtain an exemption from licensing instead of a license, but only under narrow circumstances. Such projects are subject to FERC regulation but exempt from many of the regulations affecting licensed projects. In order to obtain an exemption, projects must go through a process similar to that required to obtain a license. The Hydropower Regulatory Efficiency Act of 2013 recently expanded the qualifying circumstances for an exemption. FERC's Final Rule implementing the Act takes effect February 23, 2015 (Federal Energy Regulatory Commission, 2014).

Exemptions may be issued for small hydroelectric power projects or small conduit hydroelectric facilities. A small hydroelectric power project is a project that utilizes for electric generation the water potential of either an existing non-federal dam or a natural water feature (e.g., natural lake, waterfall, gradient of a stream, etc.) without the need for a dam or manmade impoundment. Most exemptions in Maine are small hydroelectric power projects. Projects which are eligible for a small hydroelectric power exemption must be under 10 MW, located at an existing (pre-1978) dam owned by the applicant, and accompanied by a proposal to increase generation (Federal Energy Regulatory Commission, 2014).

A small conduit hydroelectric facility is an existing or proposed hydroelectric facility that utilizes for electric power generation the hydroelectric potential of a conduit, or any tunnel, canal, pipeline, aqueduct, flume, ditch, or similar manmade water conveyance that is operated for the distribution of water for agricultural, municipal, or industrial consumption and not primarily for the generation of electricity. Under the new rules, small conduit exemptions may be located on either federal or non-federal lands and can have a maximum installed capacity of 40 MW (Federal Energy Regulatory Commission, 2014). The only small conduit hydroelectricity facility in Maine is the Veazie Energy Recovery Project (FERC No. 13164). Other potential conduit locations were not examined as part of this study, though a future analysis of this resource is worthy of consideration.

Projects exempt from licensing must operate under terms and conditions specified by fish and wildlife agencies. Exemptions have no expiration date and are issued in perpetuity.

As shown in Table 1-2, as of December 2014 there are 25 FERC exempted projects in Maine, with a total of a little more than 7 MW of installed capacity. All but one of the projects, Kennebago (FERC No. 4413), consist of a single development.

TABLE 1-2. FERC EXEMPTED PROJECTS IN MAINE

No.	Name	Exemption Date	Authorized Capacity (kW)	River	Exemption Type
3444	Rocky Gorge	8/9/1982	550	Great Works	Non Conduit
4293	Waverly Avenue	7/12/1983	400	Sebasticook	Non Conduit
4413	Kennebago	7/17/1981	900	Kennebago	Non Conduit
5613	Browns Mill	8/3/1982	594	Piscataquis	Non Conduit
5647	Milo	2/23/1982	695	Sebec	Non Conduit
5912	Moosehead	6/2/1982	300	Piscataquis	Non Conduit
6684	Days Mill	10/6/1982	30	Kennebunk	Non Conduit
7253	Sebec	9/26/1983	867	Sebec	Non Conduit
7473	Gilman Stream	6/17/1987	120	Gilman Stream	Non Conduit
7591	Wight Brook	12/23/1983	30	Wightbrook	Non Conduit
7979	Foss Mill	6/14/1984	15	Marsh Stream	Non Conduit
8417	Old Sparhawk Mill	5/24/1985	270	Royal	Non Conduit

No.	Name	Exemption Date	Authorized Capacity (kW)	River	Exemption Type
8450	Stoney Brook	9/27/1985	35	Stoney Brook	Non Conduit
8505	Abbotts Mill	1/31/1985	90	Concord	Non Conduit
8640	Seabright Dam	6/21/1985	94	Megunticook	Non Conduit
8736	Pioneer Dam	6/3/1985	300	West Branch Sebasticook	Non Conduit
8788	Ledgemere Dam	4/17/1985	450	Little Ossipee	Non Conduit
8791	Starks	5/14/1985	35	Lemon Stream	Non Conduit
9079	Upper Spears Stream	9/30/1985	65	Upper Spears Stream	Non Conduit
9411	Biscoe Falls	5/5/1986	93	Little Androscoggin	Non Conduit
9421	Gardner Brook	3/27/1986	50	Gardner Brook	Non Conduit
11365	Swans Falls	7/31/1997	820	Saco	Non Conduit
12629	Corriveau	10/24/2006	350	Swift	Non Conduit
13164	Veazie Energy Recovery	1/16/2009	75	-	Conduit
14421	Freedom Falls	3/25/2013	50	Sandy Stream	Non Conduit
TOTAL	25 Projects		7,278		

Source: FERC 2014

1.2.3 Unlicensed Projects

A very small number of hydroelectric projects are not subject to FERC jurisdiction. Any project that is not jurisdictional need not obtain a FERC license – these are indicated as “Unlicensed” facilities. Unlicensed projects are subject to state laws, principally those governing dam safety.

As shown in Table 1-3, there are a total of 18 FERC non-jurisdictional projects in Maine with a total installed capacity of nearly 24 MW.

Table 1-3. FERC Non-Jurisdictional Projects in Maine

FERC No.	Project Name	Capacity (kW)	Waterway	Location	Reason for Non-Jurisdiction
UL 88-25	Estes Lake	800	Mousam	Sanford	A
UL 88-27	Wilson Stream	700	Big Wilson Stream	Greenville	A
UL 88-27	Wilson Pond (Storage)	0	Big Wilson Stream	Greenville	A
UL 88-28	Leighs Mill	500	Great Works	South Berwick	A
UL 89-1	Grand Falls	9,480	St. Croix	Baileyville	B
UL 89-2	Woodland	11,600	St. Croix	Baileyville	B
UL 89-16	Old Falls	600	Mousam	Kennebunk	A
UL 90-15	Norway	300	Pennesseewassee	Norway	A
UL 94-1	Rangeley (Storage)	0	Rangeley	Rangeley	C
UL 94-3	First Roach (Storage)	0	Roach	Frenchtown Twp.	C
UL 97-16	Moxie (Storage)	0	Moxie	East Moxie Twp.	C
UL 98-1	Umbazookus Lake (Storage)	0	West Branch Penobscot	T6 R13 WELS	C

	Rainbow Lake	0	West Branch Penobscot	Rainbow Twn	C
	Nesowadnehunk L. (Storage)	0	West Branch Penobscot	T4 R10 WELS	D
UL 01-02	Mattagamon Lake (Storage)	0	East Branch Penobscot	T6 R8 WELS	C
	Telos Lake (Storage)	0	East Branch Penobscot	T6 R11 WELS	C
UL 01-04	Schoodic Lake (Storage)	0	Schoodic Stream	Lake View Plt.	C
	Seboeis Lake (Storage)	0	Seboeis Stream	T4 R9 NWP	C
TOTAL	18 Projects	23,980			

Source: (Maine Department of Environmental Protection, 2010)

Reasons for Non-Jurisdictional Finding

A- Pre-1935 Project Located on Non-Navigable Waterway
B- Pre-Federal Power Act Congressional Authorization for Dam
C- Insignificant Benefit to Downstream Generation
D- No Operational Connection to Downstream Generation

Developing any of the non-jurisdictional projects in Table 1-3 for new or additional hydropower would likely trigger FERC jurisdiction. The developer would then need to obtain either a license or exemption from licensing, with all the attendant costs.

A small number of FERC non-jurisdictional projects located on non-navigable waterways have been permitted directly by the state since 1984. As shown in Table 1-4, six such projects totaling less than 100 kW have been permitted.

TABLE 1-4. STATE-JURISDICTIONAL PROJECTS IN MAINE

PROJECT NAME	CAPACITY (KW)	WATERWAY	LOCATION	APPROVAL INFORMATION
Seavey Hydro	16.0	Ripley Stream	Ripley	DEP Permit #L-10204 issued 07/11/1984
Morgan's Mills	50.0	Mill Stream Union	Union	DEP Permit #L-10750 issued 03/27/1985
Tidewater Hydro	10.0	Carvers Pond	Vinalhaven	DEP Permit #L-20341 issued 01/09/2001 and modified 04/03/2008
Bradford Camps	1.4	Norway Brook	T8 R10 WELS	LURC Permit #HP-0023 issued 10/02/2001
Kates Microhydro	0.5	Stony Brook	Newry	DEP Permit #L-23519 issued 05/24/2007
Maine Hut #1	6.0	Poplar Stream	Carrabassett Valley	DEP Permit #L-23347 issued 06/06/2007
TOTAL	83.9			

Source: (Maine Department of Environmental Protection, 2010)

1.2.4 QUALIFYING CONDUIT HYDROPOWER FACILITIES

In addition to these non-jurisdictional projects, the Hydropower Regulatory Efficiency Act of 2013 created a new subset of small conduit exemptions, called “qualifying conduit hydropower facilities,” which are not required to be licensed under Part I of the FPA. A qualifying conduit hydropower facility is a facility that meets the following qualifying criteria: (1) the facility would be constructed, operated, or maintained for the generation of electric power using only the hydroelectric potential of a non-federally owned conduit, without the need for a dam or impoundment; (2) the facility would have a total installed capacity that does not exceed 5 MW; and (3) the facility is not licensed under, or exempted from, the license requirements in Part I of the FPA on or before August 9, 2013. To obtain a determination that a project is a qualifying conduit hydropower facility, an entity must file with FERC a notice of its intent to construct the facility that demonstrates the facility meets the qualifying criteria discussed above. As of December 2014, no qualifying conduit hydropower facilities have been developed in Maine.

2.0 ASSESSMENT OF NEW HYDRO POTENTIAL

The last major assessment of hydropower in Maine was published by the State Planning Office in 1992. That report found 122 hydroelectric generating dams in Maine, including 76 FERC licensed projects and 31 FERC excepted projects with combined installed generating capacities of 691 MW and 9.5 MW respectively. In addition, the report noted 15 unlicensed generating dams representing 31 MW of installed capacity and 21 unlicensed storage dams (State of Maine Planning Office, 1992). As shown in Table 2-1, in 1992 Maine's hydropower facilities provided 773 MW of capacity representing 22% of the state's electricity production.

TABLE 2-1. MAINE ELECTRIC CAPABILITY AND GENERATION, 1990-2012

Year	Capability (MW)			Generation (MWh)		
	Hydro Only	Total Electric Industry	% of Hydro	Hydro Only	Total Electric Industry	% of Hydro
2012	742	4,491	17%	3,732,604	14,428,596	26%
2011	742	4,378	17%	3,978,978	15,973,688	25%
2010	738	4,315	17%	3,810,381	17,018,660	22%
2009	738	4,229	17%	4,211,679	16,349,849	26%
2008	730	4,124	18%	4,457,405	17,094,919	26%
2007	718	4,213	17%	3,738,168	16,128,567	23%
2006	719	4,187	17%	4,278,132	16,816,173	25%
2005	720	4,185	17%	4,090,926	18,843,978	22%
2004	721	4,188	17%	3,430,249	19,098,885	18%
2003	719	4,236	17%	3,172,622	18,971,635	17%
2002	718	4,351	17%	2,767,848	22,535,033	12%
2001	681	4,208	16%	2,645,123	19,564,815	14%
2000	711	4,209	17%	3,590,816	14,047,948	26%
1999	777	2,873	27%	3,755,955	12,673,928	30%
1998	757	2,825	27%	3,715,967	11,003,320	34%
1997	762	2,863	27%	3,647,932	10,333,407	35%
1996	771	3,748	21%	4,157,394	14,934,373	28%
1995	774	3,791	20%	3,353,911	9,763,051	34%
1994	774	3,648	21%	3,510,767	16,456,149	21%
1993	773	3,604	21%	3,245,779	15,614,272	21%
1992	773	3,580	22%	3,512,607	15,683,545	22%
1991	763	3,684	21%	3,817,232	17,344,783	22%
1990	760	3,681	21%	4,090,536	15,946,014	26%

Sources: http://www.eia.gov/electricity/state/maine/xls/sept04ME.xls, http://www.eia.gov/electricity/state/maine/xls/sept05ME.xls

The report included an assessment of additional hydroelectric potential and estimated the total hydro potential for Maine, including new and redeveloped sites, was approximately 297 MW (State of Maine Planning Office, 1992). However, this estimate included capacity from several proposed new dam projects that were subsequently not developed. Following publication of the report several capacity upgrades have been undertaken while several hydroelectric facilities have been decommissioned, resulting in an overall decrease in statewide hydropower generating capacity since 1992.

More recently, the U.S. Department of Energy (DOE) has conducted several nationwide evaluations of hydropower potential. In 2012 Oak Ridge National Laboratory (ORNL) compiled an Assessment of Energy Potential at Non-powered Dams in the United States (Hadjerioua, 2012). This national study looked at dams over 5 feet high and calculated electric generating capacities "using the assumption that all water passing a facility would be available for conversion into electrical energy and that hydraulic head at the facility would remain constant" (Hadjerioua, 2012). As the analysis did not consider the economic feasibility of developing each unpowered dam, it represents only a theoretical upper limit of development potential and not necessarily a realistic estimate. The study found approximately 19 MW of potential capacity at non-powered dams in Maine.

In 2014 the DOE published the results of a much more ambitious study, the New Stream-reach Development (NSD) project (Kao, 2014). This nationwide study used a geospatial approach to analyze new hydropower development potential in stream-reaches that do not currently have hydroelectric facilities or other forms of infrastructure. Using available geospatial data, the study identified those stream reaches that had undeveloped high-energy density potential, and estimated potential capacity and energy generation at those sites. This report estimated the total potential hydropower capacity in Maine as approximately 1,059 MW or 6,146,000 MWh annually. While the 2012 study focused on adding capacity to unpowered dams over 5 feet in height, the 2014 study considered many more potential sites, accounting for the much larger estimated capacity number. These estimates include a data screening, which removed environmentally sensitive stream reaches located in proximity to National Parks, Wild and Scenic Rivers, or Wilderness Areas. As with the 2012 report, this study did not take into account economics of site development and as such is useful primarily as providing a theoretical upper limit of potential capability.

2.1 CONVENTIONAL HYDROPOWER ASSESSMENT

While many of the base engineering assumptions used in developing the State Planning Office's 1992 assessment of conventional hydropower potential remain valid, the regulatory and environmental climate has changed dramatically since then, rendering many of the conclusions obsolete. Interest in river restoration and fish passage, the federal listing of several fish species, deregulation, and public opposition all combine to make construction of new dams in Maine infeasible. And while the recent DOE studies provide useful high-level data on the upper limit of potential hydropower development, the focus of these efforts are at a national and regional level. Moreover, since these studies do not take into account many important site-specific considerations or economics, their results are limited for use in developing a comprehensive plan for development of Maine resources.

The following approach to evaluating conventional hydropower potential in Maine provides more granularity than past approaches, but remains high level and the results are best considered as a theoretical upper limit.

Two fundamental assumptions were used for this assessment and must be emphasized: (1) no new dam construction, and (2) no significant changes to the current flow regimes. Given environmental concerns, future hydropower development that included the construction of new dams with all their real and perceived impacts, is unrealistic.

This assessment also does not consider two important types of hydropower developments: pumped storage and conduit projects. Pumped storage projects can be an effective way to store excess energy for future use when energy demands are greater. Such projects generally consist of two reservoirs at different elevations and reversible pump/turbine units that can both generate electricity and act as large pumping stations. During times of low energy demand water is pumped from the lower reservoir to the upper reservoir, where it is held until needed to generate. Pumped storage projects synergize well with generation sources that are operated continuously such as nuclear plants, or with intermittent sources such as wind farms. Pumped storage projects are also valued for the ancillary services they can provide, including load following, load support, and black-start capabilities. While pumped storage projects are extremely helpful to the stability of the electric grid, opportunities to develop pump storage facilities were not examined as part of this effort.

Conduit projects utilize existing manmade structures that convey water to generate electricity; as such, they do not necessarily require an associated dam or reservoir. Conduit projects are more common in the Western United States, which have large irrigation systems ripe for deployment. Although there are many potential advantages to conduit projects, including limited environmental footprints, Maine does not have a large amount of conduit infrastructure. As a future effort, a study examining conduit potential of the Portland Water District system and other in-state systems is worthy of consideration.

2.1.1 METHODOLOGY

The conventional hydropower assessment used an iterative screening approach to identify potential sites for development. Beginning with reasonably coarse and optimistic parameters, the study was intended to gradually filter the initial MEMA dataset into smaller and smaller subsets of viable projects. With each iteration the study would eliminate non-viable sites and advance the remaining sites to the next round of screening. Each iteration would apply new and more refined parameters to further screen out the remaining candidates.

This approach assumed that if the screening identified significant potential for conventional hydropower development, the study would then analyze using newer hydropower technologies at sites eliminated from earlier screening passes, such as low-head sites.

Initial Screening: Using the MEMA data as a starting point, the conventional hydropower assessment began with 891 Maine dams. As a first step, the initial MEMA dataset was filtered to remove sites with less than 10 feet of head and less than 10 square miles of drainage area—these thresholds represent typical industry minimum criteria for development. Application of this first level of screening narrowed the number of potential dam sites from 891 to 203.

Secondary Screening: The second level of screening used a hydrology and engineering assessment to calculate the likely energy production and development costs associated with each of these sites. Based on the results of this screening, sites with less than 10 feet of head and less than 25 square miles of drainage were eliminated. This iteration also removed sites with less than 100 kW of potential additional capacity, as well as powered sites that had existing capacity equal to or greater than the calculated capacity.

Tertiary Screening: The third level of screening applied a regulatory assessment that considered potential resources issues that would affect the development potential of each site. This analysis identified sites with limited development potential due to regulatory or environmental issues; these sites would have been removed from consideration in additional screening steps.

Although additional screening steps had been planned for this study, after only the first three iterations no candidate sites remained for advancement to a fourth round of screening. As is discussed in greater detail below, the screening identified low energy prices and high development costs as the primary deterrent to development of new hydropower in Maine.

2.1.1.1 HYDROLOGY AND ENGINEERING ASSESSMENT

The assessment developed a series of hydrologic zones for the state, which were used to develop average flows at each site. It is well established that Maine has several different hydrologic zones such as the coastal plain, the central interior area, the western mountains, and the upper plateau area of northern Maine. U.S. Geological Survey (USGS) gage data throughout the state was analyzed to derive an index cfs/sq mile value for each zone.

In each of these hydrologic zones the analysis used gages that are unregulated and have sufficient period of record (10 years or more). For each gage, the average annual flow was divided by the contributing drainage area for that gage to determine an index value. As shown in Table 2-2, the resulting values were tabulated and an average index value was derived for each area.

TABLE 2-2. SUMMARY OF MAINE HYDROLOGIC ZONES

HYDROLOGICAL ZONE	AVERAGE FLOW PER SQUARE MILE (CFS/mile^2)
Coastal East	2.25
Coastal West	2.09
Northern East	1.83
Northern West	2.36
Southern Interior East	2.51
Southern Interior West	2.00

For each dam site, the contributing drainage area in the data provided by MEMA was confirmed using geospatial analysis. The dam location was also assigned to the appropriate hydrologic zone. The average annual flow for each dam site was then calculated by multiplying the drainage area of the site by the associated index flow. While this estimation of site flow is sufficient for a screening level study, it is obviously not as precise as site-specific measurements. This estimate also assumes run-of-river operations above each site.

This average annual flow was then used as the design flow for each dam site. Use of the average annual flow value is an appropriate flow value for a screening-level analysis, as this value is approximately equal to the 25% exceedance value on an annual flow duration curve. Flows equal to this exceedance value are typically used as the initial design value for run-of-river hydroelectric projects at the conceptual feasibility level. A site-specific analysis would potentially result in a design flow higher than the average annual flow.

Installed capacity for each site was derived by using the design flow determined for each site times the estimated gross head and an overall efficiency value of 83%. (Gross head was assumed using dam height in the MEMA database.) The estimated average annual generation (kWh) was determined by using the installed capacity value times the number of hours in a year times an assumed plant factor value of 38%. Plant factor is the percentage of hours that the project will operate at its installed capacity over the course of the year. A value of 38% is typical for run-of-river hydroelectric projects in New England.

An estimated project development cost was developed using index development cost values ($/kW) times the respective project's installed capacity. Development of conventional hydroelectric facilities has an inverse size versus cost function: the smaller the project, the more expensive the project on a cost/kW of capacity basis. For the initial assessment, an assumed cost was employed based on the project size, as detailed in Table 2-3. This cost was based on data from recently constructed projects and is intended to capture both direct installation costs as well as indirect costs such as regulatory costs, engineering, administration and AFDC costs.

TABLE 2-3. ASSUMED DEVELOPMENT COSTS FOR CONVENTIONAL HYDROPOWER

NEW CAPACITY (KW)	COST ($ PER KW)
<200	$6,000
200–700	$5,000
>700	$4,000

These calculated costs, while suitable for an initial screening analysis, are on the low end of the scale. Site-specific costing would include other potential expenses not included in the assumed costs of Table 2-3, such as interconnection costs or entrepreneurial profit.

A base value of the additional energy production was developed using an assumed value of $50/MWh. Based on ISO-NE data, this value is approximately 8% below the 10-year average of the average New England wholesale electricity pricing (2004–2013) but about 13% above the most recent 5-year average (2009-2013), a period characterized by lower overall energy prices (ISO-New England, 2014). While suitable for a screening level analysis, this value is probably on the higher end, as Maine run-of-river hydro projects produce the largest percentage of their annual energy in the March–June period, which have energy values much lower than annual average.

A simple cost payback period in years was then calculated by dividing the installation costs by the value of the additional annual production. Note that, because both the additional production estimates and installation costs are driven by the additional capacity calculation, and the installation costs were broken into only three tiers, the simple payback calculation clusters around only three different periods. This approach, appropriate for a screening level exercise, allows for a relative comparison between different development opportunities.

Following review of the initial screening results, the analysis further winnowed the list by removing dams with drainage areas less than 25 square miles or estimated installed capacity less than 100 kW, since it would seem impractical to develop those.

The primary benefit of this methodology is that it allows for a rapid evaluation of a large number of sites over a wide geographic area. The primary disadvantage of this approach is that the simplification tends to overestimate the potential generation available. Most of the dam sites that were analyzed have additional site restrictions that are not captured in the evaluation formula. For example, the assessment assumes run-of-river operation and looks only at individual sites in isolation; in many instances dam sites are operated as part of a larger system. Operating headwater storage projects to maximize their own generation potential, for example, would obviate many of the generation benefits these storages provide to downstream stations.

While this methodology perhaps gets closer than the recent DOE work (Hadjerioua, 2012), (Kao, 2014) to a realistic assessment of statewide conventional hydropower potential, this assessment still should be considered a theoretical upper limit of development and generation potential, and the results are perhaps most useful when considered in aggregate. A more detailed analysis that took a site-specific approach would likely further winnow the potential candidates for development.

2.1.1.2 REGULATORY ASSESSMENT

A detailed overview of the regulatory framework for hydropower projects is provided in Section 3.0. Assessing potential environmental issues and other regulatory barriers to hydropower development requires compiling information on natural resources, geopolitical boundaries, existing infrastructure, cultural, and recreational needs. For this study, selection of environmental and regulatory screening criteria used for the evaluating potential hydropower sites were driven by two primary considerations: 1) the level of effect that the environmental or regulatory factor being considered could have on the development potential of a particular hydropower site; and 2) the availability of a consistent and up-to-date source of data or GIS data layer.

To initially identify potential issues, we relied upon the collective experience of the consulting team in working on hydropower licensing and relicensing projects in Maine to compile an initial list of environmental, resource and regulatory factors that would likely affect the development potential of a particular hydropower site. For many of these factors, the presence of a resource or the proximity of that resource to a particular site may not directly impact the development potential of a site, but could affect the cost of developing that site due to added licensing, permitting, construction, or mitigation costs associated with meeting a regulatory requirement or avoiding or protecting a particular resource.

Based on our experience, an initial list of environmental resource issues that could affect the hydropower development potential of a given site was developed. Resources considered included the following: fish species and habitats, federally listed (ESA) species, critical habitats, conservation lands, water quality, recreation use, and cultural resources. From this initial list of resource issues, an evaluation of how these issues are most likely to manifest themselves in the State of Maine was made. Based on the availability of associated GIS data a list of Maine regulatory screening criteria was developed, as shown in Table 2-4.

TABLE 2-4. MAINE REGULATORY SCREENING CRITERIA

RESOURCE	CRITERIA	DATA SOURCE
Water Quality		
State Water Quality Classification	Classification of waters (AA, A, B, C) waters	MDEP
Federally Listed RTE Species		
Atlantic Salmon	GOM DPS Atlantic Salmon Critical Habitat	NMFS
Shortnose Sturgeon	Shortnose Sturgeon Critical Habitat	NMFS
Atlantic Sturgeon	GOM DPS Atlantic Sturgeon Critical Habitat	NMFS
Canada Lynx	Canada Lynx Critical Habitat	USFWS
State Listed Endangered, Threatened and Special Concern Species		
State Listed ETSc Species Habitats	ETSc Species Habitats Data Layer	MDIFW
Fish and Wildlife Habitat		
Native Trout Habitat	Brook Trout Habitat Data Layer	MDIFW
USFWS Priority Trust Species Habitats	USFWS Priority Trust Species Habitat Data Layer	USFWS or MDIFW
Essential Wildlife Habitats	Essential Wildlife Habitats Data Layer	MDIFW
Cultural Resources		
NRHP Historic District	NRHP Historic District boundaries	MHPC
Significant historic or archaeological sites	NRHP Listed or Eligible Site Locations	MHPC
Proximity to NRHP Listed Sites of any type	All Listed Site Locations	MHPC
Conservation Lands and Parks		
Located within the boundary of a National Park or National Monument	National Park and National Monument boundaries	NPS
Located within the boundary of a State Park	State Park boundaries	MDACF
Located within the boundary of Maine Public Reserve Lands		MDACF

Other resource issues that were initially considered and then eliminated from the final screening criteria included commercial whitewater boating rivers and streams, aesthetics (waterfalls), American eel range and habitat, and Tribal reservations and traditional cultural sites.

As with the engineering and hydrology assessment, these initial screening parameters were not considered comprehensive or representative of all resource concerns. Shad, alewives, and eels, for example, are all resources that would be considered in a site-specific analysis.

A brief description of each of these resource issues and screening criteria, and our assessment of how these issues are likely to affect hydropower development potential, are provided below.

Water Quality/State Water Quality Classification – Water quality is an important issue relative to hydropower development. In order to secure a FERC license, a project must first obtain water quality certification from the State of Maine, under Section 401 of the Clean Water

Act. To issue the 401 Certification, the state must find that the proposed project will meet state water quality standards. The applicable water standards that must be met vary depending on the classification of the waters on which the project is located.

In Maine, rivers and streams are generally classified within four classifications: Class AA, A, B and C waters. Great ponds and lakes are all classified as Class GPA. Maine's water quality standards include both designated uses, as well as numeric and narrative standards. In order to issue a 401 Certification for a project, the state must find that the project meets both the designated uses and the water quality standards for a given classification. Water quality standards are most stringent for Class AA waters, and least stringent for Class C waters. Hydropower is a designated use of Class GPA, A, B and C waters, but not for Class AA waters.

Therefore, as currently classified, no hydropower development, existing or proposed, located on Class AA waters could receive a 401 Certification from the state. Hydropower projects located on Class A and GPA waters can receive 401 Certification, since the designated uses for those classifications include hydropower, but the numeric and narrative standards for those classifications are more rigorous, and therefore, more likely to be a factor affecting future hydropower development than for sites located on Class B or C waters. Water quality classification and the regulatory uncertainties associated with 401 Certification have been identified as a significant barrier to hydropower development in Maine.

In addition, for many years, Maine DEP has requested applicants to withdraw and refile their WQC applications upon expiration of the one-year clock, in order to restart the clock. This then delays FERC's ability to issue a license in a timely manner because FERC is not authorized to issue a new license until the State has either issued or waived the WQC. The delay in issuance of the WQC and thus the FERC license adds to the uncertainty of the outcome and the applicant's costs, which in turn affects the ability to find investors.

Federally Listed Species/Atlantic Salmon – In 2009, the National Marine Fisheries Service (NMFS) listed the Gulf of Maine Distinct Population Segment (GOMDPS) of Atlantic salmon as an "endangered" species under the Endangered Species Act (ESA). Critical habitat for this population of Atlantic salmon was determined to include significant portions of the Androscoggin, Kennebec, and Penobscot river watersheds, as well as smaller Maine coastal rivers, including the St. George, Sheepscot, Madomak, Machias, East Machias, Dennys, Union, Graham, Narraguagus, and Pleasant. As Atlantic salmon is a highly migratory, andromous species, fish passage (upstream and downstream) at dams is a critical issue for this species. In addition, alteration of habitat and flows associated with dams and hydropower project operations can also be significant issues that have the potential to impact licensing and permitting outcomes. Fish passage for Atlantic salmon and other diadromous fish species can be very expensive to install at a new project, or retrofit at an existing project or dam. In addition, passage of an ESA listed species is likely to require a long-term commitment by the project owner to continually monitor fish passage at the project, and make modifications or upgrades to fish passage facilities, as needed, to enhance passage performance, or accommodate additional numbers of fish or fish species. The need for fish passage or modified project operations to protect listed Atlantic salmon and its habitat have been identified as a significant barrier to hydropower development in Maine.

Federally Listed Species/Sturgeon – two species of sturgeon, shortnose sturgeon and Atlantic sturgeon have been listed by NMFS under the ESA. Shortnose sturgeon is listed as an endangered species and with critical habitat in most of Maine's coastal estuaries and rivers. The Gulf of Maine population of Atlantic sturgeon is listed as threatened, and is also found in many of Maine's coastal estuaries and rivers. Sturgeon are somewhat migratory and move into freshwater to spawn in the very early spring. However, unlike salmon and other anadromous fish, sturgeon are unable to negotiate falls and rips, and their historic range up river systems has generally been limited to the tidal portion of the river, below the fall-line. For this reason, fish passage is generally not an issue for sturgeon at dams, but dams and their associated hydropower projects can alter flows and in other ways affect sturgeon habitat, particularly spawning habitat. First dams on a river system (i.e., the first dam encountered moving upstream from the coast), are most likely to impact sturgeon or their critical habitat, and therefore for some locations, sturgeon are a factor that may affect hydropower development.

Federally Listed Species/Canada Lynx – the Canada Lynx is the only other federally listed wildlife or species that occurs in Maine and that has the potential to impact future hydropower development. Critical habitat for the Canada lynx in Maine includes portions of Aroostook, Franklin, Piscataquis, Penobscot, and Somerset counties. The lynx generally inhabits boreal forests that have cold, snowy winters and a high-density snowshoe hare prey base. Other prey species include red squirrel, porcupine, beaver, voles and shrews, and fish. Lynx have large home ranges generally between 12 to 83 square miles, and timber harvest, recreation, and their related activities are the predominant land uses affecting lynx habitat. Since the lynx is a highly terrestrial species that occupies only the northern most sections of Maine, the potential direct impacts to future hydropower development are limited, and likely be to manifested in additional development costs associated with ESA regulatory requirements, including Section 7 consultation, and possibly development and implementation of an ESA species management plan.

State Listed RTE Species/State Listed Species Habitats - endangered and threatened inland fish and wildlife species in Maine are listed either under Maine's Endangered Species Act (MESA) or the U.S. Endangered Species Act (ESA), or both. Species listed under MESA receive state protection, and the Maine Department of Inland Fisheries and Wildlife (MDIFW) is responsible for inland fish and wildlife listed under MESA. Endangered and Threatened marine species are listed under Maine's Marine Endangered Species Act or ESA, and the Maine Department of Marine Resources (MDMR) has responsibility for these species. The Maine Endangered Species Act applies only to animals; plants are not included in the legislation. There are currently 55 inland fish and wildlife species listed as threatened or endangered. Any of the state listed species could affect potential hydropower development as a result of added licensing consultation requirements, or by adding additional cost to the project associated with required species management, protection or mitigation measures. Of particular concern to hydropower development are aquatic species, including most notably the state listed fish (swamp darter, redfin pickerel) and freshwater mussel (brook floater, tidewater mucket, and yellow lampmussel) species.

Fish and Wildlife Habitat/Native Trout Habitat – Preservation and restoration of native trout to Maine waters has become a priority of the MDIFW. In 2009, the MDIFW prepared its Brook Trout Management Plan for the state. Habitat requirements for brook trout are cool, clean, well-oxygenated water and suitable spawning, nursery, and adult habitat. Brook trout may spend part or all of their lives in habitats ranging from the smallest brook to the largest of lakes, provided that the habitat is suitable and competition from other fish is not excessive. Brook trout spawning occurs in high elevation waters in clean, gravel substrates in the fall. Nearly all of Maine's inland waters were originally suitable for brook trout. This situation changed as increases in human population growth, industrialization (including the construction of dams), agriculture, and timber harvesting became increasingly widespread. Even at existing dams, brook trout habitat can be impacted by hydropower project operations that modify flow, or that result in changes in water quality and temperature either upstream or downstream of the dam. As a result, the proximity to brook trout habitat has the potential to affect hydropower development potential by increasing project costs to address brook trout habitat protection and management needs.

Fish and Wildlife Habitat/USFWS Priority Trust Species Habitats - In order to protect fish and wildlife habitat for endangered, threatened, rare or declining trust species in the Gulf of Maine watershed, the USFWS's (USFWS) Gulf of Maine Coastal Program identified, mapped, and ranked important fish and wildlife habitat for priority species in the Maine portion of Gulf of Maine watershed. A total of 91 species were mapped and their habitat values ranked. Habitat maps were composited into a single map identifying priority grassland, forest, freshwater wetland and estuarine habitats. While there is no regulatory authority associated with USFWS trust species habitats, proximity of a potential hydropower project site to or within the trust species habitat area may indirectly affect the development potential of that site by increasing project costs to address habitat protection and management needs.

Fish and Wildlife Habitat/Significant Wildlife Habitats - Significant Wildlife Habitats are defined under Maine's Natural Resources Protection Act (NRPA), which is administered by the MDEP. Significant Wildlife Habitats include Deer Wintering Areas, Inland Waterfowl/Wading Bird Habitat, Seabird Nesting Islands, Shorebird Areas, Significant Vernal Pools, and Tidal Waterfowl/Wading Bird Habitat. While there is no specific regulatory authority associated with the state's Significant Wildlife Habitats, the NRPA requires state agencies to consider impacts to these habitat areas in reviewing and approving any project or activity, including a hydropower project. Thus, proximity of a potential hydropower project site to or within a significant habitat area, may affect the development potential of that site by increasing project costs to address habitat protection and management needs.

Cultural Resources/Historic Districts - The National Register of Historic Places (NRHP) is the nation's official list of cultural resources worthy of preservation. Authorized under the National Historic Preservation Act (NHPA), the National Register is a national program to identify, evaluate, and protect significant historic and archeological resources. Properties listed in the Register include districts, buildings, structures, and objects that are significant in American history, architecture, archeology, engineering, and culture. The National Register is administered by the National Park Service. The Maine Historic Preservation Commission (MHPC) has been designated as the State Historic Preservation Office (SHPO), and oversees the administration of the National Register program in Maine. There are over 140 separate National Register listed Historic Districts in Maine. The size of the historic districts varies from small neighborhoods to entire towns. In every historic district individual properties are defined as either contributing or non-contributing to the significance of the district. Contributing properties are considered to be listed in the National Register of Historic Places. Those properties identified as non-contributing, even if lying within the geographic boundaries of the district, are not listed in the National Register.

For projects that require federal approval, such as a FERC license, the federal permitting agency, or its designated representative, must consult with MHPC in accordance with Section 106 of the NHPA. The MHPC follows established consultation procedures in responding to requests for cultural resources reviews. If a project site is within a Historic District, the MHCP may seek information to determine whether the project property is a contributing element and eligible for the NRHP listing. While potential hydropower project development sites within a Historic District may not prevent the proposed development from going forward, such a location may affect the development potential of the site by increasing the costs of Section 106 consultation and evaluation, and by increasing the cost of project development to address Historic District resource protection and management needs.

Cultural Resources/Listed or Eligible Historic Sites – In addition to Historic Districts, NRHP listed sites include significant buildings, structures, and objects that are significant in American history, architecture, archeology, engineering, and culture. As noted previously, for projects that require federal approval, such as a FERC license, the federal permitting agency or its designated representative, must consult with MHPC in accordance with Section 106 of the NHPA.

If a project site includes, or is adjacent to, properties with buildings or structures over fifty years of age, or is in an archaeologically sensitive area, the MHCP may seek information to determine whether such properties are eligible for the National Register, or whether the project is likely to disturb archaeological sites. This will often be in the form of a request for additional information, and/or for an archaeological survey to be completed. When required, archaeological surveys can be expensive, and must be done by approved archaeological consultants and completed in accordance with the archaeological survey guidelines. In those cases where it is determined that a project will result in an adverse effect to an eligible site, the MHPC will consult with the party to avoid, minimize or mitigate such effects.

All projects requiring FERC approval must undergo Section 106 consultation, regardless of the location of the project site. However, potential project sites that are known to be in archaeologically sensitive areas (often determined by the previous documentation of significant archaeological sites), are more likely to require archaeological surveys, which can be both costly and time consuming, and therefore a potential barrier to hydropower project development.

Conservation Lands and Parks/National Park – The Federal Power Act prohibits FERC from granting hydropower licenses for projects located within a National Park or National Monument. Therefore, any potential hydropower site located within the boundary of a National Park or National Monument cannot be licensed by FERC. There are no National Monuments within Maine and Acadia is the only National Park.

Conservation Lands and Parks/State Park – There are 36 State Parks, one State Forest, and one State Memorial in Maine. Maine’s State Parks are administered by the Maine Department of Agriculture, Conservation and Forestry (MDACF), and are managed to preserve historic and natural resources and to provide opportunities for public recreation and education. While hydropower and other developmental projects may be developed in state parks, any potential project sites located within an existing state park boundary will require consultation with MDACF, and is likely to be difficult to permit and license. Section 21 of the FPA limits FERC’s ability to use eminent domain in public lands such as state parks. Even if a proposed project were found to be consistent with the resources and uses of the state park, the development potential of that site will likely be affected by increased costs of both consultation and management measures needed to protect and preserve park resources.

Conservation Lands and Parks/Maine Public Reserve Lands - MDACF also manages Maine’s Public Reserve Lands, which encompass some of Maine's most outstanding natural features and secluded locations. The more than half million acres of Maine’s Public Lands are managed by MDACF for a variety of resource values including recreation, wildlife, and timber. Hydropower and other developmental projects are not restricted from Maine’s Public Reserve

Lands, however any potential project sites located within a Public Reserve Lands boundary will require consultation with MDACF, and may be more difficult to permit and license than a project located outside the boundary. Even if a proposed project were found to be consistent with the resources and uses of the reserve, the development potential of that site could be affected by the increased cost of agency recommended management measures needed to protect and preserve public resources.

Other criteria were initially considered for screening, but for various reasons were dropped after further consideration. Commercial whitewater boating rivers and streams were considered as a possible screening criteria, since in many regions of the country whitewater boating opportunities are rare and therefore, carefully guarded by organizations such as American Whitewater and American Rivers. In Maine, however, nearly every river and stream has some whitewater boating potential in some locations, under some flow conditions. In short, whitewater boating opportunities are ubiquitous in Maine, therefore, nearly every potential hydropower development site likely has some whitewater boating potential associated with it, or in close proximity to the site. In addition, since all of the potential hydropower sites considered in this inventory are at existing dams or infrastructure, the impacts to whitewater boating opportunities associated with new dam construction are not an issue.

American eel range and habitat was another resource issue that was considered as a possible screening criteria. American eel are a migratory diadromous fish species that spend a portion of their life cycle in both fresh water and salt water. American eel have been proposed for listing under the Endangered Species Act, but are not currently a listed species. Like other diadromous fish species (e.g., salmon, shad, and herring) American eel can be impacted by hydropower projects, particularly conventional hydropower projects located on dams. While eels are usually quite adept at passing dams upstream, they are vulnerable to hydropower project entrainment during their downstream movements. Thus, fish passage for eels can be a concern at nearly any conventional hydropower dam site in Maine, and therefore may affect the development potential of any mainstream dam located on a river or major tributary. Although eels and eel passage may be important considerations in examining the development potential of a dam site, since American eel is ubiquitous in Maine's rivers and streams, it is a poor screening criteria, as most sites in the inventory are likely to be within the known range of the American eel.

Tribal reservations and traditional cultural sites were also considered as possible screening criteria. There are five recognized Indian Reservations in Maine: Aroostook Band of Micmac Indians, Indian Township Reservation, Passamaquoddy Reservation, Penobscot Reservation, and Pleasant Point Reservation. Section 4(e) of the Federal Power Act authorizes federal land managers to impose mandatory conditions on a FERC license for hydropower projects located on federal reservations. This mandatory conditioning authority means that tribes can condition a FERC hydropower project license for projects located on a federal reservation in any way it deems necessary to protect tribal resources. In addition, in order to secure a FERC license for a project within a reservation, the developer would have to secure property and water rights necessary for project purposes. Combined, these factors have the potential to dictate any future hydropower development at a site within an Indian Reservation, and would be a significant barrier to development. However, our initial review of the inventory sites indicated that none were located within or in close proximity to a Tribal reservation; and therefore we eliminated this as a screening criteria.

Tribal traditional cultural sites were also considered as a possible screening criteria. As part of the FERC licensing process, FERC requires that applicants consult with any tribes that might have an interest in the proposed project or its location. Even if a project is outside an Indian reservation, a tribe may comment that the proposed project could affect a traditional cultural site. Traditional cultural sites can be eligible for listing on the National Register, just as an archaeological site or historic structure. Thus, FERC will consider potential impacts from the proposed project on traditional cultural sites, and could require an applicant to prepare additional studies or may require additional license conditions or measures to protect traditional cultural sites. Thus, from the perspective of possible effects on the development potential of a site, proximity to traditional cultural sites could be a useful screening criteria. However, tribes tend to guard the existence and location of such sites very closely, and therefore, there is no readily available database providing the location and nature of traditional cultural sites to determine whether it would be a useful screening criterion.

After identifying the screening criteria, a score was assigned to each criterion, depending on its relative potential to affect hydropower development at a given site. Resource issues and criteria that have the greatest potential to significantly impact the viability of a hydropower site from a regulatory or economic standpoint, or both were assigned higher scores, while factors that would be expected to have minimal impact on the development potential of a site were assigned low values.

In this way, when all of the criteria are considered and the score values summed, sites with the lowest overall scores represent those with the greatest development potential, while sites with the highest scores are those where the development potential is likely to be seriously affected by permitting and licensing difficulties, and or the costs of mitigating for resource impacts.

Based on this scoring system, a project site with a score of <10 has **Significant Development Potential**. It is important to note that even these sites would have to complete one or more state and/federal approval processes in order to be developed, and would be required to employ some mitigation measures. However, these process and mitigation costs would be expected to be comparatively low.

A project with a score of 10-20 is a site that has **Moderate Development Potential**, but with significant regulatory and environmental barriers associated with it. Such site would likely require moderate to significant mitigation costs in order to develop.

A score of 20 or more indicates a project site that has almost **Limited Development Potential** from an environmental and regulatory standpoint; such sites could only be developed with considerable mitigation and may, for all practical purposes, be undevelopable.

Table 2-5 provides a summary of the screening criteria and the scoring values assigned to each.

TABLE 2-5. SCREENING CRITERIA AND ASSIGNED SCORES

RESOURCE	CRITERIA	DATA SOURCE	SCORE
Water Quality			
State Water Quality Classification	Site located on Class AA waters	MDEP	20
State Water Quality Classification	Site located on Class GPA/A waters	MDEP	5
Listed RTE Species			
Atlantic Salmon	Site located within GOM DPS Atlantic Salmon Critical Habitat	NMFS	5
Shortnose Sturgeon	Site located within Shortnose Sturgeon Critical Habitat	NMFS	3
Atlantic Sturgeon	Site Located within GOM DPS Atlantic Sturgeon Critical Habitat	NMFS	3
Canada Lynx	Site located within Canada Lynx Critical Habitat	USFWS	1
State Listed Endangered, Threatened, and Special			

RESOURCE	**CRITERIA**	**DATA SOURCE**	**SCORE**
Concern Species			
State Listed ETSc Species Habitats	Site located within state ETSc Species Habitat	MDIFW	3
Fish and Wildlife Habitat			
Brook Trout Habitat	Sites located in areas designated by MDIFW as Brook Trout Habitat	MDIFW	2
USFWS Priority Trust Species Habitats	Sites located within USFWS Priority Trust Species Habitat	USFWS	1
Essential Wildlife Habitats	Sites located within Essential Wildlife Habitats	MDIFW	1
Cultural Resources			
Located within NRHP Historic District	Sites located within Historic District boundaries	MHPC	2
Involves NRHP Listed Historic Sites	Sites located in close proximity to Listed Historic Site Locations	MHPC	3
Parks and Recreation			
Located within the boundary of a National Park or National Monument	Sites located within or in close proximity to National Park and National Monument boundaries	NPS	20
Located within the boundary of a State Park	Sites located within State Park boundaries	MDACF	10
Located within the boundary of Maine Public Reserve Lands	Sites located on Public Reserve Lands	MDACF	5
Other			
Dam Position	First or second dam on the river upstream of the coast	MEMA	1st – 5 2nd - 3

Finally, after identifying and developing scores for the initial list of resource-based screening criteria, additional consideration was given to other factors that have the potential to significantly affect the development potential of a site, or the cost of developing a site, or both. As discussed in more detail later in this report, during our survey of hydropower project owners and developers, one of the significant barriers to hydropower development in Maine that was identified by several of the survey respondents was stakeholder interest in river restoration.

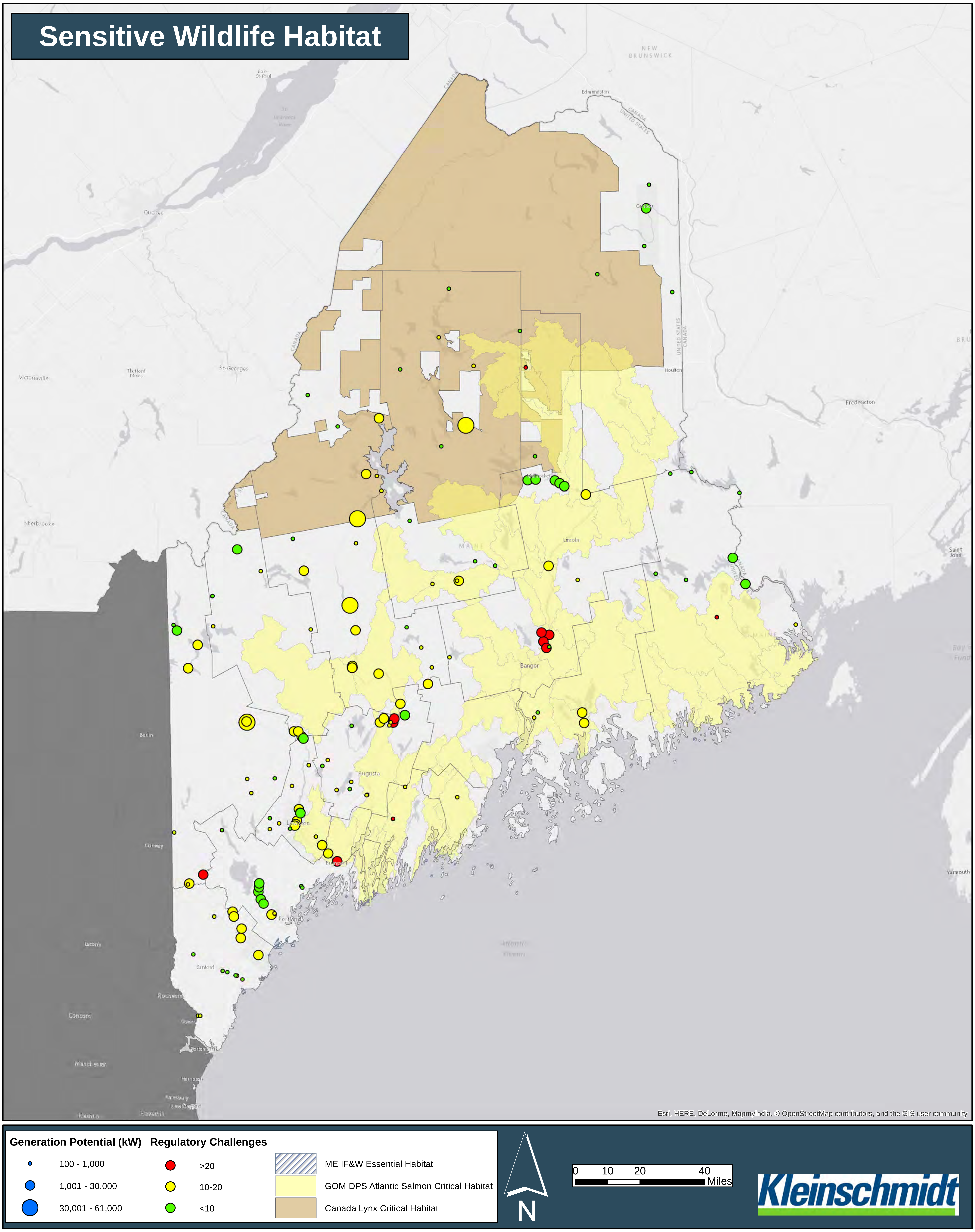
In particular, it was noted that dam sites located such that their removal would restore a significant reach of free-flowing river were most vulnerable to pressure from organized groups to not develop the site, and in some cases to remove an existing hydropower project and dam. Experience has shown that dams that are the "first" dam on a river moving upstream from the coast are the most likely to be under pressure from river restoration groups for dam removal.

Similarly, being the only dam on a particular river or stream, also makes a potential project site particularly vulnerable to pressure from dam removal and river restoration advocates. First dams are also most likely to require expensive fish passage in order to meet the fish passage needs for a number of diadromous fish species including shad and herring, as well as the previously discussed Atlantic salmon and American eel.

For these reasons, a screening criteria was added to capture a potential project site's position on a river or stream relative to other dams on the river. If a dam site is the first dam on a river it was given a score of 5, and if it was the second dam on a river a score of 3.

Using this screening criteria, a geospatial analysis was conducted on each site to identify potential regulatory or environmental considerations that would limit or outright prevent development of the site. A site located in an area of critical habitat for a fish species listed under the Federal Endangered Species Act, for example, would be far more difficult and thus far less desirable to develop. The sum of these considerations resulted in a regulatory rank for each site. A more detailed discussion of this ranking is provided in Section 3.3 *Review of Potential Regulatory Reforms*. Figure 2-1 depicts potential development sites at both powered and non-powered dams along with sensitive wildlife habitats. Figure 2-2 depicts potential development sites at both powered and non-powered dams along with conserved and tribal lands.

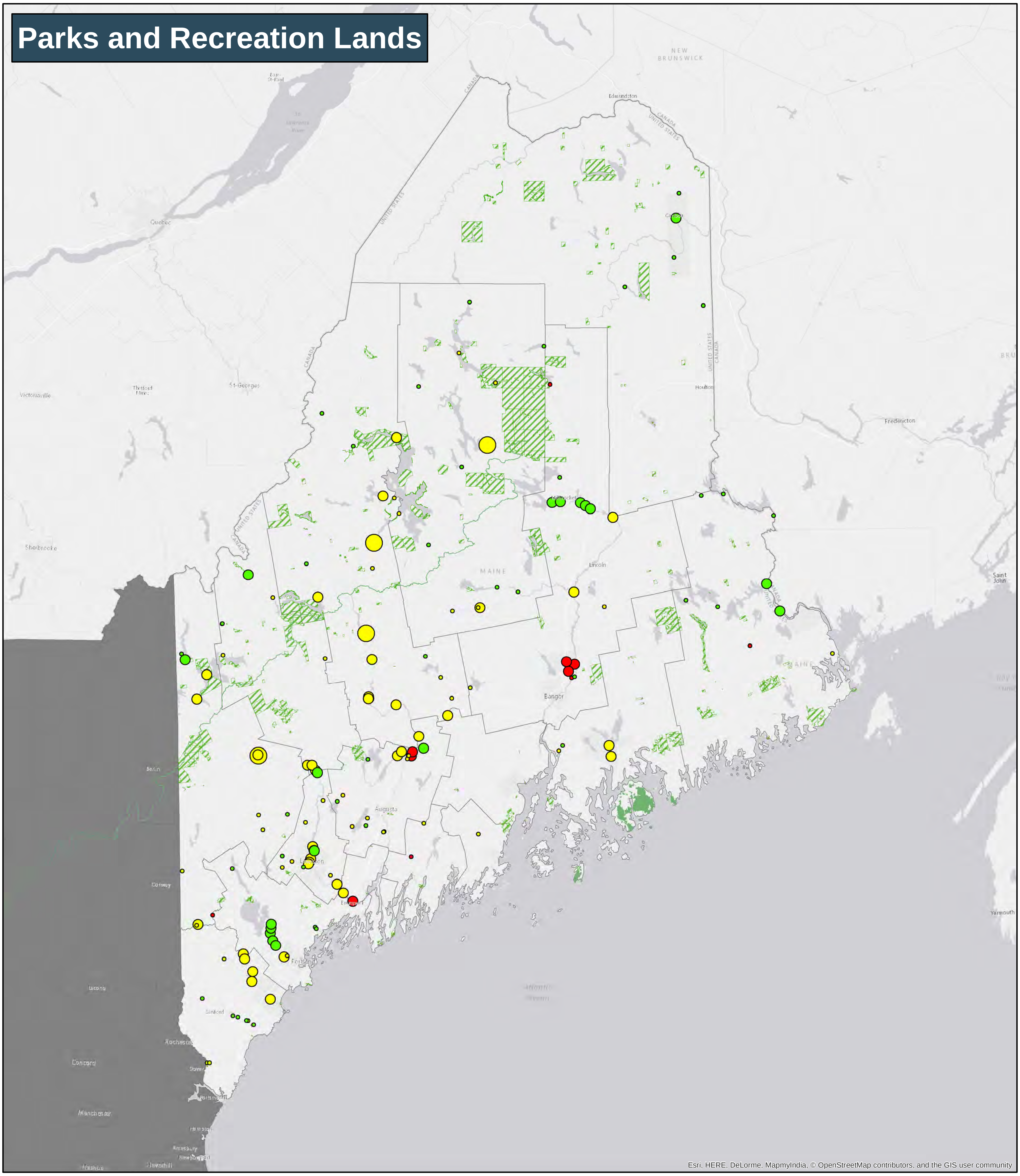
Maine Hydro Potential Considering Regulatory Challenges



Path: G:_Client_Data\MaineGEO\Hydro_Potential_MXD\Maine Dams Hydro Potential Jan 2015 Habitat Final.mxd

Source: esri, MEMA, MEDEP, USGS, USNPS, NOAA NMFS, USFWS, and Kleinschmidt

Maine Hydro Potential Considering Regulatory Challenges



Generation Potential (kW)

- 100 - 1,000
- 1,001 - 30,000
- 30,001 - 61,000

Regulatory Challenges

- >20
- 10-20
- <10

National Park Service Boundaries

State Parks and Public Reserve Lands

N

0 10 20 40 Miles

Kleinschmidt

Path: G:_Client_Data\Maine\GEO\Hydro_Potential_MXD\Maine Dams Hydro Potential Jan 2015 Lands Final.mxd

Source: esri, MEMA, MEDEP, USGS, USNPS, NOAA NMFS, USFWS, and Kleinschmidt

2.1.2 POWERED DAMS ASSESSMENT

Table 2-8 shows the result of the initial assessment, which identified 42 sites with existing hydropower facilities that met the screening thresholds for potential upgrades. These sites represent a total addition of 122 MW of additional capacity and 407 GWh of additional annual generation. As previously noted, this represents a theoretical upper limit for development and a more refined analysis would likely reduce the potential candidates for development. Hydropower has a long history in Maine, and any powered site that could be *significantly* upgraded would likely have already been upgraded.

Even before applying a regulatory screening, none of the sites have a simple payback of less than 20 years. A 20 year simple payback was selected by the study team as a reasonable criterion for a screening level analysis. Simple payback was calculated by dividing the total costs of development by the additional gross revenues generated by the upgrade. The quickest simple payback of any project was 24 years. In reality, developers would likely require much shorter payback to account for profit considerations and additional post-construction expenses such as debt service.

That said, this is based on an assumed base value of the additional energy production of $50/MWh. Table 2-6 puts this value within the historical context of New England wholesale electricity prices.

TABLE 2-6. AVERAGE WHOLESALE ELECTRICITY PRICES IN NEW ENGLAND (2004–2013)

Year	Average wholesale electricity price (per MWh)
2004	52.13
2005	76.64
2006	59.68
2007	66.72
2008	80.56
2009	42.02
2010	49.56
2011	46.00
2012	36.09
2013	56.06

Source: ISO-NE 2014

Table 2-7 demonstrates the effect of alternative pricing on potential simple paybacks. If the assumed pricing were increased to $60/MWh, 26 of the projects totaling 390,000 MWh annually would have simple paybacks of 20 years. At $80/MWh 26 projects have simple paybacks of 15 years or less.

TABLE 2-7. PRICING SENSITIVITIES AND RESULTING PAYBACK PERIODS: POWERED DAMS

ENERGY VALUE	PARAMETER	PROJECTS WITH 20 YEAR SIMPLE PAYBACK OR LESS	PROJECTS WITH 15 YEAR SIMPLE PAYBACK OR LESS	TOTAL PROJECTS
$60/MWh	Number of Projects	26	0	26
	Total Capacity (kW)	117,354	0	117,354
	Annual Energy Increase (MWh)	390,760	0	390,760
$75/MWh	Number of Projects	35	0	35
	Total Capacity (kW)	121,260	0	121,260
	Annual Energy Increase (MWh)	403,750	0	403,750
$80/MWh	Number of Projects	9	26	35
	Total Capacity (kW)	3,906	117,354	121,260
	Annual Energy Increase (MWh)	12,960	390,790	403,750
$90/MWh	Number of Projects	16	26	42
	Total Capacity (kW)	4,902	117,354	122,256
	Annual Energy Increase (MWh)	16,250	390,790	407,040
$100/MWh	Number of Projects	7	35	42
	Total Capacity (kW)	996	121,260	122,256
	Annual Energy Increase (MWh)	3,290	403,750	407,040

Considering regulatory screening, 5 sites have regulatory ranks over 20, suggesting they would not be developable due to the sensitivities of associated resources. Ten sites have a regulatory rank of less than 10, indicating Significant Development Potential; these projects represent 34 MW of potential additional capacity and 113 GWh annually of potential additional energy production. Of these projects Grand Falls is currently non-jurisdictional; increasing energy capacity would trigger FERC jurisdiction and require the project undergo FERC licensing, which would make development extremely unattractive.

TABLE 2-8. HYDROPOWER SITES WITH POTENTIAL FOR ADDITIONAL GENERATION

DAM NAME	COUNTY	RIVER[2]	REGULATORY RANK	EXISTING INSTALLED CAPACITY (KW)	POTENTIAL ADDITIONAL CAPACITY (KW)	INSTALLATION COST ($)	ADDITIONAL ANNUAL GENERATION (MWH)	ADDITIONAL ANNUAL REVENUE ($/YEAR)	SIMPLE PAYBACK (YEARS)
Rumford Falls Project (Upper)	Oxford	Mooselookmeguntic	15	22,250	11,750	47,000,000	39,140	1,957,000	24
Livermore Falls	Androscoggin	Androscoggin	7	800	10,215	40,858,117	34,020	1,701,000	24
Pejepscot	Sagadahoc/Cumberland	Androscoggin	20	13,880	10,120	40,480,000	33,710	1,685,500	24
Androscoggin #3	Androscoggin	Androscoggin	7	3,800	9,662	38,647,145	32,180	1,609,000	24
Ripogenus	Piscataquis	West Branch Penobscot	13	37,530	7,470	29,880,000	24,880	1,244,000	24
Stillwater	Penobscot	Stillwater River	26	3,458	6,422	25,688,000	21,390	1,069,500	24
Deer Rips	Androscoggin	Androscoggin	12	6,625	6,375	25,500,000	21,230	1,061,500	24
Orono Hydro Project	Penobscot	Stillwater River	25	3,822	6,058	24,232,000	20,170	1,008,500	24
Shawmut	Somerset	Kennebec River	20	8,740	5,260	21,040,000	17,520	876,000	24
Lockwood Hydro Station	Kennebec	Kennebec River	27	6,915	5,085	20,340,000	16,930	846,500	24
Cataract	York	Saco River	20	6,650	4,350	17,400,000	14,490	724,500	24
Hydro Kennebec	Kennebec	Kennebec	25	7,717	4,283	17,132,000	14,260	713,000	24
East Millinocket Hydro	Penobscot	West Branch Penobscot River	7	6,936	4,064	16,256,000	13,530	676,500	24
North Twin	Penobscot	West Branch Penobscot	9	6,972	4,028	16,112,000	13,410	670,500	24
Anson	Somerset	Kennebec River	19	9,000	4,000	16,000,000	13,320	666,000	24
Weston - North Channel	Somerset	Kennebec River	20	15,980	3,020	12,080,000	10,050	502,500	24
Weldon (Mattaceunk)	Penobscot	Penobscot River	15	19,200	2,800	11,200,000	9,320	466,000	24
Medway	Penobscot	West Branch Penobscot	4	3,440	2,460	9,840,000	8,190	409,500	24
Williams Station	Somerset	Kennebec	17	13,000	2,000	8,000,000	6,660	333,000	24
Caribou	Aroostook	Aroostook River	9	800	1,900	7,600,000	6,320	316,000	24

[2] Projects located on regulated rivers may predict potential hydroelectric capacity that is much different than the existing capacity because the hydrology data is based upon data from unregulated USGS gages.

Dam Name	County	River[2]	Regulatory Rank	Existing Installed Capacity (kW)	Potential Additional Capacity (kW)	Installation Cost ($)	Additional Annual Generation (MWh)	Additional Annual Revenue ($/year)	Simple Payback (years)
Rumford Falls Project (Middle)	Oxford	Richardson Lake	14	22,250	1,750	7,000,000	5,820	291,000	24
Burnham	Waldo	Sebasticook	15	1,050	1,150	4,600,000	3,830	191,500	24
Brunswick	Cumberland/Sagadahoc	Androscoggin	25	19,000	1,000	4,000,000	3,330	166,500	24
Mallison Falls	Cumberland	Presumpscot	8	800	713	2,851,885	2,370	118,500	24
Moosehead East Outlet	Somerset/Piscataquis	Kennebec	13	150	710	2,840,000	2,360	118,000	24
Moosehead West Outlet	Somerset	Kennebec	12	150	710	2,840,000	2,360	118,000	24
Bar Mills Station	York	Saco River	12	4,000	700	3,500,000	2,330	116,500	30
Bonny Eagle	York	Saco River	15	7,200	600	3,000,000	1,990	99,500	30
Kezar Falls Upper	Oxford	Ossipee	12	350	590	2,950,000	1,960	98,000	30
Grand Falls	Washington	Saint Croix	3	9,480	520	2,600,000	1,730	86,500	30
Browns Mill	Piscataquis	Piscataquis River	17	594	506	2,530,000	1,680	84,000	30
Dundee Falls	Cumberland	Presumpscot	13	2,400	300	1,500,000	990	49,500	30
Upper Barker	Androscoggin	Little Androscoggin	12	950	250	1,250,000	830	41,500	30
Ledgemere	York	Little Ossipee	12	450	230	1,150,000	760	38,000	30
North Gorham Hydro Station	Cumberland	Presumpscot	13	2,190	210	1,050,000	690	34,500	30
Kesslen	York	Mousam	6	150	198	1,190,226	660	33,000	36
Hackett Mills	Androscoggin	Little Androscoggin	15	485	175	1,050,000	580	29,000	36
Waverly	Somerset	Sebasticook	10	400	170	1,020,000	560	28,000	36
Eustis Hydro	Franklin	North Branch Dead	14	250	150	900,000	490	24,500	37
Barkers Mill	Androscoggin	Little Androscoggin	15	1,500	100	600,000	330	16,500	36
Kezar Falls Lower	York	Ossipee	12	1,000	100	600,000	330	16,500	36
Sebec Lake	Piscataquis	Sebec River	9	867	103	618,000	340	17,000	36

TABLE 2-9. POWERED DAMS WITH REGULATORY RANK OF LESS THAN 10

DAM NAME	COUNTY	RIVER	REGULATORY RANK	EXISTING INSTALLED CAPACITY (KW)	POTENTIAL ADDITIONAL CAPACITY (KW)	ADDITIONAL ANNUAL GENERATION (MWH)	INSTALLATION COST ($)	ADDITIONAL ANNUAL REVENUE ($/YEAR)	SIMPLE PAYBACK TIME (YEARS)
Livermore Falls	Androscoggin	Androscoggin	7	800	10,215	34,020	40,858,117	1,701,000	24
Androscoggin #3	Androscoggin	Androscoggin	7	3,800	9,662	32,180	38,647,145	1,609,000	24
East Millinocket Hydro	Penobscot	West Branch Penobscot River	7	6,936	4,064	13,530	16,256,000	676,500	24
North Twin	Penobscot	West Branch Penobscot	9	6,972	4,028	13,410	16,112,000	670,500	24
Medway	Penobscot	West Branch Penobscot	4	3,440	2,460	8,190	9,840,000	409,500	24
Caribou	Aroostook	Aroostook River	9	800	1,900	6,320	7,600,000	316,000	24
Mallison Falls	Cumberland	Presumpscot	8	800	713	2,370	2,851,885	118,500	24
Grand Falls	Washington	Saint Croix	3	9,480	520	1,730	2,600,000	86,500	30
Kesslen	York	Mousam	6	150	198	660	1,190,226	33,000	36
Sebec Lake	Piscataquis	Sebec River	9	867	103	340	618,000	17,000	36

TABLE 2-10. POTENTIAL ADDITIONAL CAPACITY AT POWERED DAMS BY COUNTY AND REGULATORY CATEGORY

COUNTY	LIMITED DEVELOPMENT POTENTIAL		MODERATE DEVELOPMENT POTENTIAL		SIGNIFICANT DEVELOPMENT POTENTIAL		TOTAL	
	NUMBER OF SITES	TOTAL POTENTIAL ADDITIONAL CAPACITY (KW)	NUMBER OF SITES	TOTAL POTENTIAL ADDITIONAL CAPACITY (KW)	NUMBER OF SITES	TOTAL POTENTIAL ADDITIONAL CAPACITY (KW)	NUMBER OF SITES	TOTAL POTENTIAL ADDITIONAL CAPACITY (KW)
Androscoggin			4	6,900	2	19,876	6	26,776
Aroostook					1	1,900	1	1,900
Cumberland			2	510	1	713	3	1,223
Franklin			1	150			1	150
Kennebec	2	24,000					2	9,368
Oxford			3	14,090			3	14,090
Penobscot	2	12,480	1	2,800	3	10,552	6	25,832
Piscataquis			3	8,686	1	103	4	8,789
Sagadahoc	1	20,000	1	10,120			2	11,120
Somerset			6	15,160			6	15,870
Waldo			1	1,150			1	1,150
Washington					1	520	1	520
York			5	5,980	1	198	6	6,178
Grand Total	**5**	**22,848**	**27**	**65,546**	**10**	**33,863**	**42**	**122,257**

2.1.3 UNPOWERED DAMS ASSESSMENT

Table 2-12 shows the result of the initial assessment, which found 68 unpowered dams that met the screening thresholds for adding generation. These sites represent a total addition of approximately 70 MW of additional capacity and 234 GWh of additional annual generation. While most powered dams would already have transmission available for interconnection, many unpowered dams would not. This screening analysis did not account for transmission needs, which would be a further limitation on development: an isolated site with no approximate point of interconnection would be more expensive to develop.

Even before applying a regulatory screening, none of the unpowered dam sites have a simple payback of less than 20 years; the quickest payback of any project was 24 years. As noted in the Powered Dam Assessment, this is based on an assumed base value of the additional generation of $50/MWh. Table 2-11 demonstrates the effect of alternative pricing on potential paybacks. If the assumed pricing were increased to $60/MWh, 13 of the projects totaling 153,000 MWh annually would have paybacks of 20 years. At $80/MWh many projects have paybacks of 15 years or less.

TABLE 2-11. PRICING SENSITIVITIES AND RESULTING PAYBACK PERIODS: UNPOWERED DAMS

ENERGY VALUE	PARAMETER	PROJECTS WITH 20 YEAR SIMPLE PAYBACK OR LESS	PROJECTS WITH 15 YEAR SIMPLE PAYBACK OR LESS	TOTAL VIABLE PROJECTS
$60/MWh	Number of Projects	16	0	16
	Total Capacity (kW)	57,165	0	57,165
	Annual Energy Production (MWh)	190,340	0	190,340
$75/MWh	Number of Projects	46	0	46
	Total Capacity (kW)	67,281	0	67,281
	Annual Energy Production (MWh)	223,890	0	223,890
$80/MWh	Number of Projects	30	16	46
	Total Capacity (kW)	10,116	57,165	67,281
	Annual Energy Production (MWh)	33,550	190,340	223,890
$100/MWh	Number of Projects	22	46	68
	Total Capacity (kW)	3,036	67,281	70,317
	Annual Energy Production (MWh)	10,000	223,890	233,890

Considering regulatory screening eliminates 4 sites from further consideration, as all have regulatory ranks over 20. A total of 35 sites representing 21 MW of potential capacity and 70 GWh of additional annual production have regulatory ranks of less than 10, as shown in Table 2-13.

TABLE 2-12. UNPOWERED DAMS WITH HYDROPOWER POTENTIAL IN MAINE

DAM NAME	COUNTY	RIVER	REGULATORY RANK	POTENTIAL CAPACITY (KW)	ANNUAL GENERATION (MWH)	INSTALLATION COST ($)	ANNUAL REVENUE ($/YEAR)	TIME TO PAYBACK COST (YEARS)
Gilman Falls	Penobscot	Stillwater Penobscot River	22	13,000	43,300	52,000,000	2,165,000	24
Middle Dam Project	Oxford	Rapid	15	9,900	32,970	39,600,000	1,648,500	24
Stone	Penobscot	West Branch Penobscot	9	8,500	28,310	34,000,000	1,415,500	24
Madison Paper Corp Log	Somerset	Kennebec River	14	8345	27,790	33,380,820	1,389,500	24
Seboomook	Somerset	West Branch Penobscot River	10	3,400	11,320	13,600,000	566,000	24
Flagstaff (Long Falls)	Somerset	Dead River	12	3,300	10,990	13,200,000	549,500	24
Chain of Ponds	Franklin	North Branch Dead River	9	1509	5,020	6,036,462	251,000	24
Graham Lake	Hancock	Union	17	1,500	4,990	6,000,000	249,500	24
Upper	Oxford	Rapid	12	1,100	3,660	4,400,000	183,000	24
Littlefields	Androscoggin	Little Androscoggin	7	1030	3,430	4,121,990	171,500	24
Canada Falls	Somerset	West Branch Penobscot River	6	1,000	3,330	4,000,000	166,500	24
Vanceboro	Washington	Saint Croix	0	990	3,290	3,960,000	164,500	24
Abbott Brook Dike	Oxford	Abbott Brook	9	960	3,190	3,840,000	159,500	24
Cumberland Mills	Cumberland	Presumpscot	13	950	3,160	3,800,000	158,000	24
Grand Lake	Penobscot	Penobscot River	21	940	3,130	3,760,000	156,500	24
Milo Hydro	Piscataquis	Sebec River	9	740	2,460	2,960,000	123,000	24
Upper Piscataquis	Piscataquis	Piscataquis River	17	660	2,190	3,300,000	109,500	30
Estes Lake	York	Mousam	6	550	1,830	2,750,000	91,500	30
Churchill	Piscataquis	Allagash River	2	543	1,800	2,716,668	90,000	30
Head Tide	Lincoln	Sheepscott	44	540	1,790	2,700,000	89,500	30
New Mills	Kennebec	Cobbosseecontee	10	520	1,730	2,600,000	86,500	30
Telos	Piscataquis	Allagash Stream	12	516	1,710	2,579,959	85,500	30
Old Falls	York	Mousam	9	460	1,530	2,300,000	76,500	30
West Grand Lake	Washington	West Br. St. Croix	6	400	1,330	2,000,000	66,500	30
South Berwick	York	Great Works	17	380	1,260	1,900,000	63,000	30
Danforth	Washington	Baskehegan	9	350	1,160	1,750,000	58,000	30
Great Moose Lake	Somerset	Sebasticook River	12	320	1,060	1,600,000	53,000	30

DAM NAME	COUNTY	RIVER	REGULATORY RANK	POTENTIAL CAPACITY (KW)	ANNUAL GENERATION (MWH)	INSTALLATION COST ($)	ANNUAL REVENUE ($/YEAR)	TIME TO PAYBACK COST (YEARS)
Nezinscot River	Androscoggin	Nezinscot	12	310	1,030	1,550,000	51,500	30
Orland Village	Hancock	Narramissic River	11	302	1,000	1,507,580	50,000	30
Kingfield	Franklin	Carrabassett	12	300	990	1,500,000	49,500	30
Collins Mills	Kennebec	Cobbosseecontee Stream	7	296	980	1,478,377	49,000	30
Forest City	Washington	East Grand Lake	6	290	960	1,450,000	48,000	30
Range Pond #3	Androscoggin	Range Brook	15	290	960	1,450,000	48,000	30
State Street	Aroostook	Presque Isle	1	279	930	1,397,390	46,500	30
Little Madaswaska	Aroostook	Little Madaswaska River	1	268	890	1,342,292	44,500	30
Lock	Piscataquis	Allagash Stream	10	260	860	1,300,000	43,000	30
Alamoosook Lake	Hancock	Narramissic River	9	253	840	1,262,864	42,000	30
East Elm Street	Cumberland	Royal River	4	249	820	1,244,190	41,000	30
Bridge Street	Cumberland	Royal River	6	229	760	1,145,590	38,000	30
Moxie	Somerset	Moxie Stream	12	230	760	1,150,000	38,000	30
Cobbosseecontee Outlet	Kennebec	Cobboseecontee Stream	12	220	730	1,100,000	36,500	30
Dead River	Androscoggin	Dead	10	220	730	1,100,000	36,500	30
Great Pond	Kennebec	Belgrage Stream	9	220	730	1,100,000	36,500	30
Millinocket Lake	Penobscot	Millinocket Stream	9	220	730	1,100,000	36,500	30
Pokey	Washington	East Machias River	26	221	730	1,104,791	36,500	30
Robinson	Aroostook	Prestile Stream	3	220	730	1,100,000	36,500	30
Billings	Oxford	Little Androscoggin	15	180	590	1,080,000	29,500	37
Dornan Mill	Knox	Mill Pond	11	177	590	1,062,847	29,500	36
Coopers Mills	Lincoln	Sheepscot River	20	176	580	1,056,114	29,000	36
Wilson Stream	Piscataquis	Big Wilson Stream	1	172	570	1,033,728	28,500	36
Lower	Androscoggin	Sabattus River	20	170	560	1,020,000	28,000	36
Ragged Lake	Piscataquis	Ragged Stream	7	170	560	1,020,000	28,000	36
North Street Dam	Penobscot	Sebasticook	13	160	530	960,000	26,500	36
Rangeley	Franklin	Rangeley	15	160	530	960,000	26,500	36
Munsungan Lake	Piscataquis	Munsungan Lake	2	154	510	925,272	25,500	36

Dam Name	County	River	Regulatory Rank	Potential Capacity (kW)	Annual Generation (MWh)	Installation Cost ($)	Annual Revenue ($/year)	Time to Payback Cost (years)
Annabessacook Lake	Kennebec	Jug Stream	12	130	430	780,000	21,500	36
C. Withington & Son	Oxford	Nezinscot	7	131	430	786,216	21,500	37
Perry Station Dam	Washington	Boyden Stream	11	130	430	780,000	21,500	36
Gilman Mill	Penobscot	Blackman Stream	6	119	390	714,622	19,500	37
Higgins	Somerset	Higgins Stream	7	119	390	715,195	19,500	37
Loon Lake	Piscataquis	Loon Stream	7	120	390	720,000	19,500	37
Lovejoy Pond	Kennebec	Lovejoy Stream	10	120	390	720,000	19,500	37
Spencer Lake	Somerset	Little Spencer Stream	7	113	370	680,216	18,500	37
Emery Mills	York	Mousam	6	110	360	660,000	18,000	37
Sysladobsis	Washington	Grand Lake Stream	6	110	360	660,000	18,000	37
Wayne Village	Kennebec		7	109	360	652,880	18,000	36
Stevens Brook	Cumberland	Stevens Brook	1	105	350	632,959	17,500	36
Dole Pond	Somerset	Dole Brook	1	100	330	597,632	16,500	36

Table 2-13. Unpowered Dams with Regulatory Ranks of Less than 10

Dam Name	County	River	Regulatory Rank	Potential Capacity (kW)	Annual Generation (MWh)	Installation Cost ($)	Annual Revenue ($/year)	Simple Payback (years)
Stone	Penobscot	West Branch Penobscot	9	8,500	28,310	34,000,000	1,415,500	24
Chain of Ponds	Franklin	North Branch Dead River	9	1509	5,020	6,036,462	251,000	24
Littlefields	Androscoggin	Little Androscoggin	7	1030	3,430	4,121,990	171,500	24
Canada Falls	Somerset	West Branch Penobscot River	6	1,000	3,330	4,000,000	166,500	24
Vanceboro	Washington	Saint Croix	0	990	3,290	3,960,000	164,500	24
Abbott Brook Dike	Oxford	Abbott Brook	9	960	3,190	3,840,000	159,500	24
Milo Hydro	Piscataquis	Sebec River	9	740	2,460	2,960,000	123,000	24
Estes Lake	York	Mousam	6	550	1,830	2,750,000	91,500	30
Churchill	Piscataquis	Allagash River	2	543	1,800	2,716,668	90,000	30
Old Falls	York	Mousam	9	460	1,530	2,300,000	76,500	30
West Grand Lake	Washington	West Br. St. Croix	6	400	1,330	2,000,000	66,500	30
Danforth	Washington	Baskehegan	9	350	1,160	1,750,000	58,000	30
Collins Mills	Kennebec	Cobbosseecontee Stream	7	296	980	1,478,377	49,000	30
Forest City	Washington	East Grand Lake	6	290	960	1,450,000	48,000	30
State Street	Aroostook	Presque Isle	1	279	930	1,397,390	46,500	30
Little Madaswaska	Aroostook	Little Madaswaska River	1	268	890	1,342,292	44,500	30
Alamoosook Lake	Hancock	Narramissic River	9	253	840	1,262,864	42,000	30
East Elm Street	Cumberland	Royal River	4	249	820	1,244,190	41,000	30
Bridge Street	Cumberland	Royal River	6	229	760	1,145,590	38,000	30
Great Pond	Kennebec	Belgrage Stream	9	220	730	1,100,000	36,500	30
Millinocket Lake	Penobscot	Millinocket Stream	9	220	730	1,100,000	36,500	30
Robinson	Aroostook	Prestile Stream	3	220	730	1,100,000	36,500	30
Wilson Stream	Piscataquis	Big Wilson Stream	1	172	570	1,033,728	28,500	36
Ragged Lake	Piscataquis	Ragged Stream	7	170	560	1,020,000	28,000	36
Munsungan Lake	Piscataquis	Munsungan Lake	2	154	510	925,272	25,500	36
C. Withington & Son	Oxford	Nezinscot	7	131	430	786,216	21,500	37
Gilman Mill	Penobscot	Blackman Stream	6	119	390	714,622	19,500	37
Higgins	Somerset	Higgins Stream	7	119	390	715,195	19,500	37

Dam Name	County	River	Regulatory Rank	Potential Capacity (kW)	Annual Generation (MWh)	Installation Cost ($)	Annual Revenue ($/year)	Simple Payback (years)
Loon Lake	Piscataquis	Loon Stream	7	120	390	720,000	19,500	37
Spencer Lake	Somerset	Little Spencer Stream	7	113	370	680,216	18,500	37
Emery Mills	York	Mousam	6	110	360	660,000	18,000	37
Sysladobsis	Washington	Grand Lake Stream	6	110	360	660,000	18,000	37
Wayne Village	Kennebec		7	109	360	652,880	18,000	36
Stevens Brook	Cumberland	Stevens Brook	1	105	350	632,959	17,500	36
Dole Pond	Somerset	Dole Brook	1	100	330	597,632	16,500	36

Table 2-14. Potential new capacity at unpowered dams by county and regulatory category

	Limited Development Potential		Moderate Development Potential		Significant Development Potential		Total	
County	Number of Sites	Total Potential Capacity (kW)	Number of Sites	Total Potential Capacity (kW)	Number of Sites	Total Potential Capacity (kW)	Number of Sites	Total Potential Capacity (kW)
Androscoggin			4	990	1	1,030	5	2,020
Aroostook					3	768	3	768
Cumberland			1	950	3	583	4	1,533
Franklin			2	460	1	1,509	3	1,969
Hancock			2	1,802	1	253	3	2,054
Kennebec			4	990	3	624	7	1,614
Knox			1	177			1	177
Lincoln	1	540	1	176			2	716
Oxford			3	11,180	2	1,091	5	12,271
Penobscot	2	13,940	1	160	3	8,839	6	22,939
Piscataquis			3	1,436	6	1,900	9	3,336
Somerset			5	15,595	4	1,332	9	16,927
Washington	1	221	1	130	5	2,140	7	2,491
York			1	380	3	1,120	4	1,500
Grand Total	**4**	**14,701**	**29**	**34,426**	**35**	**21,190**	**68**	**70,317**

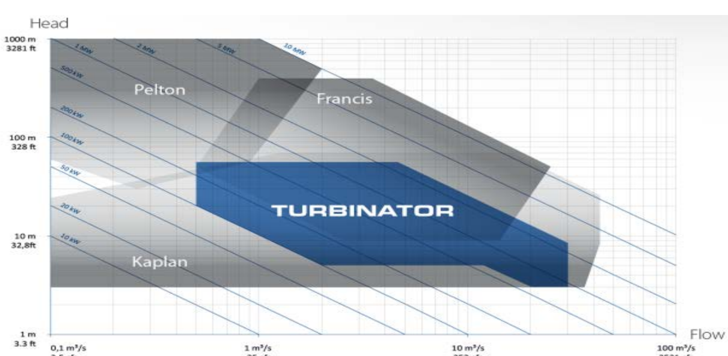
2.1.4 EMERGING TECHNOLOGIES

In many ways hydropower is an ancient technology with the Greeks, Romans, and Chinese using waterpower to grind wheat, but the technology has developed over time with water wheels first driving electric generators in 1882(ASME Hydro Power Technical Committee, 1996, pp. 2-1) and efficiencies improving from 15% in the 1700's to upwards of 96% today (ASME Hydro Power Technical Committee, 1996, pp. 2-2 &3). Innovation and refinement continue today with a number of emerging technologies being developed, tested, and proven.

As none of the conventional hydropower sites demonstrated viability in the screening analysis, this study did not analyze the potential deployment of newer technologies, which are assumed to be more expensive than conventional development at this time. The following is a non-analytic overview of emerging hydropower technologies. Although not comprehensive in nature, a number of the more proven new technologies are discussed below with other technologies such as Voith's StreamDiver, Toshiba eKIDS, Mavel Siphon Turbines, and Ossberger's "movable powerhouse." Given the promise of these technologies, particularly at low head sites, a future effort analyzing the commercial viability of these technologies seems worthy of consideration.

2.1.4.1 CLEAN POWER AS – (TURBINATOR)

The first full-scale pilot installation of the Clean Power AS Turbinator was in 2010 at the Hegset facility in Norway and was based on the concept of a ship's directional thruster. The design comes in six sizes and is essentially a semi-regulated axial-flow machine with an integrated, direct-drive, permanent-magnet generator. The machine's design intent was to minimize the civil works by combining the turbine and generator into one single housing and making it simple to install with minimal changes to the facility's infrastructure. As seen in the chart below the equipment can operate between the head range of 15 to 180 feet with flow ranges of 18 cfs to 420 cfs (100 to 3000 MW)(Hydro Vision Presentation, 2013), (Clean Power , n.d.).



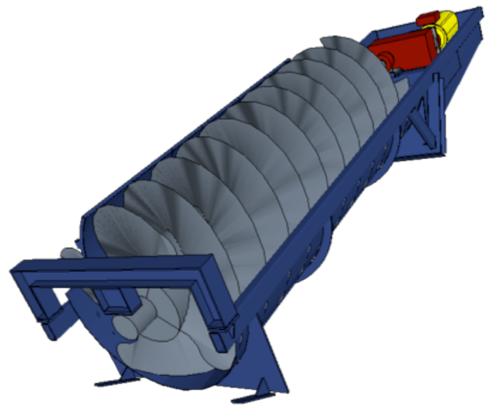
2.1.4.2 MJ2 TECHNOLOGIES – (VERY LOW HEAD TURBINE)

This fully submerged combination turbine/generator design has experienced a significant amount of growth since its recent development especially because it does not require a full powerhouse and is intended more for open canal installations. The machine is unique in that it can operate at very low heads (from 5 feet to just over 15 feet) making it ideal for applications where conventional hydro installations are not cost effective. The allowable flow ranges from 350 cfs to 950 cfs at an 80% efficiency. The turbine is offered in five sizes for a variety of operating parameters.

There have been over 35 VLH turbines installed in Europe and the first North American installation is underway at Wasdell Falls in Ontario, Canada. Furthermore they have performed extensive environmental testing and have determined that the VLH turbine meets or exceeds "the US Department of Energy's five hydraulic design criteria that qualify the degree of fish friendliness of a hydro turbine including; peripheral speed, maximum pressure, rate of change of pressure, shear stress indicators and blade to discharge ring gap." Testing results indicate an average survival rate of over 94%(27th IAHR Symposium on Hydraulic Machinery and Systems, 2014), (MJ2 Technologies, n.d.).

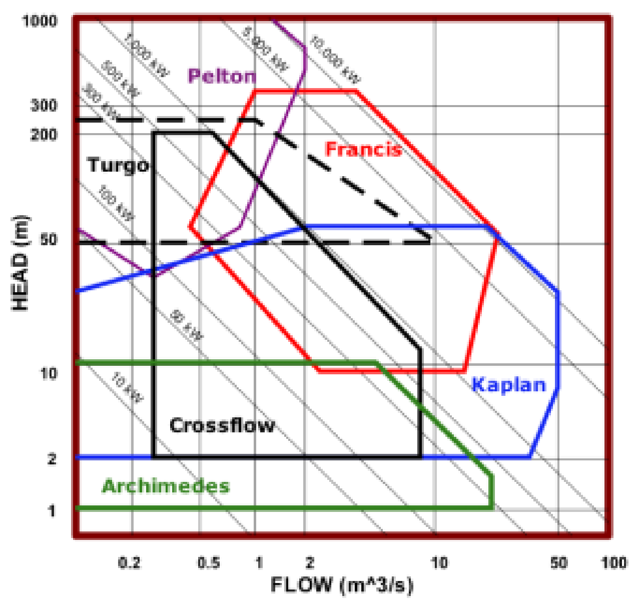
2.1.4.3 3 Helix Power & Andritz-Altro – (Archimedes Screw)

The 3 Helix Power Archimedes screw design differs from some other technologies in this report in that it does not have the generator integral with the turbine. This is a US based company acting as an agent for an English based design that has completed more than 40 low head projects. This equipment is design for head ranges from 3 to 33 feet and flows ranging from 14 to 350 cfs (http://www.3helixpower.com/, n.d.).



Archimedes Screw

A competitor (Andritz-Altro) also provides a similar design and they have found that the Archimedes screw turbines are “fish friendly and do not require fine screening” (Applegate Group, 2013). The ability to eliminate the fine screening, was actually the benefit of the equipment original intent as pump for heavy solid laden material in the pulp and paper industry which has now been converted for low head generation purposes (http://www.3helixpower.com/, n.d.).



2.2 MARINE AND HYDROKINETIC INDUSTRY OPPORTUNITIES

Marine and hydrokinetic (MHK) project development has the potential to address Maine's numerous power needs on local and regional scales. MHK projects align with the State of Maine's renewable energy goals, which were enacted by legislation in 2009 to facilitate the development of ocean energy test sites and laid the foundation for Maine's renewable ocean energy industry. The legislation, known as the Ocean Energy Act, cited the urgent public interest to reduce the use of fossil fuels; to use state submerged lands for testing ocean energy technologies in an environmentally safe manner; and to create new economic development opportunities (Public Law, Chapters 270 and 615).

MHK projects can also help meet the State of Maine's Renewable Resource Portfolio Requirement and contribute to a diversified and balanced portfolio of energy supply options. Since 2000, Maine has required retail electricity suppliers to meet 30 percent of their retail load in Maine from eligible resources, a category that included renewable resources, and specifically, tidal generation (Public Law 1999, Chapter 298). In 2007, the Maine Legislature passed a renewable resource requirement intended to promote the development of new renewable resources, by mandating that a percentage of electricity provided by retail suppliers come from renewable resources that began service, resumed operation or were substantially refurbished after September 2005 (Public Law 2007, Chapter 403).

Maine Public Utilities Commission (MPUC) 2007 rules, which implemented that legislation, designated these new renewable resources, including tidal generation, as "Class I" resources. As of 2011, four percent of Maine's retail supply must be met from Class I resources; this requirement will rise in one percent increments annually until reaching 10 percent in 2017. Ocean Renewable Power Company (ORPC), a developer of tidal energy projects, has not yet applied for MPUC certification for the Cobscook Bay Tidal Energy Project as a Class I resource, but the Project meets the statutory requirements for such certification.

Additionally, MHK project development will help New England meet its renewable portfolio standards and contribute to a diversified and balanced portfolio of energy supply options for the State of Maine. A tidal power resource qualifies as a Class I resource in all five of the New England states that have mandatory renewable portfolio standards: Connecticut, Massachusetts, Maine, New Hampshire, and Rhode Island. The same holds true for wave energy conversion with the exception of Maine. For Maine specifically, the rules adopted by the MPUC require that each electricity provider, including standard offer providers, supply at least 40 percent of its total retail electric sales in Maine using electricity generated by eligible renewable resources, such as tidal power, and certain efficient resources by 2017.[3]

By 2020, Class I demand in the New England states will be over 18,000 gigawatt-hours (GWh) per year. The Class I renewable energy demand is shown in Figure 2-3.

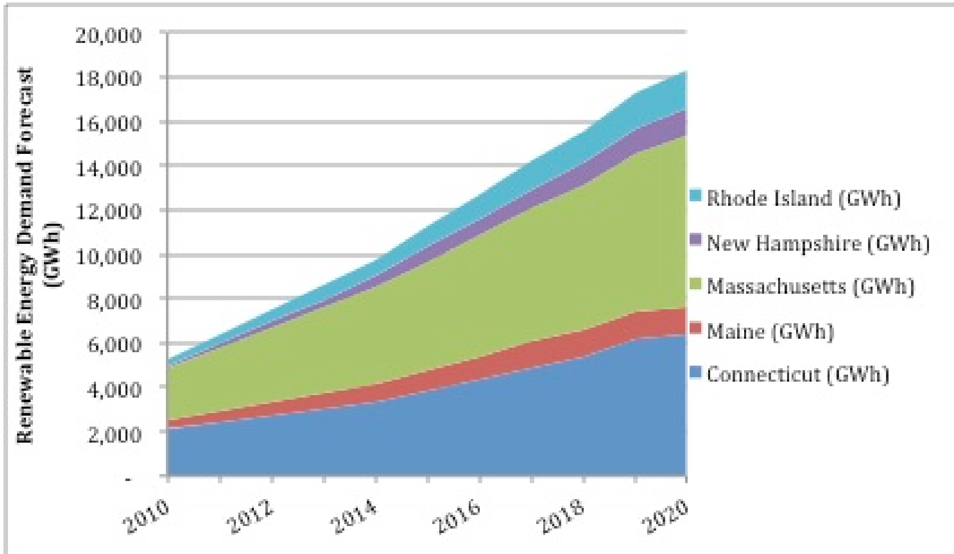


FIGURE 2-3. NEW ENGLAND RENEWABLE ENERGY CLASS I DEMAND FORECAST

Source: ISO New England

2.2.1 MHK INVENTORY METHODOLOGY

a. To create an MHK inventory for the State of Maine, existing data sources (state and federal, academic and industry) were reviewed. These sources contributed to an enhanced knowledge of the following site characteristics: (1) resource data (tidal, wave, river); (2) Existing and emerging technologies; (3) Site characteristics (depth, width, proximity to shore); (4) Existing grid accessibility and compatibility; (5) Environmental factors; and (6) Existing uses (commercial fishing, marine traffic, and recreation).

Because previous assessments of MHK resources in the State of Maine were conducted on a macro scale, this study further defined development opportunities with a goal of maximizing potential output while limiting environmental effects and potential conflicts with existing resource users.

[3] In June 2006, Maine enacted legislation (LD 2041) creating a renewable portfolio goal to increase new renewable energy capacity from 30 percent to 40 percent by 2017. Public Law 2007, Chapter 403 converted the 2006 goal into a mandatory standard, which MPUC has since designated the "Class I" standard.

2.2.1.1 PREVIOUS STUDIES

The first assessments of wave and tidal energy resources in the State of Maine were published by the Electric Power Research Institute (EPRI) in 2004 and 2006 respectively:

- E2I EPRI Survey and Characterization of Potential Offshore Wave Energy Sites in Maine, EPRI Report: E2I EPRI WP-003-ME, June 9, 2004 (Electric Power Research Institute, 2004);
- System Level Design, Performance and Costs – Maine State Offshore Wave Power Plant, EPRI Report: E2i EPRI Global WP – 006 – ME, December 2, 2004 (Electric Power Research Institute, 2004);
- Maine Tidal In-Stream Energy Conversion (TISEC): Survey and Characterization of Potential Project Sites, EPRI Report: EPRI – TP – 003 ME Rev 1, 2006 (Electric Power Research Institute, 2006); and
- System Level Design, Performance, Cost and Economic Assessment – Maine Western Passage Tidal In-Stream Power Plant, EPRI Report: EPRI – TP – 006 - ME, 2006 (Electric Power Research Institute, 2006).

The EPRI reports identified potential wave and tidal energy sites along the Maine coast and developed a theoretical design for a wave energy plant off Old Orchard Beach and a tidal energy power plant in Western Passage. The purpose of EPRI's work was to identify resource potential, stimulate interest in creating public policy favorable to ocean energy development, and encourage developers to investigate sites in more detail. Because MHK energy technologies are still emerging, it has taken time to translate results of the reports into potential project development opportunities.

2.2.1.2 NEW DATA AND DEVELOPMENTS

Since the 2006 EPRI reports, numerous industry advancements have occurred that have contributed to a better understanding of the State's ocean energy resource and its development potential. Advancements include the following:

<u>Policy</u>

- Ocean Energy legislation (2009)
- Federal Energy Regulatory Commission (FERC) Memorandum of Understanding with the State of Maine (2009). This MOU established the Maine Department of Environmental Protection as the lead state agency for hydrokinetic projects.

- Climate change analysis provided from the University of Maine Climate Change Institute to the state of Maine (2009) estimating total statewide tidal energy potential of 200-250 MW.

Test site development

- Maine Maritime Academy (MMA) Test Site (2010-)
  - MMA received a FERC Order exempting its test area in Castine Harbor and the Bagaduce Narrows from a project license. Multiple small-scale hydrokinetic devices have subsequently been tested.

Project development and resource characterization

- ORPC's Cobscook Bay Tidal Energy Project (2012-present). The Cobscook Bay Tidal Energy Project demonstrated the successful design, permitting, installation, and operation of a hydrokinetic device. The following project components are noteworthy:
  - First grid connection and long term power purchase agreement of in all of the Americas
  - FERC license issuance
  - Maine Department of Environmental Protection General Permit for a tidal energy project
  - Maine Department of Agriculture and Conservation and Forestry Submerged Land Lease
  - Environmental monitoring that has indicated negligible observed effects from the power system
  - Industry and academic partnerships, including the University of Maine and the National Labs
  - Local and regional supply chain development
  - Local and regional economic benefits
- Resource assessment and modeling to validate and quantify tidal energy resources have been conducted using Acoustic Doppler Current Profiler equipment at multiple locations near Eastport, Lubec, and Wiscasset

Ocean energy and marine data

Several regional and national initiatives have been conducted to characterize tidal energy resources and existing ocean users through marine spatial planning. These include:

- Georgia Tech Resource Assessment (2011) http://www.tidalstreampower.gatech.edu/
- The Georgia Tech project created a national database of tidal stream energy potential, as well as a GIS tool usable by industry in order to accelerate the market for tidal energy conversion technology. Tidal currents were numerically modeled with the Regional

Ocean Modeling System and calibrated with the available measurements of tidal current speed and water level surface.

- Northeast Data Portal (2011) http://www.northeastoceandata.org/maps/energy/
- NortheastOceanData.org is an information resource and decision support tool for ocean planning from the Gulf of Maine to Long Island Sound. The website provides user-friendly access to maps, data, tools, and information needed for regional ocean planning. The tidal resource layer represents a sample of modeled maximum tidal currents speed in meters/second for January 2009. Tidal data were processed from the Unstructured Finite Volume Coastal Ocean Model (FVCOM) based at the University of Massachusetts Dartmouth. See Figure 2-4. below provides a snapshot of tidal energy resource data for the coast of Maine.

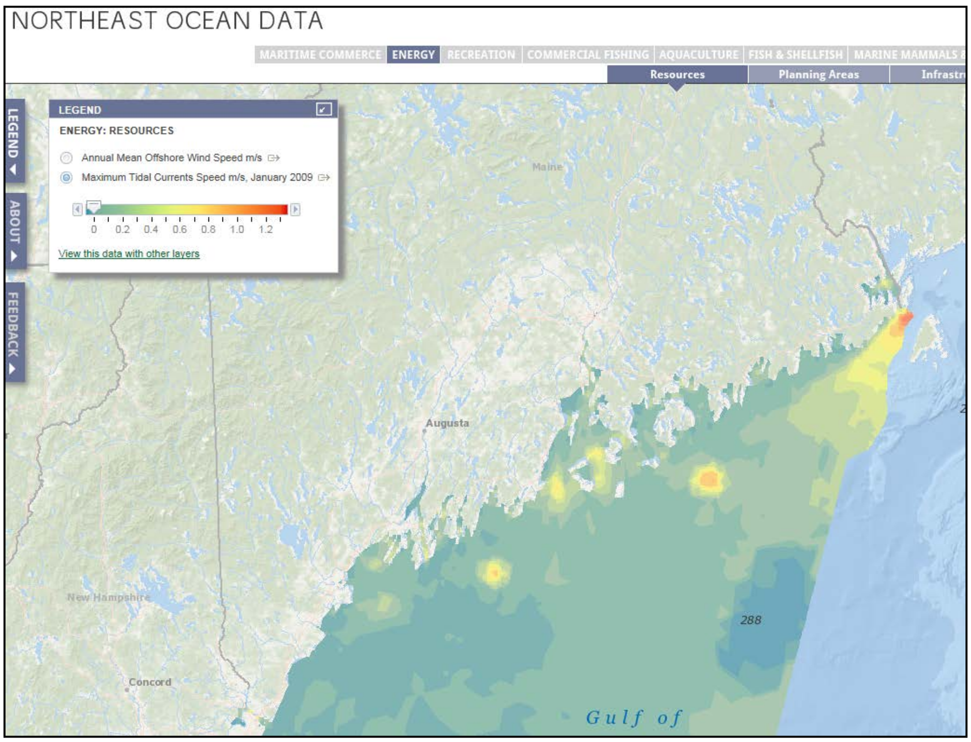


FIGURE 2-4. TIDAL ENERGY RESOURCE LAYER, NORTHEAST OCEAN PORTAL

2.2.1.3 SITE SCREENING PROCESS

Using existing data, a matrix was developed to assess site characteristics that are beneficial for assessing the viability of project development. Key criteria evaluated included the following:

- Project rated capacity
- Site characteristics (depth, width, substrate material)
- Grid accessibility (proximity to shore and kV distribution system)
- Environmental factors (endangered and threatened species)

- Existing users (commercial fishing, recreational activities, navigation)
- Other (i.e. planned infrastructure)

2.2.2 TIDAL ENERGY INVENTORY ASSESSMENT

Potential sites for tidal energy development were identified based on previous studies as well as recently available resource data and personal communication with individuals and/or communities that expressed interest in a local resource. Potential sites for most hydrokinetic technology providers include tidal sites where velocities are at least 2 meters per second (approximately 4 knots or 6.75 feet per second). Technologies that capture lower flow velocities are in development but few if any are commercially available at this time. Power density and rated capacity were previously determined by EPRI however, many sites, especially those with community scale (< 1 MW) potential resources, have little available information. Table 2-15 summarizes tidal energy sites identified in this study and associated resource data. Figure 2-5 shows locations of tidal energy sites along the coast of Maine.

In addition to tidal energy resource and site characterization, locations where infrastructure projects may occur were identified. These sites may provide an opportunity to incorporate tidal energy into construction or bridge projects that lead to lower installation and maintenance costs.

TABLE 2-15. IDENTIFIED POTENTIAL TIDAL ENERGY SITES FROM EPRI REPORT DATE

SITE NAME	LOCATION	VELOCITY/POWER DENSITY (OBSERVED OR TESTED)	TOTAL TISEC PROJECT RATED CAPACITY AT 15% ENERGY WITHDRAWAL*
Western Passage	Eastport, ME	Currents measured in excess of 3 m/s on Flood tide - Modeled 5.1 kW/m2 flood - 4.6 kW/m2 ebb	10.8 MW
Lubec Narrows	Lubec, ME	Currents measured in excess of 4 m/s on the ebb tide - Modeled 8 kW/m2 flood, 16 kW/m2 ebb	1.2 MW
Cobscook Bay	Eastport, ME/ Lubec, ME	Currents measured up to 2.5 m/s flood tides, ebb is very similar. Modeled 4.6 kW/m2 flood and ebb.	7.1 MW
Taunton Bay	West Sullivan, ME	No modeling or current measurements have been done, unless there were current studies done when the Rt. 1 Sullivan Bridge was built	Not evaluated
Bagaduce Narrows	Castine, ME	Tidal Currents of 2.5 m/s have been observed near Jones Point. Estimated power production from modeling 5.2 kW/m2 on both flood and ebb tides.	230 kW
Penobscot River	Bucksport, ME	Modeled .2 kW/m2 on flood, 3.3 kW/m2 on ebb tide. Currents up to 2.5 m/s have been reported.	1.1 MW

SITE NAME	LOCATION	VELOCITY/POWER DENSITY (OBSERVED OR TESTED)	TOTAL TISEC PROJECT RATED CAPACITY AT 15% ENERGY WITHDRAWAL*
Cowseagen Narrows	Wiscasset, ME	8.7 kW/m2 based on Coast Pilot reports of 2.5 m/s currents on flood and ebb, no modeling has been done. Some localized ADCP work was done in an area deep enough to support a turbine and a maximum of 2 m/s currents were measured. This work was relatively near shore, current may be faster toward the center of the narrows.	Not evaluated
Kennebec River Entrance	Bath, ME	1 kW/m2 flood, 1.7 kW/m2 ebb tide.	130 kW
Ewin Narrows	Harpswell, ME	No modeling or data	Not evaluated
Piscataqua River	Kittery, ME	3.3 kW/m2 flood, 5.9 kW/m2 ebb	1.0 MW
Knubble Bay	Bath, ME	.73 kW/m2 modeled 2 m/s currents	Not evaluated
Hackomock Bay	Bath, ME	1.747 kW/m2 modeled 2.6 m/s max currents based on model	Not evaluated
Half Moon Cove	Eastport, ME	No current data - Tidal range averages 20 feet	Not evaluated
Reversing Falls (Cobscook Falls)	Pembroke, ME	No current data - Tidal range averages 20 feet - Very strong currents observed on both flood and ebb tides.	Not evaluated
Cross Island Narrows	Cutler, ME	No Current Data	Not evaluated
Roque Island	Jonesport, ME	No Current Data - Tidal range of approximately 13 feet on average	Not evaluated
Moosabec Reach Bridge	Jonesport, ME	Strong tidal currents reported at the bridge site	Not evaluated
Eggomoggin Reach Bridge	Sargentville. ME	Tidal range of approximately 11 feet, no current data	Not evaluated
Damariscotta River	Damariscotta and Newcastle, ME	No velocity data, tidal range approximately 9 feet.	Not evaluated

* Note: This calculation assumes the project withdraws 15% of the Total Annual In-Stream Energy, converts it to electrical energy at an average power train efficiency of 80%, and that its average annual generated power is 40% of its total rated electrical capacity.

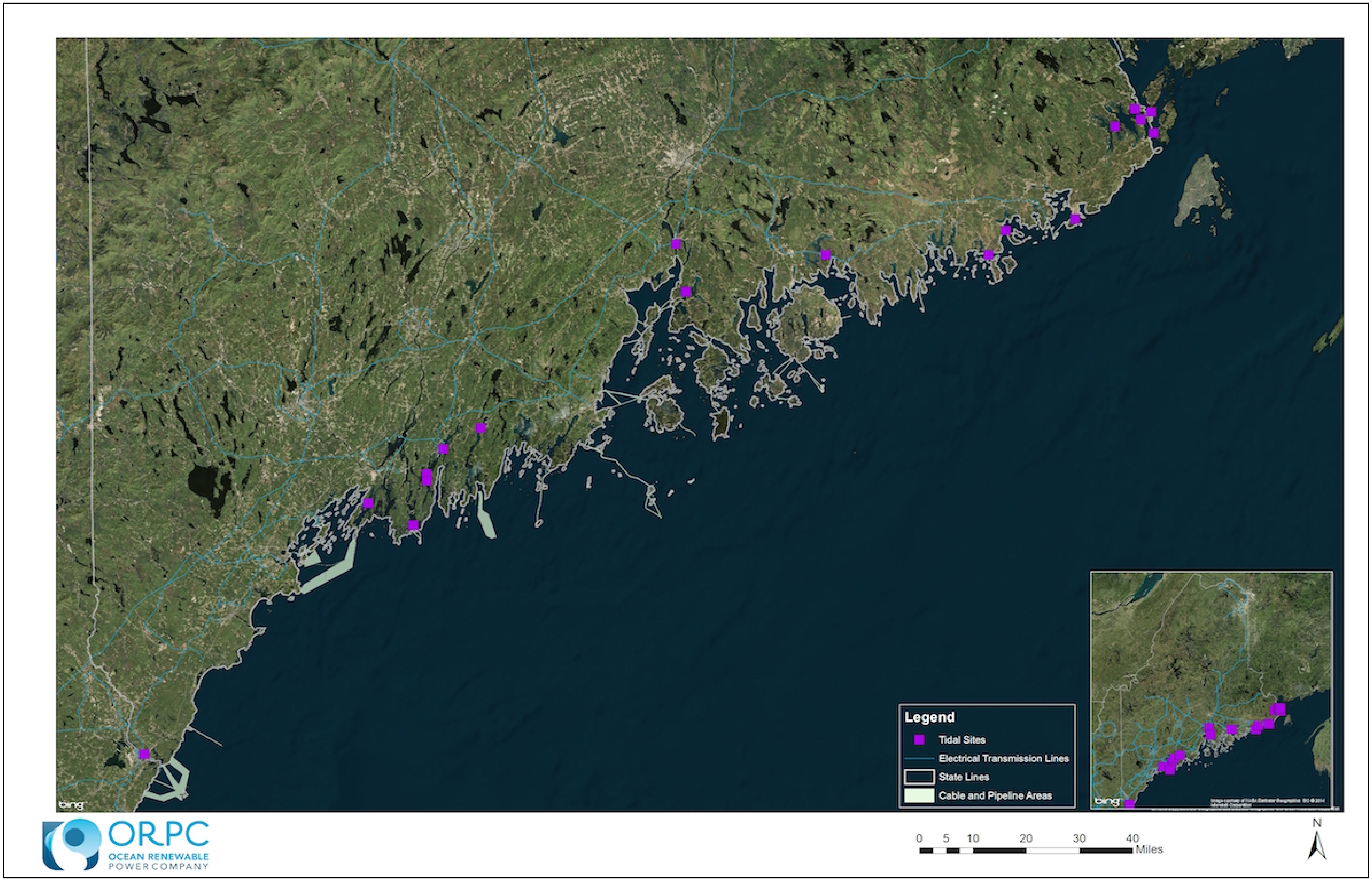


FIGURE 2-5. LOCATIONS OF POTENTIAL TIDAL ENERGY SITES ALONG THE COAST OF MAINE

2.2.3 Wave Energy Inventory Assessment

The inventory assessment of Gulf of Maine wave resource data was based on information obtained from oceanographic buoys and publically available reports of modeled wave power. Oceanographic buoys have been deployed in the Gulf for over ten years by multiple organizations involved in the regional ocean observing system for the Northeastern U.S. and Canadian Maritime provinces, including University of Maine (UMaine), the National Oceanic and Atmospheric Association (NOAA), and the Northeastern Regional Association of Coastal and Ocean Observing Systems (NERACOOS). Figure 2-6 and Figure 2-7 below show weekly average wave height (previous twelve months) as well as average wave periods for oceanographic buoys located south of Casco Bay (buoy 44007), south of Monhegan Island (buoy E01), and the southeast of Mount Desert Island (Buoy I01 – Eastern Shelf). These output criteria were selected because of their relative consistency with industry standards for wave resource assessment (period of time at a specified significant wave height and period) and their ability to broadly demonstrate the resource potential.[4]

Table 2-16. Identified Potential Wave Energy Sites

Site Name	Buoy Name	Buoy Data	Estimated Annual Power Density (Modeled)
Western Shelf (off Ogunquit)	B01	http://neracoos.org/datatools/realtime/all_data?platform=B01	2.9 kW/m
Casco Bay Region (off Cape Elizabeth)	44007	http://neracoos.org/datatools/realtime/all_data?platform=44007	2.6 kW/m
Monhegan Island	E01	http://neracoos.org/datatools/realtime/all_data?platform=E01	4.3 kW/m
Matinicus Rock	MISM1	http://neracoos.org/datatools/realtime/all_data?platform=MISM1	4.3 kW/m
Eastern Shelf (off Mt. Desert Is.)	I01	http://neracoos.org/datatools/realtime/all_data?platform=I01	5.2 kW/m
Jonesport	44027	http://neracoos.org/datatools/realtime/all_data?platform=44027	5.7 kW/m

[4] It should be noted that the NERACOOS buoys were located for generalized weather and ocean condition data collection and were not sited or designed specifically for resource assessment for wave energy projects.

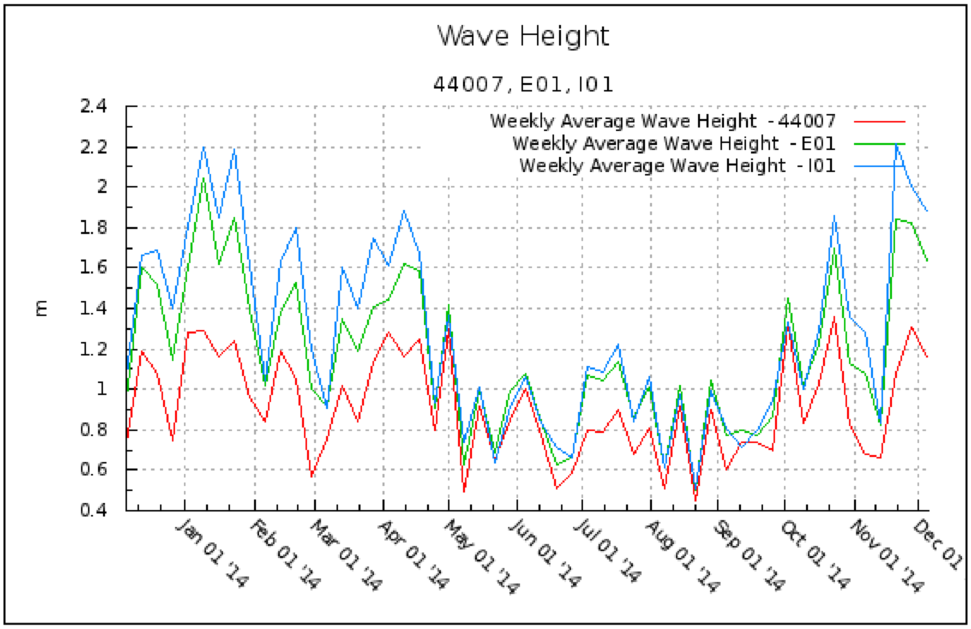


FIGURE 2-6. WEEKLY AVERAGE WAVE HEIGHT IN METERS.
Source: NERACOOS

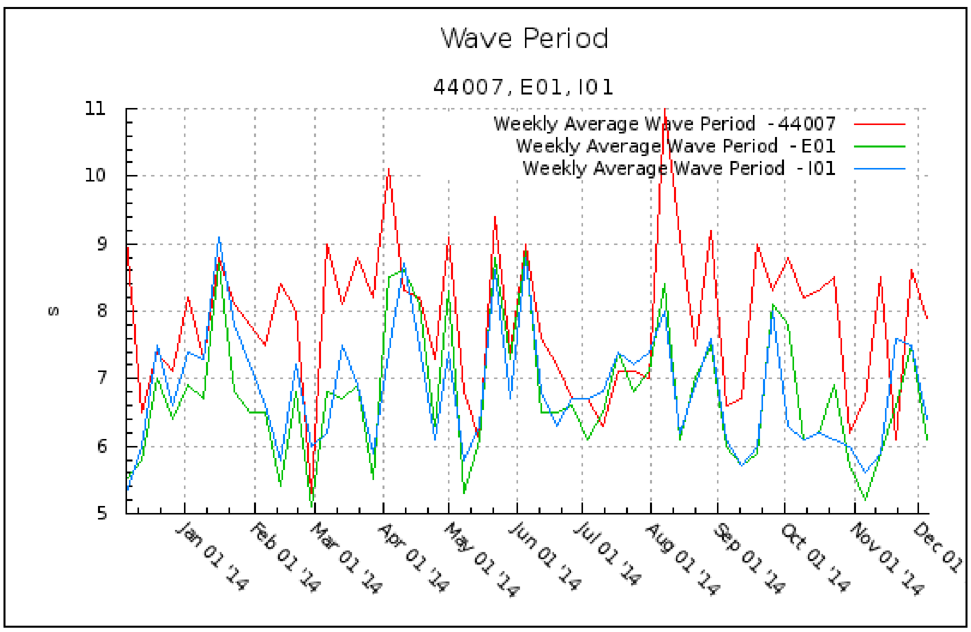


FIGURE 2-7. WEEKLY AVERAGE WAVE PERIOD IN SECONDS.
Source: NERACOOS

Preliminary analysis of the data indicated that there are offshore locations in federal waters (> 12 nautical miles) that experience significant wave heights (Hs) of over 1m for over 80% of the year while in-shore buoys analyzed near the identified sites of interest experienced significant wave heights of over 1m over 60% of the year although the data was limited (EPRI, 2004; NERACOOS).

In addition to point data from oceanographic buoys, an available hindcast model layer from the online MHK Atlas (http://maps.nrel.gov/mhk_atlas) was reviewed. The Wave Energy Resource Assessment project is a joint venture between National Renewable Energy Laboratory (NREL), EPRI, and Virginia Tech. Wave power density is the calculated kilowatts per meter of wave crest width at any given water depth. The model data indicates that wave power density increases from western to eastern portions of the coast, in agreement with the buoy data. Despite significant wave height in the Gulf of Maine being less than the U.S. west coast or portions of Europe, the consistency (less seasonal variation) of the resource is favorable towards early stage wave energy development and potentially lower levelized cost of energy (Clifford A. Goudey, 2015).

Based on the assessed resource data and as shown in Figure 2-8, the most promising areas in Maine include, but are not limited to, the following locations:

- Monhegan Island
- Matinicus Island
- Eastern Shelf (Isla au Haut, Swan's Island, Frenchboro)
- Casco Bay region

EPRI's system level design, performance, and costs assessment of a wave power plant off Old Orchard in 2004 concluded that development would not be economically viable based on the high cost of emerging wave technologies and the wave resource. However, a revision to the report provided additional information related to the viability of wave energy development in eastern Maine as described in the following excerpt:

> *Subsequent to completing the design study for the Old Orchard Beach site, new hindcast wave data for the Gulf of Maine became available from the U.S. Army Corps of Engineers. The Project Team (EPRI) evaluated this new data to see if there were other locations along the Maine coastline that would have a better wave energy climate and thus better economics.*
>
> *This analysis indicated that relative to Old Orchard Beach, wave energy fluxes may be 70-100% higher in similar water depths off Great Wass and Head Harbor Islands in Washington County, and 50-80% higher off the entrances to Penobscot Bay in Knox County. In unsheltered waters off Penobscot Bay, the output of a wave power plant might be 80% higher, which would translate to a 45% lower cost of energy compared with a similar plant off Old Orchard Beach.*

In addition to wave energy resource and site characterization, Maine communities with high costs of power were identified due to the potential for cost competitive development and initial market entry for wave energy technologies. Monhegan, Matinicus and other Maine islands experience high energy costs ranging from $0.30/kWh to over $0.70/kWh due to grid isolation and reliance on diesel fuel for electricity generation (Island Institute). On Monhegan Island, where the cost to rate payers has recently been over $0.70/kWh, the annual average electric load is approximately 35 kW, with an annual peak of 210 kW occurring during the summer. The total annual electric load is 330,000 kWh. In comparison, the Matinicus Plantation Electric Company sold 225,000 kWh of electricity at an average rate (including supply and distribution) of $0.65/kWh in 2010. Monhegan is currently undergoing a grid upgrade project sponsored by the federal government, in part, to better prepare the islands infrastructure to incorporate renewable energy.

An advantage of wave energy development at the Monhegan Island site is that it could fall within the approved regulatory boundary of the offshore wind project being developed by the University of Maine (UMaine.) A wave project could be associated with UMaine's potential offshore wind project, which would provide an opportunity to share certain infrastructure with UMaine, including the transmission line to Monhegan, while allowing a wave energy project access to vital site and environmental data collected to date. Another option would be to site a wave energy project adjacent to or in close proximity to the UMaine wind site (Figure 2-8).

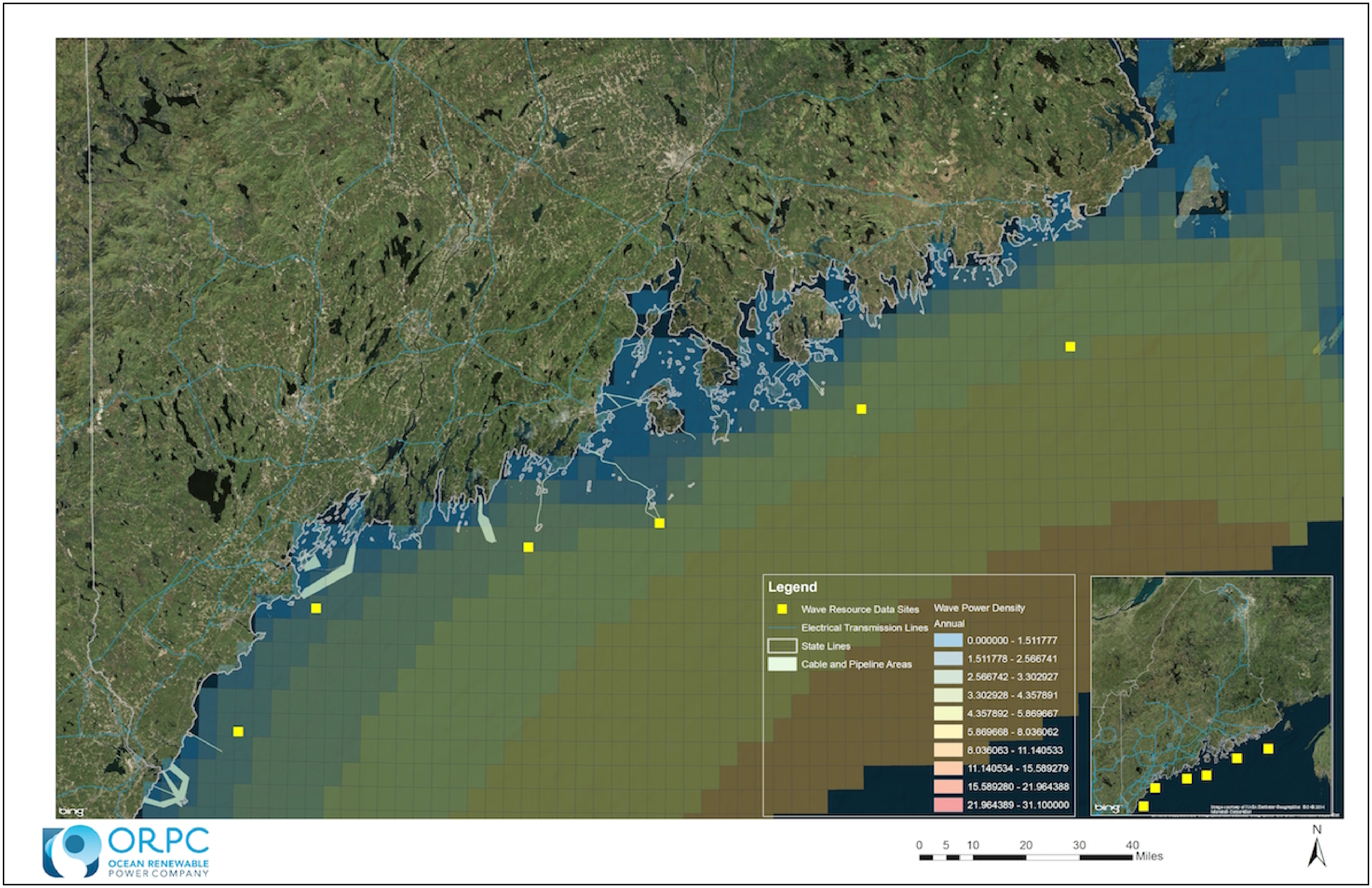


FIGURE 2-8. MAINE WAVE RESOURCE DATA

2.2.4 RIVER HYDROKINETIC RESOURCE ASSESSMENT

The hydrokinetic potential of river currents in Maine has, to date, been largely unexplored. Due to the anticipated fast, efficient, and ecologically benign deployment of hydrokinetic turbines compared to traditional hydropower projects, this technology is ideal for places like Maine, which possess large rivers with considerable hydropower potential. The nature of this hydrokinetic technology requires an adaptation of conventional project engineering, development, and environmental monitoring approaches. In addition to site characterization as previously described for tidal and wave energy project, rivers sites pose unique challenges and opportunities (such as base load potential). For this assessment, the following site development criteria for river hydrokinetic development were considered:

- River profile: average width, depth (this enables the conversion from volumetric flow rate to average velocity)
- River bed material
- Seasonal ice conditions, as applicable (ice in/out)
- Potential for heavy debris
- Seasonal river height/flow fluctuations

2.2.4.1 METHODOLOGY

Potential sites for most hydrokinetic technology providers include those river reaches that are a minimum of 10 meters long, where velocities are at least 2 meters per second (approximately 4 knots or 6.75 feet per second), have a minimum river depth of 5 meters, and a minimum width of 45 meters. Technologies that capture lower flow velocities are in development but few if any are commercially available at this time.

Available river data were derived from available, existing resources including hydrological data, topographical maps, navigation charts, satellite images and digital elevations models, and were evaluated to determine potential locations for hydrokinetic development. Due to a lack of historical velocity data from Maine rivers, site specific development potential is difficult without quantitative measurement of the resource (typically a volumetric flow rate/discharge rate is recorded versus velocity). Notwithstanding the absence of velocity data, the following methodology was utilized to inventory potential sites in Maine:

- USGS Stream Gage info in the State was accessed from http://waterdata.usgs.gov/nwis/inventory.
- Gages at river or stream locations with drainage areas greater than 500 square miles were evaluated. Larger drainage areas contribute to greater flows and site characteristics that are conducive to potential hydrokinetic site development.
- Average velocity data was developed from USGS field measurements. It should be noted that velocity data is opportunistic based and may not be at the gage itself. A mean (average) velocity for each site was calculated based on historical measurements.
- Due to the current state of hydrokinetic technologies, only rivers with average annual velocities greater than 0.75 m/s were prioritized.

Table 2-17 summarizes Maine river sites identified with drainage areas greater than 500 square miles. Sites are listed from highest to lowest mean velocity. Locations are shown on Figure 2-9.

TABLE 2-17. IDENTIFIED RIVER HYDROKINETIC SITES

SITE NAME	USGS GAGE	AVERAGE VELOCITY (M/S)*	DRAINAGE AREA (SQUARE MILES)
Kennebec River at The Forks, Maine	01042500	1.06	1,590
Penobscot River at Eddington, Maine	01036390	0.90	7,515
Kennebec River near Madison, Maine	01047150	0.86	3,245
Kennebec River at Moosehead, Maine	01041000	0.83	1,268
Androscoggin River at Rumford, Maine	01054500	0.82	2,068
Penobscot River at West Enfield, Maine	01034500	0.81	6,422
St. John River below Fish River, near Fort Kent, Maine	01014000	0.79	5,929
Kennebec River near Waterville, ME	01049205	0.78	5,179
Kennebec River at North Sidney, Maine	01049265	0.77	5,403
St. John River at Dickey, Maine	01010500	0.76	2,680
Androscoggin River near Auburn, Maine	01059000	0.75	3,263
Allagash River near Allagash, Maine	01011000	0.73	1,478
Kennebec River at Bingham, Maine	01046500	0.73	2,715
Sebasticook River near Pittsfield, Maine	01049000	0.73	572
Aroostook River at Washburn, Maine	01017000	0.70	1,654
Fish River near Fort Kent, Maine	01013500	0.67	873
Mattawamkeag River near Mattawamkeag, Maine	01030500	0.65	1,418
Sandy River near Mercer, Maine	01048000	0.65	516
Saco River at Cornish, Maine	01066000	0.64	1,293
West Outlet Kennebec River near Rockwood, ME	01041100	0.62	1,268
Dead River near Dead River, Maine	01043500	0.60	516

SITE NAME	USGS GAGE	AVERAGE VELOCITY (M/S)*	DRAINAGE AREA (SQUARE MILES)
Piscataquis River at Medford, Maine	01034000	0.59	1,162
St. Croix River at Baring, Maine	01021000	0.59	1,374
Aroostook River near Masardis, Maine	01015800	0.57	892
East Branch Penobscot River at Grindstone, Maine	01029500	0.51	837
St. John River at Ninemile Bridge, Maine	01010000	0.49	1,341
Presumpscot River at Westbrook, Maine	01064118	0.42	577
Penobscot River near Mattawakeag, ME	01030000	NA	3,107

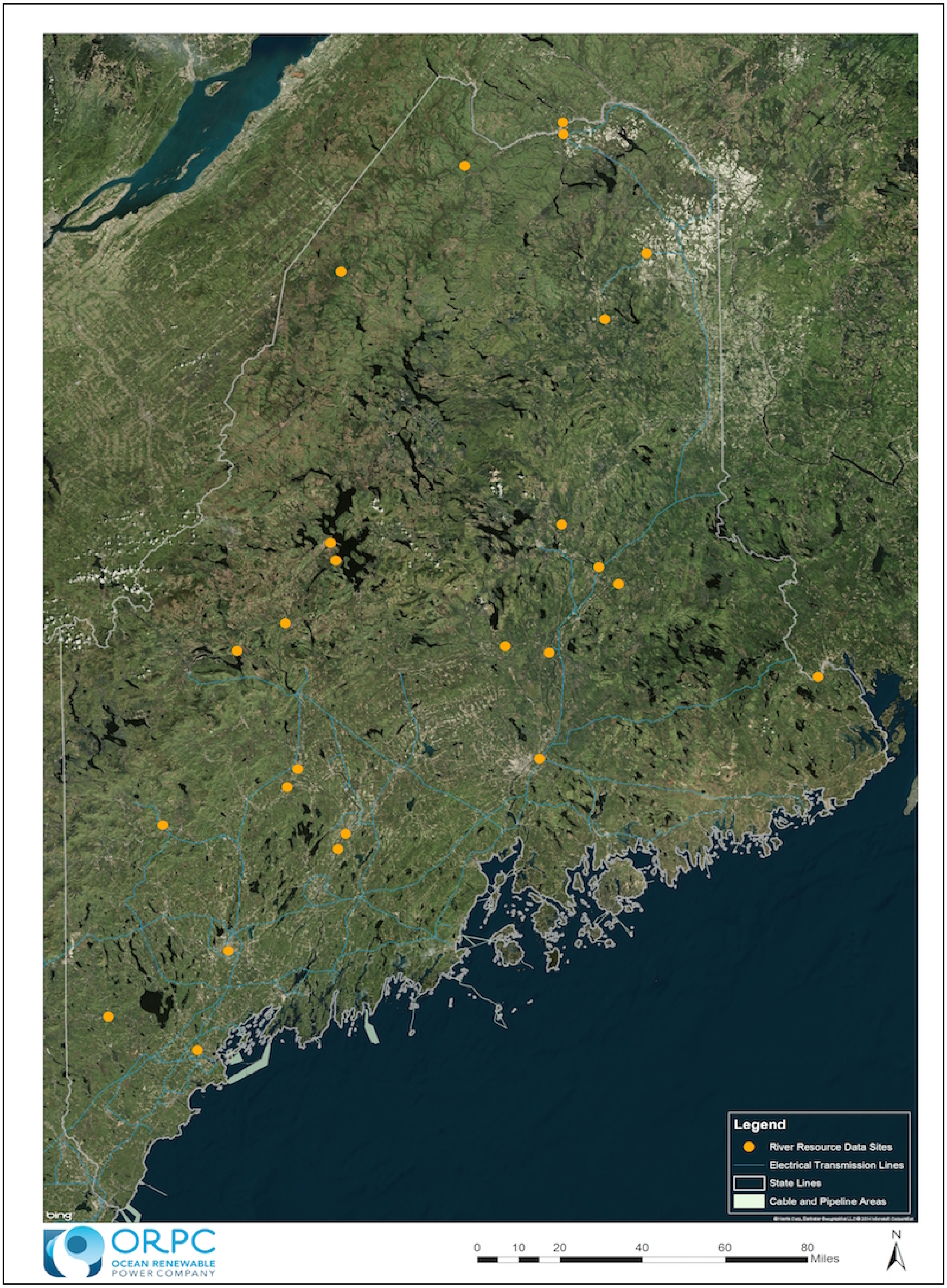


FIGURE 2-9. LOCATION OF IDENTIFIED RIVER KINETIC PROJECTS

The raw inventory of potential hydrokinetic sites and associated flow and velocity data confirm the highly variable nature of Maine's rivers. Flow and velocities tend to be greatest during the spring and fall at which times measured velocities at multiple sites has been shown to exceed 3 m/s. Figure 2-10 shows the variability of discharge for the Kennebec River at the Forks from 2010 to 2012. In addition, river flow in many Maine rivers is highly influenced by hydropower or flood control dams. For example, Figure 2-11 depicts the daily fluctuation in flow at the Forks that results from the operation of the Harris Station Dam. Potential river hydrokinetic development in the State should take flow fluctuations into account to determine periods when generation will not be feasible.

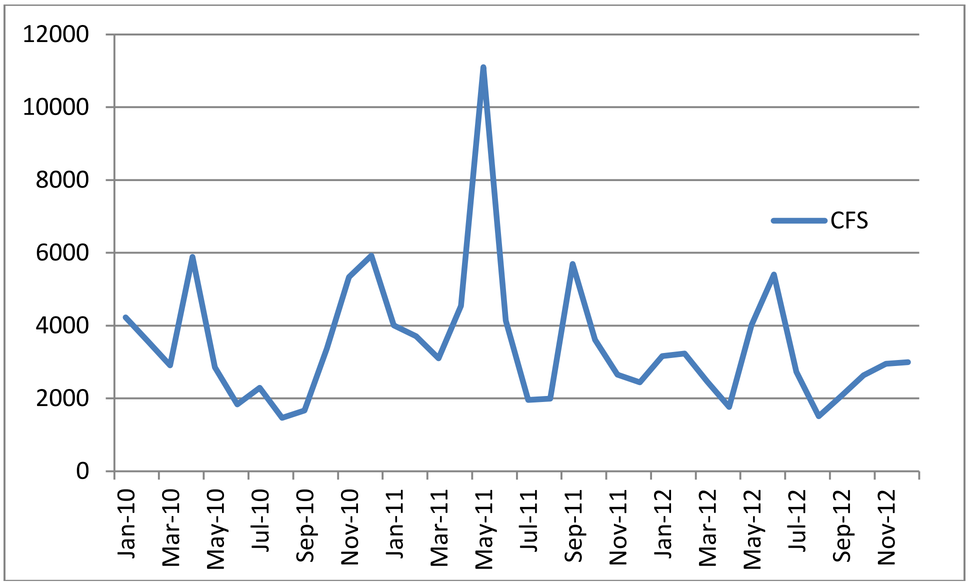


FIGURE 2-10. MONTHLY DISCHARGE (CFS) AT USGS GAGE 01042500, KENNEBEC RIVER AT THE FORKS (2010-2012).

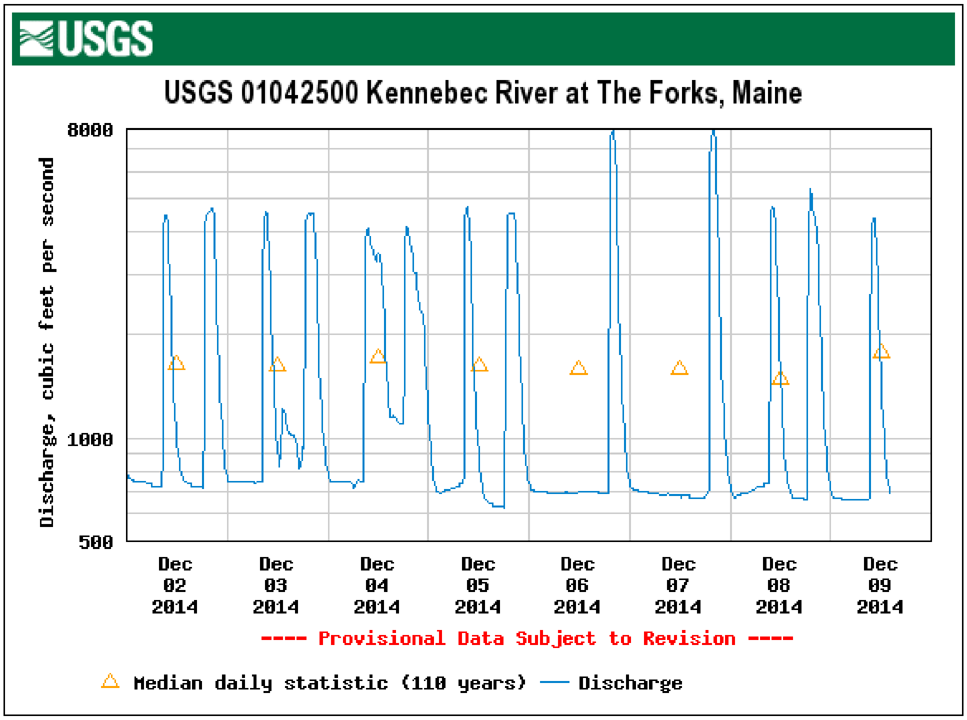


FIGURE 2-11. DAILY DISCHARGE (CFS) AT USGS GAGE 01042500, KENNEBEC RIVER AT THE FORKS.

2.2.5 Marine and Hydrokinetic Technologies

There are a multitude of hydrokinetic technologies, many of which are still in development. For this study, the following proprietary and commercially available hydrokinetic technologies were identified to represent a wide range of energy conversion devices. Technologies range in suitability for specific sites, are rated at various output capacities, and are in various stages of commercialization. Due to the emerging status of the industry levelized cost of energy from these technologies is currently high but expected to decline rapidly as the market matures.

2.2.5.1 Tidal Technologies

2.2.5.1.1 Cross-flow

Ocean Renewable Power Company, LLC (U.S.)

Ocean Renewable Power Company (ORPC), a Maine-based company, develops hydrokinetic power systems and has developed three versions of its patented power system—all designed around its proprietary turbine generator unit, or TGU: the TidGen® Power System for use at shallow to medium-depth (50 to 150 ft) tidal energy sites, OCGen® Power System for use at deeper tidal and offshore ocean current sites, and RivGen® Power System for use at river and estuary sites near remote communities that currently rely on high cost diesel generation or have no electricity.

ORPC built and delivered power to the grid from the first commercial, Federal Energy Regulatory Commission (FERC)-licensed, grid-connected hydrokinetic tidal energy project in the Americas in 2012. The company has a 20-year power purchase agreement with Emera Maine.

2.2.5.1.2 VERTICAL AXIS

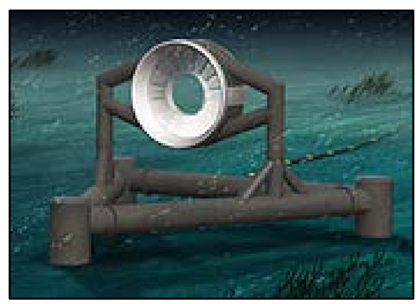
Verdant Power, LLC (U.S.)

Verdant Power has developed an underwater horizontal-axis three-bladed turbine, similar to a wind turbine, that is designed to capture energy from tidal and river currents. In 2012, FERC issued a pilot project commercial license for the East River Project. Under the license, Verdant Power will develop a 1 MW pilot project in the East Channel of the East River comprised of up to 30 commercial class Generation 5 (Gen5 KHPS) turbines.

The U.S. Trade and Development Agency awarded Verdant a grant to study the feasibility of installing a Verdant Power KHPS downstream of the Seyhan hydropower plant, near the city of Adana, Turkey.

2.2.5.1.3 DUCTED

OpenHydro Group Ltd. (Ireland)



Open Hydro manufactures and installs of tidal energy systems. OpenHydro's tidal energy device consists of a single piece rotor integrated with a permanent magnet generator contained within a duct-shaped housing.

Open Hydro plans to install a device in 2015 the Bay of Fundy at the FORCE test site in Minas Basin, Nova Scotia. OpenHydro is also active in France.

2.2.5.2 WAVE ENERGY TECHNOLOGIES

2.2.5.2.1 NEAR SHORE

Resolute Marine Energy (USA)

Resolute Marine Energy (RME) builds and sells smaller-scale, wave-driven power devices (1-50kW) that are used in commercial applications such as open-ocean aquaculture, seawater desalination and ocean observation systems. RME designed its proprietary SurgeWEC™ device specifically to be deployed in the near-shore environment to maximize access to the available energy flux and to minimize energy transmission costs. SurgeWEC™ belongs to a class of WEC devices called oscillating wave surge converters (OWSC). OWSCs are relatively simple machines comprising two principal components: a flap that rotates about a hinge in response to wave excitations, and a power take-off (PTO) device that converts flap movements into a more useful form of energy e.g. electricity or, in the case of SurgeWECTM, pressurized seawater.

The company owns subsidiaries in Ireland and South Africa.

2.2.5.2.2 MID TO DEEP WATER

Fred.Olsen (UK and Norway)

Fred.Olsen's Bolt Lifesaver™ is a point absorber WEC, capturing the energy of waves and converting it into electricity. The Bolt Lifesaver was successfully installed in 2012 at the marine device test site, FaBTest, Falmouth UK. The company plans to move Lifesaver to the Hawaiian island of Oahu in 2015.

Ocean Power Technologies, Inc. (USA)

Ocean Power Technologies (OPT) proprietary PowerBuoy® technology captures wave energy using large floating buoys anchored to the sea bed and converts the energy into electricity. The first utility-scale Mark 3 PowerBuoy, fabricated in Scotland, was deployed in 2011 off the Eastern coast of Scotland for ocean trials.

The company intends to deploy its PB40 PowerBuoy® off the coast of New Jersey in 2015.

2.2.5.3 RIVER HYDROKINETIC TECHNOLOGIES

2.2.5.3.1 CROSS-FLOW

Ocean Renewable Power Company, LLC (U.S.)

ORPC's RivGen® Power System generates electricity either with direct power grid connection or in remote communities with isolated power grids. Its core component is the turbine generator unit (TGU), which utilizes innovative control systems to drive two advanced design cross-flow turbines that efficiently provide reliable energy even within highly turbulent flow environments.

ORPC successfully installed and operated the RivGen® TGU in 2014 in Igiugig, AK, a community with high electrical costs due to reliance on diesel fuel generators, and the community and ORPC will partner on another deployment of the device in 2015.

2.2.5.3.2 VERTICAL AXIS

Verdant Power, LLC (U.S.)

Verdant completed a demonstration project at the Roosevelt Island Tidal Energy Project in New York City's East River in 2006-2009. In 2012, FERC issued a pilot project commercial license for the East River Project. Under the license, Verdant Power will develop a 1 MW pilot project in the East Channel of the East River comprised of up to 30 commercial class Generation 5 (Gen5 KHPS) turbines, which would be installed in phases.

2.2.5.3.3 DUCTED

Smart Hydro Power GmbH (Germany)

Smart Hydro Power (SHP manufactures a three-bladed rotor, a 5 kW generator SHP has installed its turbines in Switzerland, Brazil, India, Germany, Nigeria and Colombia.

2.2.6 SITE PRIORITIZATION

2.2.6.1 METHODS

A modified version of an ocean energy site characterization model developed by the Pacific Northwest National Laboratory (PNNL), and contributed to by ORPC, was utilized to prioritize project development opportunities in the State of Maine. To support the State of Washington's marine spatial planning efforts, PNNL was asked to conduct a spatial analysis of basic siting factors to determine where marine renewable energy development may be feasible on the Washington coast. The scope includes ocean energy projects that would commence to a planning or feasibility phase within the next five to seven years.

This study uses a multi-criteria decision analysis framework of weighted additive algorithms to evaluate site suitability. Attributes of suitability used in the analysis represented fundamental economic and technical feasibility considerations and included energy potential, water depth, proximity to shore, ports, and transmission infrastructure.

Conceptual models were developed to organize attributes of suitability. Available literature and expert advisors familiar with the industry, technologies, and devices informed the application of scores and weights to attributes for each model. Additive algorithms enabled a numerical translation of composite suitability that could then be represented spatially in a geographic information system.

For the purpose of this Maine assessment, some model attributes were modified to adjust for Maine's coastline and port infrastructure. In addition, higher weighting was placed on the Site Quality sub-model with a particular emphasis on the hydrokinetic resource.

Due to the lack of information available for river hydrokinetic sites prioritization was made solely on mean velocity.

2.2.6.2 RESULTS

Prioritized marine hydrokinetic site locations are shown in Table 2-18, Table 2-19, and Table 2-20. Prioritized marine hydrokinetic site locations are shown on Figure 2-12, Figure 2-13, and Figure 2-14.

TABLE 2-18. PRIORITIZED POTENTIAL TIDAL ENERGY SITES

SITE	DESCRIPTION
Lubec Narrows	Flows have been measured in excess of 4 m/s with an estimated project capacity of 1.2 MW. Opportunities may be available to incorporate projects into infrastructure development at the bridge site. Addition measurements of resource recommended.
Cobscook Bay	Flows have been measured in excess of 2.5 m/s with an estimated project capacity of 7.1 MW. Existing tidal energy infrastructure offers opportunities for build out and additional product testing.
Western Passage	Flows have been measured in excess of 3 m/s with an estimated project capacity of 10.8 MW.
Piscataqua River	Flows have been measured in excess of 2 m/s with an estimated project capacity of 1.0 MW. Opportunities may be available to incorporate projects into infrastructure development at multiple bridge sites.
Cowseagen Narrows	Flows greater than 2.5 m/s have been reported. Some resource measurements have been made but other potential sites in the area, including the southern end of Westport Island are largely uncharacterized. Addition measurements of resource recommended.
Moosabec Reach	Strong tidal currents have been reported at the bridge site but the resource has not been measured. Opportunities may be available to incorporate projects into infrastructure development at the bridge site. Measurements of resource recommended.

TABLE 2-19. PRIORITIZED POTENTIAL WAVE ENERGY SITES

SITE	DESCRIPTION
Monhegan Island	Estimated annual power density of 4.3 kW/m, opportunities to address community with high cost or power, State designated test area with detailed site information.
Matinicus Island	Estimated annual power density of 4.3 kW/m, opportunities to address community with high cost or power.

TABLE 2-20. PRIORITIZED RIVER HYDROKINETIC SITES

Site	Description
Kennebec River at The Forks[5]	Mean velocity estimated at 1.06 m/s. Additional resource and site characterization recommended.
Penobscot River at Eddington	Mean velocity estimated at 0.90 m/s. Additional resource and site characterization recommended.
Kennebec River near Madison	Mean velocity estimated at 0.86 m/s. Additional resource and site characterization recommended.
Kennebec River at Moosehead	Mean velocity estimated at 0.83 m/s. Additional resource and site characterization recommended.
Androscoggin River at Rumford	Mean velocity estimated at 0.82 m/s. Additional resource and site characterization recommended.
Penobscot River at West Enfield	Mean velocity estimated at 0.81 m/s. Additional resource and site characterization recommended.

[5] AA water classification could prohibit development

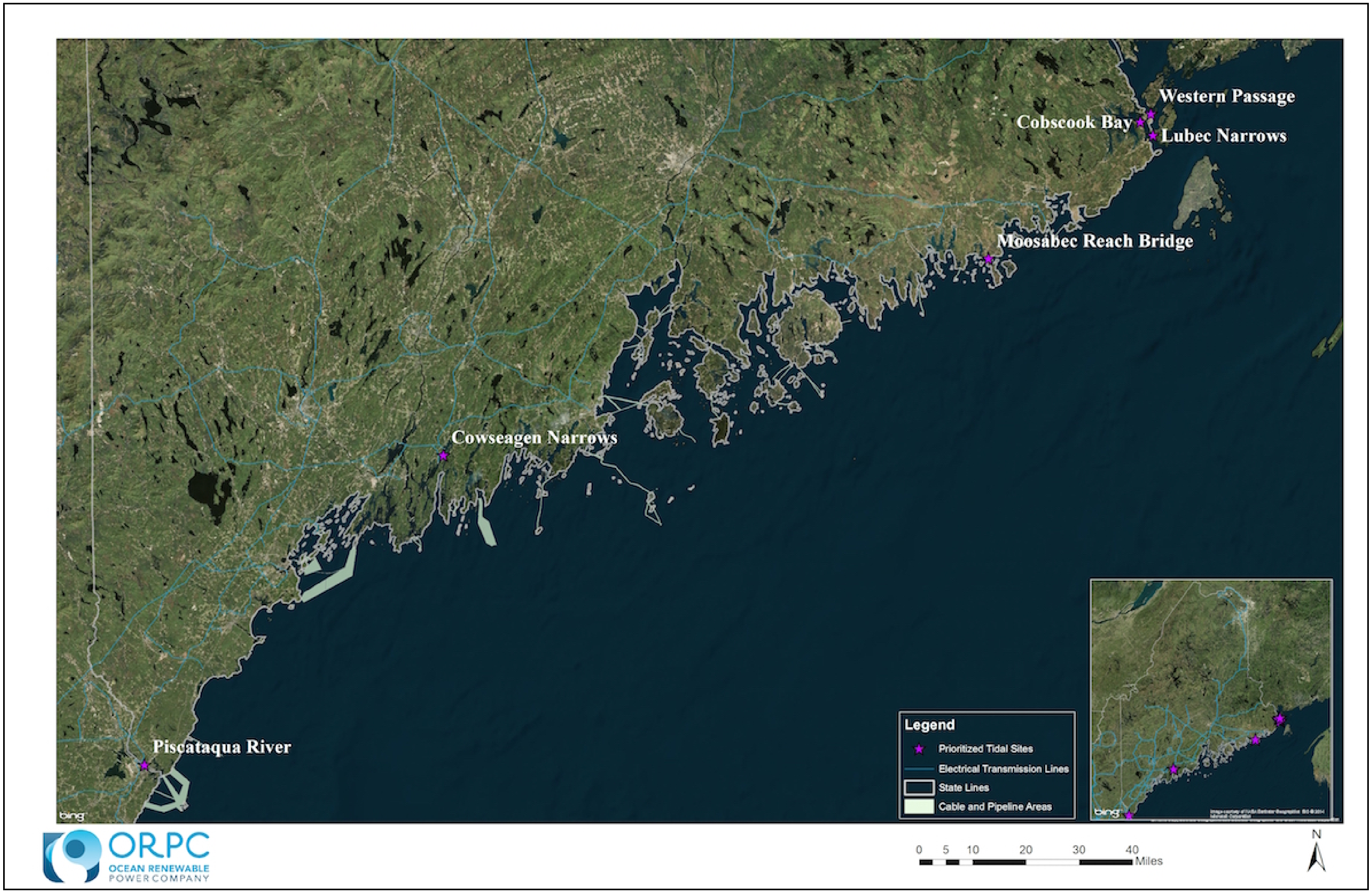


FIGURE 2-12. LOCATION OF PRIORITIZED TIDAL SITES

FIGURE 2-13. LOCATION OF PRIORITIZED WAVE SITES

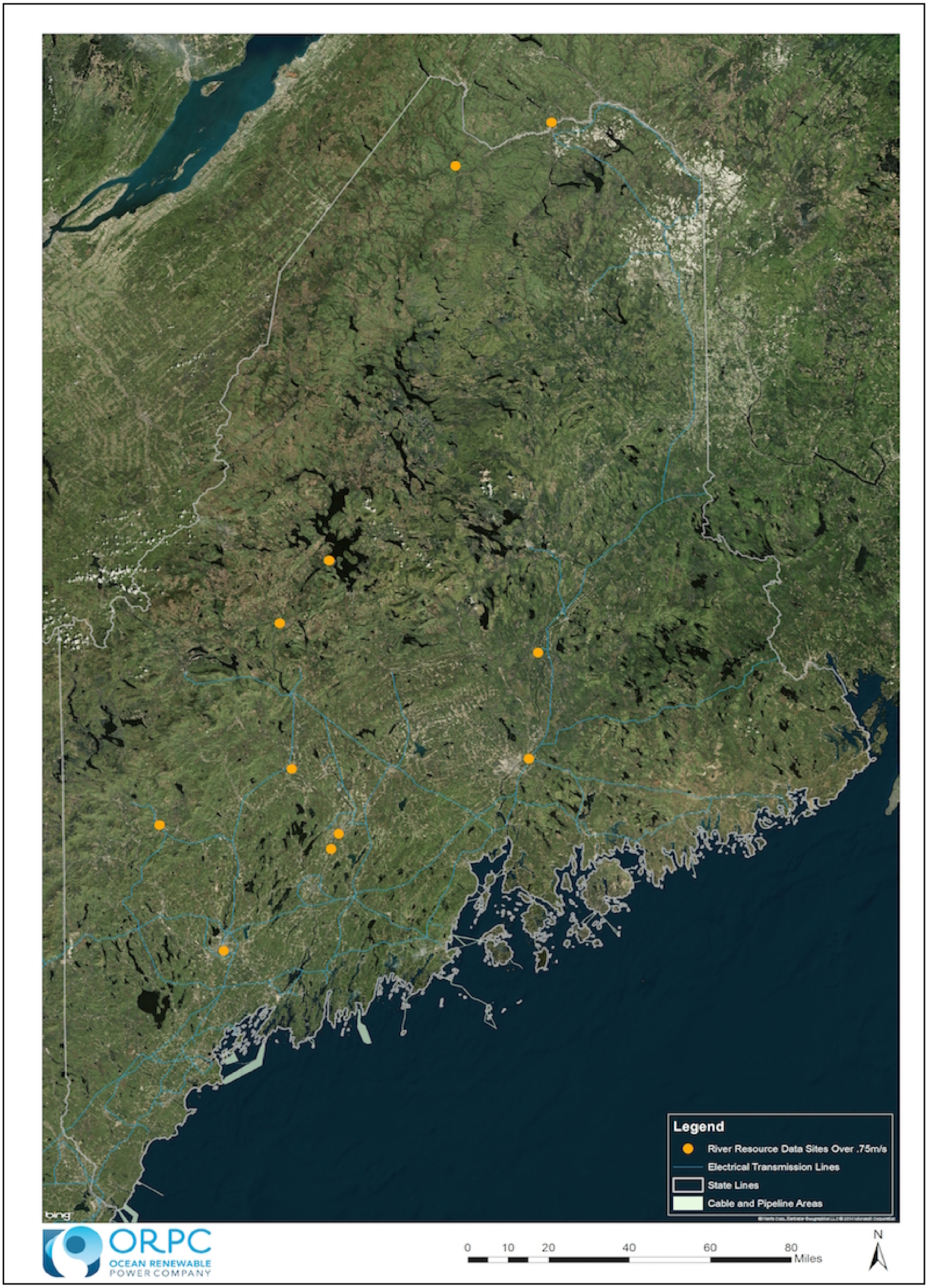


FIGURE 2-14. LOCATION OF PRIORITIZED RIVER SITES.

3.0 ASSESSMENT OF REGULATORY ENVIRONMENT

Hydropower projects in Maine are subject to regulation under several federal and state laws. Individually these laws protect important public resources, but the interaction of these laws creates a very complex regulatory environment that makes licensing hydropower projects a relatively long and costly process, particularly when compared to other forms of generation. For owners of hydropower projects, the FERC licensing process often represents a significant capital and operation and maintenance investment that can potentially render a project non-viable.

As seen in Table 3-1, in Maine the FERC licenses for four projects have already expired and the projects have been operating on annual licenses ever since, pending issuance of new licenses.

TABLE 3-1. FERC PROJECTS IN MAINE WITH EXPIRED LICENSES

FERC NO.	PROJECT NAME	LICENSE EXPIRATION	CAPACITY (KW)	RIVER
2660	Forest City (Storage)	08/31/00	-	East Branch St. Croix River
2618	West Branch (Storage)	09/29/00	-	West Branch St. Croix River
2984	Eel Weir	03/31/04	1,800	Presumpscot River
2615	Brassua	03/31/12	4,180	Moose River

In addition, as shown in Table 3-2, 31 projects, totally 349 MW or nearly half of all licensed capacity in Maine, have licenses expiring in the next 15 years.

TABLE 3-2. FERC PROJECTS IN MAINE WITH LICENSES EXPIRING 2015-2030

FERC NO.	PROJECT NAME	LICENSE EXPIRATION	CAPACITY (KW)	RIVER
2492	Vanceboro (Storage)	03/01/16	-	East Branch St. Croix River
2335	Williams	12/31/17	13,000	Kennebec River
2531	West Buxton	12/31/17	7,812	Saco River
2727	Ellsworth Graham	12/31/17	8,900	Union River
2520	Mattaceunk	08/31/18	19,200	Penobscot River
2808	Barker's Mill	01/31/19	1,500	Little Androscoggin River
2809	American Tissue	04/30/19	1,000	Cobbosseecontee Stream
12711	Cobscook Bay Tidal Energy	01/31/20	300	Cobscook River
2804	Goose River	02/29/20	375	Goose River
2322	Shawmut	01/31/21	8,740	Kennebec River
2368	Squa Pan	12/03/21	1,500	Squa Pan Stream
5362	Lower Mousam	03/31/22	600	Mousam River
4784	Pejepscot	08/31/22	13,880	Androscoggin River
2530	Hiram	11/30/22	10,500	Saco River
3562	Barker Mill Upper	07/31/23	950	Little Androscoggin River
4202	Lowell Tannery	09/30/23	1,000	Passadumkeag R
7189	Green Lake	03/31/24	500	Reeds Brook
2600	West Enfield	05/31/24	13,000	Penobscot River
6398	Hackett Mills	08/31/24	485	Little Androscoggin River

FERC No.	PROJECT NAME	LICENSE EXPIRATION	CAPACITY (KW)	RIVER
2333	Rumford Falls	09/30/24	44,500	Androscoggin River
4026	Aziscohos	03/31/25	5,311	Magalloway River
3428	Worumbo	11/30/25	19,100	Androscoggin River
2302	Lewiston Falls	08/31/26	36,354	Androscoggin River
11006	Upper Androscoggin	08/31/26	1,695	Androscoggin River
2458	Penobscot Mills	09/30/26	70,810	W Br Penobscot R
2572	Ripogenus	09/30/26	37,530	W Br Penobscot R
11132	Eustis	11/30/26	250	N.Br.Dead River
2284	Brunswick	02/28/29	19,000	Androscoggin River
2666	Medway	03/31/29	3,440	West Branch Penobscot River
2528	Cataract	11/30/29	6,650	Saco River
9340	Kezar Falls Lower	09/30/30	1,000	Ossipee River

3.1 FERC PRELIMINARY PERMITS

For developers examining a completely new site for hydropower, FERC issues preliminary permits. The developer must file an application for such a permit, which includes a basic description of the site and the conceptual hydropower project. FERC then publically notices and processes the application. Preliminary permits can be issued for up to three years, with a potential for a two year extension. Permits cannot be transferred and are not authorization for construction; they simply secure priority of the permittee’s application, allowing the permittee to study to site and to prepare for a subsequent FERC license or exemption process. During the permit term the permittee will be expected to demonstrate due diligence and is required to file regular status reports at six month intervals.

Preliminary permits are not required for FERC licenses, and are certainly not guarantees that the permittee will be issued a license or exemption, but do provide an important level of security for developers investigating a new hydropower site or new hydro technology. As of January 2015, Maine has only one active FERC preliminary permit, for the Pennamaquan Tidal Power Plant (FERC NO. 13884), issued on September 25, 2014.

3.2 FERC LICENSING

Most privately-owned hydroelectric projects in the United States are licensed by FERC under the Federal Power Act (FPA), with license terms of 30 to 50 years. Upon expiration of the license, the new owner must relicense the project. FERC licensing—whether licensing a new project or relicensing an existing project—is an expensive, multi-year process that requires a minimum of

3–5 years, with many licensing processes requiring even more time. Relicensing must begin 5 to 5½ years prior to the expiration of the existing license, and an application for a new license must be filed with FERC 2 years prior to the expiration of the existing license.

The purpose of the FERC licensing process is to develop a complete description of the proposed project, the surrounding environment, and to assess the effects of the project on existing resources such as water quality, fisheries, recreation, wildlife and botanical resources, cultural resources, endangered species, and in some instances socioeconomics. Licensing is a public process that requires consultation with federal and state agencies, Indian tribes, federal, regional, and local Non-Governmental Organizations, and other interested stakeholders. The process allows these entities input to suggest issues to be studied during the process. At the end of the process all consultation materials and new information developed during the licensing are submitted to FERC as a license application.

FERC then conducts an environmental analysis in accordance with the federal National Environmental Policy Act (NEPA). Using the NEPA guidelines and the FPA FERC considers the power and non-power issues associated with the proposed project. If FERC decides to license the project, it may issue a new license with terms and conditions that establish how the project will be operated as well as any protection, mitigation, or enhancement measures that must be undertaken to address adverse effects to surrounding resources. (Exempt projects, discussed in Section 1.2.2, follow a similar process.)

FERC develops its license conditions based on an independent review of the merits of the project. In addition to the conditions it imposes, FERC is required to incorporate some licensing provisions ("mandatory conditions") required by resource agencies. FERC must incorporate in the license provisions required by specified state agencies under Section 401 of the Clean Water Act (water quality), and specified federal agencies under FPA Sections18 (fishway prescriptions) and 4(e) (use of federal lands), and Section 7 of the Endangered Species Act. The Advisory Council on Historic Preservation under Section 106 of the Historic Preservation Act (Cultural Resources) has a strong influence on FERC's licensing decisions but they do not have mandatory conditioning authority. Generally speaking, the mandatory conditioning agencies do not need to take the economics of a condition into account when making its decision.

TABLE 3-3. FEDERAL LAWS AFFECTING HYDROPOWER PROJECTS

LAW	YEAR ENACTED
Rivers and Harbors Act	1899
Federal Power Act (FPA)	1920
Fish and Wildlife Coordination Act	1934
National Historic Preservation Act (NHPA)	1966
Wild and Scenic Rivers Act	1968
National Environmental Policy Act (NEPA)	1969
Clean Water Act (CWA)	1972
Coastal Zone Management Act (CZMA)	1972
Endangered Species Act (ESA)	1973
Americans with Disabilities Act	1990

3.2.1 SECTION 401 WATER QUALITY CERTIFICATION

Section 401 of the Clean Water Act (CWA) requires certification by authorized state agencies that Federal licensing actions will not result in violation of state water quality standards. Thus, Projects must receive a §401 water quality certification (WQC) or waiver in order to obtain a FERC license. If agencies do not issue §401 certification within one year of the applicant's request, then certification is deemed waived under the FPA. If they do issue a§401 certification, FERC must adopt all of the conditions of the §401 certification into the project license.

In Maine, the Maine Department of Environmental Protection (MDEP) has 401 certification authority. Maine has historically had a fairly broad interpretation of powers under the Clean Water Act, and its past §401 certifications have included provisions beyond strict water quality, including requirements for construction of recreation facilities, minimum bypass flow releases, and requirements for downstream fish passage. The basis for expanding their 401 conditions beyond those necessary to attain numerical standards is found in the narrative standards of the Clean Water Act that require protection of "designated uses" (i.e., fishing, swimming, etc.). These expanded conditions have been upheld through legal challenge.

3.2.2 SECTION 18 FISHWAY PRESCRIPTIONS

The Department of Interior (DOI) and the Department of Commerce (DOC) have the authority to prescribe fishways as part of project licensing or relicensing under §18 of the FPA. As with §401, FERC must incorporate these prescriptions in the license. The DOI's prescriptive authority is delegated to the USFWS and DOC's authority is delegated to NOAA Fisheries.

3.2.3 SECTION 7 ENDANGERED SPECIES ACT CONSULTATION

Under Section 7 of the Endangered Species Act (ESA), DOI and DOC, through the USFWS and NOAA Fisheries, respectively, have the responsibility to ensure that projects are not likely to impact threatened, rare or endangered species (known collectively as "listed" species) of plants or animals. In Maine three fish species potentially occurring at hydropower projects have been listed under ESA: Atlantic salmon, Atlantic sturgeon, and shortnose sturgeon. A fourth species, American eel, is currently under review for listing.

3.2.4 SECTION 106 CULTURAL RESOURCES COORDINATION

The National Historic Preservation Act (NHPA) requires that federal licensing actions take into account whether the federal licensing decision will adversely impact historic or cultural resources. (Historic and cultural resources include both historic structures, such as powerhouses and dams, and archaeological resources, such as Native American and Euro-American archaeological sites.) In each state, the NHPA is administered by the State Historic Preservation Officer (SHPO) and the Tribal Historic Preservation Officer (THPO), when applicable. In Maine, the SHPO is the Maine Historic Preservation Commission (MHPC). The Advisory Council on Historic Preservation is the federal entity that reviews cultural recommendations made by the FERC.

The Maine SHPO routinely determines whether or not project licensing or relicensing will have "no effect" or "no adverse effect" on cultural resources eligible for listing in the National Register of Historic Places. This allows FERC to issue licenses without further consultation with the ACHP in instances where there is "no effect" or "no adverse effect." FERC requires that all projects develop a project-specific Historic Properties Management Plan (HPMP), which then becomes a condition of the new license. The HPMP dictates the protection and management of eligible cultural resources known at the time of licensing as well as cultural resources discovered during the term of the license. Overall costs of these HPMPs are generally not prohibitive, but can affect the overall economics of a project. On the other hand, the cost of some cultural resource assessments can be one of the most expensive of the licensing studies conducted.

3.2.5 MAINE REGULATORY ENVIRONMENT

In part due to the large number of hydropower projects as well as the long history of hydropower development within the state, the regulatory environment in Maine is fairly complex and requires extensive consultation with many different participants, including numerous state and federal agencies, Indian tribes, Non-Governmental Organizations (NGOs), and members of the public. Each participant has a different priority or agenda and has an opportunity to provide input throughout the multiyear process. And as described above, many of the state and federal agencies also have the ability to impose mandatory conditions on hydropower projects in addition to the FERC.

TABLE 3-4. STATE AND FEDERAL AGENCIES OFTEN CONSULTED DURING HYDROPOWER LICENSING

FEDERAL AGENCIES	FERC
	U.S. Fish and Wildlife Service
	Bureau of Indian Affairs
	National Park Service
	National Marine Fisheries Service
	U.S. Army Corps of Engineers
	U.S. Coast Guard
	U.S. Environmental Protection Agency
STATE AGENCIES	Department of Environmental Protection
	Department of Inland Fisheries and Wildlife
	Department of Marine Resources
	Department of Agriculture, Conservation, and Forestry
	Maine Emergency Management Agency

The sheer number of participants, combined with conflicting goals and overlapping jurisdictions make licensing even small hydropower projects a difficult, time-consuming, and expensive process. The ability of multiple agencies to issue binding terms and conditions on projects adds an additional level of uncertainty and risk for hydropower developers.

In addition to any federal processes required, hydropower development in the state is also subject to the Maine Waterway Development and Conservation Act (MWDCA), which is administered by MDEP for projects in organized municipalities and by LUPC in unorganized territories. The MWDCA requires that a permit be issued for the construction, reconstruction, or structural alteration (including maintenance and repair) of new or existing hydropower projects. As with the Federal Power Act, this state law requires consideration of the full range of economic, environmental, and energy benefits and adverse impacts of a hydro project.

A FERC licensing in Maine requires significant financial and labor resources and exposes the hydropower owner to serious economic and operational uncertainty, given the length of time to complete, the complexity of the process, and the number of entities with the ability to impose mandatory conditions. Further, the costs and requirements of a FERC licensing do not scale down well for small projects; costs generally range from over $100,000 for very small, non-controversial projects to multiple millions of dollars for large projects. Compared to other forms of generation such as natural gas, the regulatory costs associated with permitting a hydropower plant are much higher, and the process times much longer, making hydropower a less attractive option for many investors (See Section 3.3.1).

3.3 Review of Potential Regulatory Reforms

3.3.1 Barriers to Hydropower Development in Maine

There are a number of barriers to hydropower development in Maine. Most of the barriers are not exclusive to Maine, but affect hydropower development throughout the U.S. Some of the most significant barriers can be grouped into (1) federal permitting requirements, (2) state permitting requirements, (3) grid interconnection, (4) financial and cost barriers, (5) technology barriers, and (6) information barriers.

One of the most significant barriers to hydropower development in Maine are **federal permitting requirements**. Most hydropower generation is regulated by the FERC and due to the length and complexity of the FERC licensing process, FERC's regulations have been viewed as a significant barrier to hydropower development for decades. (An overview of the licensing process is provided in Section 3.2.)

Efforts to reform and stream FERC's hydropower licensing requirements have been ongoing for several decades, and recently there has been a renewed focus on alleviating the federal permitting requirements for small hydro. As noted earlier, in August 2013, the President signed into law two pieces of legislation aimed at making the regulatory process more efficient for small hydro: H.R. 267, the *Hydropower Regulatory Efficiency Act*, and H.R. 678, the *Bureau of Reclamation Small Conduit Hydropower Development and Rural Jobs Act*. While the recent legislation does not exempt small hydropower projects from FERC licensing, the new legislation is intended to help lessen the FERC permitting requirements for non-controversial hydro projects that are less than 10 MW in capacity.

As noted earlier, there are also **state permitting barriers** to hydropower development in Maine, including requirements for complying with state water quality, environmental and historical preservation requirements. Of these, Maine's requirements for issuing water quality certification under Section 401 of the Clean Water Act, represents the greatest barrier to hydropower development. In part, this is due to Maine's water classification system, and water quality standards and regulations, which include rigorous standards and policy guidelines for the protection of aquatic life and habitat.

Grid interconnection can also be a barrier to hydro development in Maine. A grid-connected hydro project will typically be required to secure an interconnection agreement as well as a power purchase agreement. Interconnection can be particularly difficult in states like Maine, where promising hydropower development sites may be located far from the closest grid connection, thus making transmission difficult and costly. Moreover, the costs for grid interconnections for small projects can be nearly equal to those for large projects, making small remote sites even less attractive for future hydropower development. In addition, there are no small hydropower specific standards for interconnections, and each installation site can have varying requirements set by utilities, which may require custom designs and can further drive up costs.

Financing and cost barriers are a significant obstacle to hydro development in Maine, as they are elsewhere in the U.S. Some states have begun to try to address the funding issue, as have several federal agencies including USDOE and USDA. However, financing remains a huge problem for hydro development since most hydropower development is capital intensive, and the payback periods are long. Lenders are risk averse, and the primary challenge for hydropower financing is the long development timeline and uncertainties about requirements of the permitting process and the outcomes. Typically, banks and other investors will not invest in a new project unless there is certainty in the development schedule, power purchase agreement and permitting outcome.

The lack of power purchase agreement opportunities are a significant financial barrier to hydropower development. A Power Purchase Agreement (PPA) provides the long-term economic stability necessary for hydropower development are is often considered to make or break the viability of development. Many lenders are reluctant to provide financing without a

PPA in place, and most developers would be unwilling to make significant, long term capital investments without the pricing assurance provided by a PPA.

Another financial barrier to additional hydropower development is the conflict with increasing the natural gas supply to Maine. As more gas becomes available the wholesale price of electricity drops, which creates a larger economic barrier to hydro development.

Another important financial barrier is property taxes. These are typically the single highest line item expense to hydro owners, and have the potential to dramatically affect the economic viability of a development.

Technology barriers are also significant both in Maine and elsewhere in the U.S. Some companies are beginning to focus on developing new technologies specifically aimed at low-head and hydrokinetic applications. However, designing and testing innovative hydropower technologies is time consuming and costly and as a result technologically advanced equipment costs still tend to be high. Because of permitting and other barriers, the U.S. small hydro industry is relatively immature, with a small number of equipment providers manufacturing a small amount of equipment annually.

A few standardized turbine designs are on the market: these are turbines that are designed and manufactured to fit a certain range of head and flow conditions. Manufacturers of standardized turbines generally choose 2 to 5 standard models to cover a larger range of sites. This standardization can reduce the cost of a turbine, but also creates limitation on site applications. Alternatively, a custom turbine that is designed and manufactured for specific site condition will match the conditions at a site and extract an optimal amount of energy from a site, but in general the cost is significantly more than a standardized turbine.

Finally, there are **information barriers** that may affect future hydro development in Maine. Although Maine has a long history of using water for transportation and both mechanical and electric power, most potential energy developers have little or no understanding of available small hydro or hydrokinetic options and no direct experience with small hydro or hydrokinetic equipment. Ready access to factually correct information regarding potential hydropower development sites and how to proceed with development would be helpful. In addition, providing potential developers with economically compelling information regarding the economic benefits of installing small hydro might also have a positive effect.

Environmental concerns are a serious barrier to hydro development in Maine. Because of Maine's long history of water power, and its historic use of rivers for industrial purposes, since the beginning of the environmental movement in the early 1970s there has been a focus on the environmental restoration of Maine's rivers.

Initially, following passage of the Clean Water Act, these efforts were aimed at improving river water quality, but very quickly the effort expanded to include a focus on dams and the environmental impacts associated with the existence and operation of dams for water control, industrial use, or hydroelectric generation. Several hydropower dam related news stories, including the proposed Dickey-Lincoln project in the 1970s, the "Big A" project in the 1980s, and the Edwards Dam removal in the 1990s, as well as litigation in the 2000s over Maine's administration of its authority under Section 401 of the CWA, gained national attention that propelled Maine into the spotlight and gave Maine the reputation as a "difficult" state for the hydropower industry to operate within.

3.3.2 Hydropower Programs in Other States

This study included a review of programs undertaken in other states to promote the development of hydropower resources there, with the goal of applying any lessons learned to Maine.

Colorado has been one of the most active state governments in supporting small hydropower development. In 2010 Colorado increased its state Renewable Energy Standard to require investor-owned utilities to purchase thirty percent of its power supply from renewable sources by 2020 – among the highest standards of any state. In the same year Colorado signed a Memorandum of Understanding (MOU) with FERC in hopes of streamlining the licensing process for small hydropower projects. Under the agreement, a pilot program was created in which 20 projects would be "pre-screened" by the state before being submitted to the FERC for approval.

Initial efforts via the pilot program resulted in six FERC hydropower project license exemptions were issued in a period of only twelve months. During the same time period, only six other hydropower exemptions were issued by FERC in the rest of the United States. The program's initial success served as a catalyst, creating new momentum in the low-impact hydropower industry in Colorado.

While the initial Colorado MOU was limited to conduit projects and small, low impact projects that would qualify for a FERC exemption (which present a far greater opportunity in the West than in the Northeast), the key to the program was the availability of funding to hire an outside consultant to assist the developers secure their exemptions as part of the pilot program. When the funding ran out, the program essentially went dormant. However, the Colorado MOU demonstrated that the provisions in the FERC- Colorado MOU designed to "expedite" the process – from shortening timelines to eliminating consultation stages – could be otherwise accomplished in the absence of an MOU, under the existing provisions of the Federal Power Act and FERC regulations. Since the 2010 MOU, Colorado has continued its efforts to promote small hydropower development, particularly conduit development. In 2014, Colorado prepared a Small Hydro Handbook, which outlines for potential developers all of the steps needed to successfully develop small hydropower projects. Colorado is also establishing programs that offer small hydro feasibility grants and has started a low-interest rate financing program for conduit hydropower project construction (Colorado Energy Office, 2013).

Alaska is another state that has made a concerted effort to gain increased regulatory authority. In 2000, Alaska sought an amendment to the FPA designed to ease the regulatory burden for developing small hydro in the state. The amendment gave the state an opportunity to develop a regulatory system to oversee projects of 5 MW or less, and bypass the FERC process altogether. Before the authority could be exercised, the state was to develop a program that provided equal protection to environmental resources and public as FERC's existing jurisdiction, and be in compliance with several federal environmental statutes including the Endangered Species Act, Fish and Wildlife Coordination Act, and NEPA. Once approved by FERC, the Alaska state regulatory system would essentially replace FERC's regulatory oversight of projects with generating capacity less than 5 MW in Alaska.

In the years since the amendment to the FPA, Alaska has created no such program, and Alaska's opportunity to replace the FERC approval process with a state permitting process has gone completely unutilized. However, the Alaska case is another example of FERC showing its willingness to work with states to develop a more efficient regulatory system.

Vermont has recently taken steps to promote the development of small hydropower projects in that state. In 2012, the Vermont Legislature passed, and the governor signed, Act 165 (S. 148), "An act relating to expanding development of small and micro hydroelectric projects." One provision of Act 165 directed Vermont's Department of Public Service to enter into a MOU with FERC "for a program to expedite the procedures for FERC's granting approvals for projects in Vermont that constitute small conduit hydroelectric facilities and small hydroelectric power projects." Vermont state agencies responsible for implementing the legislation believe they can accomplish the requirements of Act 165 through better interagency coordination and developer support and have elected not to pursue an MOU with FERC.

As such, the Vermont Public Service Department, Agency of Natural Resources, Agency of Commerce and Community Development, and Division for Historic Preservation entered into a multi-agency MOU, which outlines the assistance, and support Vermont will provide to small hydro developers. Under Act 165 the VermontT/FERC MOU is supposed to result in an "MOU Program" that includes at least five hydro projects to be approved and commence operation. In January, 2014 the State of Vermont developed a Report to the Vermont General Assembly on Progress toward an MOU Program for Expediting Development of Small and Micro Hydroelectric Projects, which outlines progress the state has made, thus far in implementing Act 165. Vermont is also developing a small hydropower developer guidebook and a project intake form to help make the state approval process easier. As the Vermont MOU was just recently put in place, it is too soon to see whether these actions have produced any small hydropower development in the state.

Oregon has been very active in developing efforts to support hydropower development. In 2009, the Energy Trust of Oregon prepared a report on small hydropower development, "Small Hydropower Technology and Market Assessment." The intent of the report was to develop a greater understanding of small hydropower project types, the types of technology available and how projects could be configured. The report also examined the costs of hydropower development in Oregon, and examined the current conditions, barriers, and opportunities related to the formation of a functional hydropower installation market in Oregon.

The report listed barriers to creating a robust market for small hydro in Oregon, including lack of internal expertise, permitting being too complex, expensive, time-consuming and inhibiting, and difficult interconnection processes. The report recommended actions needed to move the Oregon small hydro market forward, including providing a paid expert to help those interested to navigate the developmental process; raising awareness about the Oregon Energy Trust's hydro support by increasing outreach; creating a roadmap of all permitting requirements; creating long-term certainty in available incentives since the development process can span years (Oregon has related state tax incentives); and using existing diversions and infrastructure; leveraging planned construction, such as added hydro when new and replacement pipes are already being constructed.

California is beginning to consider activities to promote hydropower development in that state. In 2013, the California State Water Resources Control Board entered into an MOU with FERC to coordinate the review of pre-application activities for hydropower proposals in the state. The MOU is intended to facilitate a more efficient and coordinated process for license applications and water quality certifications that include consultation, environmental scoping, study planning and commenting on an applicant's preliminary licensing proposal. As part of the MOU, the parties have also agreed to set deadlines to ensure a timely process and actively participate in study plan development. Additionally, SWRCB will participate in FERC's environmental scoping process and identify studies and information necessary for water quality certification. The focus of the MOU is conventional hydropower projects including pumped storage projects, and does not pertain to offshore hydrokinetic projects.

In November 2014, California voters passed Proposition 1 - the Water Quality, Supply and Infrastructure Improvement Act of 2014, a $7.545 billion general obligation bond. The measure will provide funding for needed investments as part of a statewide, comprehensive water plan for California. Proposition 1 is the product of more than five years of discussions and negotiations among state lawmakers, stakeholders and others to craft a responsible bond measure to provide targeted funding for new surface and groundwater storage projects, regional water reliability, sustainable groundwater management and cleanup, water recycling, water conservation and safe drinking water, particularly for disadvantaged communities. Although Proposition 1 does not contain any specific provisions for hydropower development, it is thought that the availability of funds for storage projects could also benefit hydropower development.

The **U.S. Department of Energy** (DOE) has been actively supporting the hydropower industry for the past several years. In December 2013, the DOE convened the first meeting of a “Small Hydro Innovation Collaborative” which was tasked with developing a report that will provide a look at how small hydropower can be furthered in a cost-effective manner. The effort was to include development of a database of information that will be useful to the small hydropower community as well as a policy agenda to advance small hydropower.

The report generated by this new DOE effort are expected to be released early in 2015 as part of its new initiative to develop a long-range national Hydropower Vision. According to the USDOE, this landmark vision will establish the analytical basis for an ambitious roadmap to usher in a new era of growth in sustainable domestic hydropower over the next half century, and will include: A close examination of the current the state of the hydropower industry; A discussion of the costs and benefits to the nation arising from additional hydropower; and, a roadmap addressing the challenges to achieving higher levels of hydropower deployment within a sustainable national energy mix.

3.3.3 INPUT FROM HYDROPOWER DEVELOPERS AND OWNERS

As part of this effort, a survey of hydropower owners and developers with varying levels of familiarity with State of Maine hydropower process and development opportunities was conducted. The survey consisted of approximately a dozen questions aimed at getting insight from hydropower owners and developers on hydropower development potential in Maine. Survey questions were aimed at understanding both the barriers to hydropower development and incentives for future hydropower development. The surveys were conducted by phone and in writing over the period November 15 through December 15, 2014. Results of the survey are summarized below. Survey participants were mostly hydropower developers and owners, or companies that support the hydropower development industry. In total there were six survey respondents representing both small and large companies with ownership of conventional hydropower projects of all sizes in several states. Most of the respondents, but not all, own and operate conventional hydropower projects in the state of Maine.

1) *What do you see as the biggest hurdles to additional conventional hydropower development in the State of Maine? For new generation at existing dams or infrastructure (conduits, canals, etc.)? For expansion of existing generation or efficiency improvements?*

There was a range of responses to this open-ended question. Most respondents suggested that the three primary barriers to hydropower development are project permitting/licensing, project financing, and grid interconnection, as these are the things most likely to affect project economics. Regarding financing, respondents suggested that access to long term energy sales or power purchase agreements (PPA) at attractive rates, is the primary factor in obtaining project financing.

Nearly all respondents indicated that efficiency improvements at existing projects, using new technologies, seem to offer the greatest opportunities for hydro development, but noted that new technology is costly, and therefore also a potential barrier. Nearly all respondents said that the only other viable development opportunities in Maine are at existing dam sites. It was consistently noted that barriers to development at non-hydro dams are greater than for efficiency improvements or additional development at already powered dams. Several respondents indicated that access to grid interconnection is likely to be a barrier at non-powered dams, especially in the more remote areas of Maine.

Several respondents also noted that lack of hydropower development incentives in Maine is another potential barrier to future development. One respondent indicated that stakeholder groups are also a serious barrier to hydropower development in Maine, noting that these privately funded groups are often well-organized and well-funded opponents of new hydropower development, as well as advocates of existing dam removal and river restoration.

2) *What are the biggest regulatory hurdles facing additional conventional hydropower development in the State of Maine?*

In response to this question, which focused on just the regulatory barriers to hydropower development, most respondents indicated that the primary regulatory barriers are the lengthy regulatory processes and the cost of addressing resource issues, including primarily fisheries requirements and upstream and downstream fish passage.

At the federal level, the cost and length of the FERC licensing process was consistently mentioned as a significant barrier to hydropower development. Respondents also indicated that the FERC licensing process is exacerbated by stakeholders and by state agencies who "frequently yield to FERC and the federal agencies" on relicensing issues.

The State 401 Certification process was also mentioned as a barrier to licensing approval. Several respondents specifically identified the cost of addressing fish and fish passage issues at hydropower projects as a significant barrier to hydropower development, particularly for dams located close to the coast or on the mainstem of major rivers. One respondent indicated that the Endangered Species Act was also a significant regulatory barrier, particularly for ESA listed fish species.

3) *How important to hydropower development do you consider "certainty of pricing" to be?*

All survey respondents agreed that certainty of pricing was a critical factor to future hydropower development. One respondent called it "huge" and another went so far as to say that it is the "single most important issue", noting that without pricing certainty, it is difficult to invest large sums of money on new or existing projects with a high risk of low return. Several respondents noted that without certainty of pricing in the form of a PPA, securing financing from banks or other investors was "impossible."

4) *When evaluating potential upgrade projects, does your firm have a minimum economic threshold for viability -- $/kW or $/kWh? And what is your firm's typical planning horizon when looking at project economics?*

Not surprisingly, almost none of the survey respondents provided a specific dollar rate, in answer to the first part of this question. One respondent indicated that their firm tended to use a $/kWh rate for screening projects rather than a $/kW rate. This respondent also indicated that while there was much variability in how they screened potential projects, on the whole their "sweet spot" was about $600–$750 per MWh.

Several respondents indicated that their firms did have a minimum rate that they used for project planning, but they did not share that rate in their survey response. Others indicated that their company did not have a single rate that they used as a minimum threshold for project viability, noting that other factors would be taken into consideration during their review of a potential project.

Regarding planning horizon, responses ranged widely. One respondent indicated that for hydropower project upgrades, the typical payback period sought was 1.5 to 3 years; and for "major" projects, a payback period of 7 to 11 years. (Note that these are not simple paybacks, as used in Section 2.0.) Other planning horizons (as opposed to payback periods) for conventional hydropower specifically mentioned by respondents were 20 years and 50 years. One respondent indicated that all projects are different, and that for some projects a flat rate per kW may not be as important as the cost of money and the value of the PPA.

In a follow-up question on power pricing, survey respondents were specifically asked to provide their perspective on whether, if the State of Maine were able to offer or guarantee a fixed-price purchase rate of 7.5 - 8 cents/kWh for new hydropower generation that would help to make potential hydropower development sites economically feasible. Responses were overwhelmingly favorable to the concept of a fixed-price for hydropower as being positive incentive, but the respondents that specified all indicated that 8 cents/kWh would be below the minimum needed to be effective. One respondent indicated that for projects less than 2.5 MW in size, 8.3 cents/kWh would be the minimum threshold in today's market. Another respondent indicated a price of 10 cents/kWh would be "more realistic", while a third respondent indicated between 9 - 10 cents/kWh "at a minimum."

5) *What regulatory changes at the state or federal level do you think could have a positive impact on future conventional hydropower development in Maine?*

This question produced a variety of responses, several of which had as a common theme suggestions for shortening or streamlining the permitting and licensing processes. At the state level, one respondent suggested that steps should be taken to shorten and add certainty to the timeline for state regulatory approvals/denials.

Another respondent indicated that the state should adopt "common sense" water quality certification criteria to help streamline and add certainty to the 401 Certification process. One respondent stated that 401 Certification is an "enormous" barrier in a state where the standards and criteria by which a project will be judged are not clear. This respondent suggested that Maine revise and clarify its criteria for determining whether hydropower projects meet state water quality standards.

It was also suggested that the state create a "one-stop-shop" for state approvals, pricing certainty and economic incentives. Finally, one respondent suggested the possibility of regulatory changes at the state level that would identify and designate "hydropower rivers," and that projects located on or planned for these rivers be subject to more "lenient" rules and regulations. There were also suggestions from respondents that "smaller" hydropower projects be subject to less review and regulation than larger projects.

One respondent to this question indicated that anything that the state could do to demonstrate Maine's support of and commitment to hydropower would be very helpful. This respondent noted that their firm is much more likely to pursue potential hydropower development in states, like Colorado, that are perceived as "friendly to hydropower", regardless of any specific regulatory or site-specific barriers encountered.

At the federal level, one respondent indicated that the current FERC licensing process should be streamlined to reduce the process from the current 5 year process to a 2.5 year process. Another respondent indicated that at the federal level, in response to the 2013 Regulatory Efficiency Act, the U.S. Department of Energy (DOE) is preparing a report to Congress on the issue of regulatory efficiency for permitting hydropower development. This report is expected in 2015.

Finally, specifically regarding the issue of fish and fish passage, one respondent suggested that fish passage requirements for hydropower projects should be reviewed to understand the economic impact on both hydropower and fisheries. This respondent also suggested that a more coordinated effort should be undertaken to identify the locations, state-wide, where it makes economic sense to install fish passage.

6) *Are there any State of Maine policies or programs with which you are familiar that, if changed, could act to encourage additional hydropower development in the state?*

As with the previous question, this question prompted a diversity of responses. A common theme among the responses was the need for policies and programs that incentivize hydropower. Several respondents noted that a PPA program that provided certainty of pricing, over a fixed period of time, would be of critical importance. One respondent specifically suggested that Maine should offer pricing certainty through the Maine Public Utilities Commission (PUC).

Other respondents mentioned changes to Maine's renewable portfolio standard (RPS) as a way to further incentivize hydropower development. Regarding RPSs, one respondent specifically suggested that Maine's RPS should be "overhauled" and should focus more on in-state generation and long-term projects. This same respondent suggested that Maine's RPS Class I qualifications should be made more like New Hampshire's and allow all in-state hydropower projects that meet current fish passage requirements and are under 1.5 MW to be eligible for Class I treatment.

Other programs that were suggested by respondents to help incentivize hydropower included interconnection and financing programs. One respondent noted that the state of Colorado has established a hydropower financing program that recently provided $15 million in financing for two new small hydropower projects.

Also related to financing, one respondent commented on Maine's Chapter 329; An Act to Establish the Community-based Renewable Energy Pilot Program, specifically noting that changes to the current Chapter 329 would be beneficial to hydropower developers if it could be expanded to include more companies and corporations, by removing the requirement for the 51% company owner to reside in state.

In response to a follow-up question regarding potential specific regulatory actions the State of Maine could take that would effectively incentivize additional hydropower development in the state, some additional ideas were put forth. One respondent reiterated that the two largest issues faced by developers is the time it takes to permit a project, and the cost of developing the project. With respect to time, this respondent suggested that the legislature could develop a state agency that would be a one-stop-shop for permitting, and that would serve as the official liaison with all the other state agencies. In order to be effective, this respondent suggested that the liaison would need to have "very stringent" time periods to review applications and information, request additional information, and process the collected information with the appropriate agencies. Failure of any agency to meet its deadline(s) would waive their oversight or input to permit conditions and/or future project enforcement.

With respect to project development cost, this respondent suggested the State of Maine consider a program similar to Vermont's SPEED program for renewables, whereby the project proponent is guaranteed a particular rate for energy sales that make the project viable for at least a 20 year period. Consistent with their response to an earlier question, this respondent indicated that a fixed price for hydropower would need to be in the 9–10 cents/kWh range, at a minimum.

Another respondent suggested that it would be useful if the State of Maine could address dam safety and the fact that often the dams themselves, at sites with attractive potential for hydropower generation, would need significant rehabilitation in order to meet federal dam safety standards. This respondent noted that dam rehabilitation costs are often prohibitive for small projects with thin margins. It was mentioned that Massachusetts is considering the feasibility of state-funded dam rehabilitation. This respondent also reiterated their concern with the need for clear state regulations and policies around issues such as water quality, fisheries and recreation, so that the uncertainty is eliminated from the state regulatory process.

A final suggestion put forth by a respondent would be the development of a two-tier policy aimed primarily at adding power to existing dams and re-powering existing projects. This respondent suggested a two-tiered scheme that would allow projects to take advantage of what the program would cost rate payers, and what the economic impact in terms of job creation would be. Specifically, the respondent suggested the following:

Tier 1 – An act to incentivize and promote fish passage requirements by state and federal agencies, whereby hydropower projects under 2.5 MW that meet fish passage requirements or install required fish passage would qualify for long-term fixed contract pricing.

Tier 2 – An act to incentivize and promote development or repowering, whereby projects under 20 MW that are developed or repowered with investment equal to current tax base, will be eligible to qualify for long-term fixed contract pricing according to a specified scale, such as shown below;

Project Size	≤ 2.5 MW	2.5-5 MW	5-10 MW	10-20 MW
Fixed Pricing (per kWh)	8.3 cents	7.3 cents	6.3 cents	5.3 cents

7) *What role, if any, does public opinion or political climate have in any decisions your company has made with respect to additional hydropower development in Maine, or elsewhere in the U.S.?*

Answers to this question were variable and covered both local and national perspectives. At the local and state level, respondents were unanimous in indicating that local politics and public support play a big role in hydropower project licensing and development considerations.

Several respondents noted that local organizations, as well as local chapters of national non-governmental organizations (NGOs) can have a significant adverse impact on the viability of a hydropower project, both from a licensing and economic perspective. One respondent noted that many NGOs and local organizations in Maine are focused on river restoration and dam removal, a situation that makes new development impossible, and can make relicensing of existing hydropower projects, particularly small projects, very difficult. This respondent suggested that the state should perhaps "run interference" with the "anti-dam" groups and NGOs, and/or work on programs to educate and reeducate the public about the economic and environmental value of hydropower.

Nearly all respondents indicated that local support of hydropower projects was important to their companies' consideration of new or continued hydropower development within a particular state or locality. Another respondent indicated that state support of a proposed hydropower project is just as important as local support, noting that "nothing makes them happier than knowing their projects are wanted." One respondent noted that public opinion is particularly important to hydropower generation since, unlike other forms of generation and renewable technologies that can be located in a different area or region, hydropower projects can only be located at the source of the fuel, water, and have to be site-specifically designed for that location. As summarized by another respondent, "our company needs both public and local support to make any project happen."

8) *Are there any incentives that could be offered within the State of Maine that you believe could have a positive influence on hydropower development in Maine?*

Survey respondents provided a number of general suggestions regarding possible incentives for hydropower development, many of which were mentioned in their responses to earlier questions including, low interest financing, pricing incentives for energy sales, PPA programs and pricing guarantees, and a revised Maine RPS program that incentivizes hydropower. A couple of respondents also mentioned tax incentives and tax exemptions as possible incentives. However, another respondent explicitly indicated that they were "not a fan" of using tax policy as incentive for hydropower development. This same respondent specifically mentioned feed-in tariffs as a way to incentivize hydropower development in Maine, noting that feed-in tariffs have been very effective in California.

Also in response to this question, several respondents revisited the fish passage issue. A specific suggestion from one respondent is that Maine consider a PPA for hydropower generation, with possible criteria for qualification being investments needs of 80% of current tax value, and that investments could include fish passage installation as well as turbines and other generating equipment. Another respondent suggested that a state program to promote or incentivize the installation of new technology and "fish friendly turbines" could be highly beneficial. Also in regard to new technology, a couple of survey respondents suggested that a state program to promote the installation of new hydropower technologies, such as state supported feasibility or demonstration projects, could help bring new, more cost effective hydropower technology to the state of Maine, and help make such technologies more widely available to potential new hydropower developers.

In response to this question, several respondents again mentioned the idea of Maine creating a state "hydropower coordinator" position or office, whose role would be to work with developers and agencies to make the development and licensing/permitting processes more certain. This person would act as a state clearinghouse for hydropower licensing and permitting activities, but would also be empowered to facilitate a coordinated state review of both federal (e.g., FERC, ESA) and state (e.g., 401 Certification, CZMA) regulatory approvals.

It was noted by at least one respondent that until relatively recently the State of Maine had a hydropower coordinator in the former State Planning Office, but noted that the previous hydropower coordinator position was relatively ineffective in coordinating state agency positions on hydropower licensing issues, presumably due to a lack of regulatory authority.

9) *In your opinion, what is the biggest threat to the potential for future additional conventional hydropower development in the State of Maine?*

In response to this question, few of the respondents named a single threat to future hydropower development. However, nearly all of the respondents agreed that low, volatile and uncertain energy prices is probably the greatest threat to hydropower development both in Maine and elsewhere in the U.S. One respondent indicated that most states are grappling with these same issues, and trying to understand how their state can adapt its own policies and programs to help alleviate the threat that uncertain power prices have on hydropower and other renewable energy development. Other threats that were identified included threats associated with the environmental and resource issues often associated with hydropower, including the need for costly fish passage, and the continued advocacy for dam removal and river restoration. One respondent also specifically mentioned the Endangered Species Act for Atlantic salmon and the possible future ESA listing of American Eel as significant threats to future hydropower development.

10) *If you could change a single factor that in your experience influences your firm's consideration and determination of potential new hydropower development in the State of Maine, what would that be?*

Again, few respondents identified a single factor that they would change that would affect their consideration of future hydropower development in Maine. One respondent said simply "energy pricing certainty at a level that promotes development." Another respondent indicated that with a "proper RPS program", changes to Chapter 325, and/or long-term PPA incentives, their company would "strongly consider" repowering their existing Maine hydropower projects. This respondent also noted that the State of Maine should recognize the value of hydropower projects to the state since, in the event of natural disaster or other catastrophic events, these projects can provide a dependable, available, renewable source of electricity and black start capabilities. One respondent said simply "regulatory certainty."

Are you familiar with any of the following? And if so, could you comment on how these programs or similar programs/efforts might be implemented or modified in the State of Maine to further encourage hydropower development?

a) Low Impact Hydropower Institute (LIHI) Certification

Some respondents were not familiar with LIHI. Among those that were familiar with the LIHI program, most indicated that the LIHI Certification program is undergoing some changes, and that it is unclear what LIHI's future role might be. One respondent characterized the LIHI Certification process as being "somewhat broken," noting that the approval process is too long (currently 1 to 2 year approval time), and the qualification criteria is difficult for most hydro projects.

Collectively, respondents familiar with LIHI suggested that there is currently much debate within the hydropower community about the role and value of the LIHI Certification process. That said, one respondent indicated that their firm found LIHI to be "quite valuable," noting that it provides a baseline that a particular project has successfully minimized or avoided environmental impacts, and that these project owners are good environmental stewards.

b) State of Colorado MOU with FERC to Streamline and Simplify the Authorization of Small Scale Hydropower Projects

Some of the respondents were not familiar with Colorado-FERC MOU. Among those who were familiar with it, but not the details of the MOU, there was general acknowledgement that the Colorado MOU helped to demonstrate that the FERC process is inefficient, and that there may be more efficient ways to review and approve hydropower projects, consistent with FERC's existing statutory and regulatory requirements.

c) Feed-in tariffs

Feed-in tariffs were mentioned by several respondents in answers to other survey questions. In response to this specific question, those familiar with feed-in tariffs agreed that they could be very beneficial to the future of hydropower development in Maine for both repowering existing generating sites or developing new hydropower generation sites. One respondent opined that the potential for feed-in tariffs to incentivize hydropower development in Maine is "huge."

d) Renewable Energy Tax Credits

Response to this question was mixed. On respondent indicated that the reissuance of the federal Hydropower Energy Tax Credits "would be extremely helpful." A couple of other respondents indicated that renewable energy tax credits are only likely to benefit large developers, noting that "most small developers cannot value these credits as they don't have the tax appetite required to use them." One respondent again indicated that they felt using tax policy as an incentive to energy development is fundamentally unsound.

e) Renewable Portfolio Standards (state/PUC mandated)

Most respondents suggested that the state RPS could help to incentivize hydropower, under certain circumstances. One respondent noted that an RPS may be beneficial, but only if it drives suppliers to offer rates that encourage development. Another respondent reiterated their view that to be effective, Maine's RPS would have to be completely revamped such that all hydropower would qualify as renewable. Respondents did not indicate a clear consensus as to whether the Maine RPS should be revised to include Canadian hydropower.

f) Carbon Trading

Most respondents suggested that they saw little role for carbon trading to help incentivize hydropower in Maine, particularly for small hydro. One respondent indicated that they were "not a fan" of carbon trading, and that a carbon fee/carbon tax approach would be a better solution to curbing carbon emissions. One respondent noted that their company currently participates in carbon trading at hydro projects that currently generate renewable energy credits, but did not make any suggestions as to how this concept might be useful for encouraging hydropower development in Maine.

11) *What are your thoughts about the potential for pumped-storage project development in the State of Maine?*

Respondents generally agreed that current energy pricing and the non-existent PPA opportunities in Maine make pumped storage projects extremely uneconomical, and therefore the future development potential low.

4.0 FINDINGS AND RECOMMENDATIONS

4.1 CONVENTIONAL HYDROPOWER

The inventory of conventional hydropower development at existing powered and unpowered dam sites in Maine indicates that there is still hydroelectric development potential at existing dam sites located throughout Maine, but these opportunities do not appear economic under current market conditions. As shown in Table 4-1, the screening analysis identified 110 total sites at powered and non-powered dams with potential for installation of 193 MW of additional capacity. But as noted earlier, as a result of limitations of the overall assessment methods and engineering assumptions made, these estimates must be considered an upper limit of development and generation potential. In additional, when regulatory considerations are taken into account only 45 sites with 55 MW of potential capacity showed significant development potential.

TABLE 4-1. SUMMARY OF CONVENTIONAL HYDRO SCREENING.

REGULATORY CATEGORY	PARAMETER	POWERED DAMS	UNPOWERED DAMS	TOTAL
Limited Development Potential	Number of Sites	5	4	9
	Additional Capacity (MW)	22.85	14.70	37.55
Moderate Development Potential	Number of Sites	27	29	56
	Additional Capacity (MW)	65.55	34.43	99.98
Significant Development Potential	Number of Sites	10	35	45
	Additional Capacity (MW)	33.86	21.19	55.05
Total	Number of Sites	42	68	110
	Additional Capacity (MW)	122.26	70.32	192.58

The study also considered what actions could be taken by the State of Maine to help clear hurdles or otherwise incentivize new conventional hydropower development in Maine.

Compared to other types of renewable energy, conventional hydropower development is capital intensive and has a long payback period, making the economics of most new projects marginal. The survey of hydropower developers conducted as part of this study effort found that most developers perceive the three greatest hurdles to hydropower development in Maine to be project permitting/licensing, project financing, and grid interconnections.

Ultimately, the decision to develop or not develop a project is based on the economics of the project, and each of these major factors has the potential to significantly affect project economics. Because hydropower project economics are so specific to site and resource conditions, no one answer would address the economic challenges associated with new hydropower development. However, certain actions might be taken by the State of Maine to reduce the regulatory and economic hurdles faced by developers and create an environment more attractive to new hydropower development.

4.1.1 Further Research and Development Opportunities

While Maine does not have a large water delivery infrastructure comparable to many Western states, the Portland Water District and industrial sites might provide opportunities for deployment of conduit hydropower. Because of the limited footprint and potentially reduced regulatory requirements associated with conduit projects, these installations may have very different and more favorable economics than conventional hydropower. As such, an investigation targeting potential conduit hydropower development in Maine seems worthy of consideration.

Many of the existing hydropower sites in Maine are required to pass minimum flows to ensure river reaches receive adequate flows. Typically, these minimum flows are not passed through a turbine and are therefore unavailable for generation. Many conventional sites have been able to increase generation by deploying smaller hydropower units to take advantage of these flows. A large number of Maine hydropower sites are coming up for FERC relicensing in the next 15 years, and there could be potential economic synergies to incorporate the additional of new minimum flow units into these processes. Given this, an investigation that specifically looked at the potential of adding minimum flow units at existing sites seems worthy of consideration.

As the screening level study did not find any conventional hydropower sites that would be economic to develop under current pricing, this study did not analyze deployment of emerging hydropower technologies under the presumption that these would be more expensive to deploy. That said, an investigation targeting the commercial viability of these emerging technologies at Maine sites seems worthy of consideration.

4.1.2 Regulatory Hurdles to Hydropower Development

All of the respondents to the hydropower developers survey mentioned the length, cost, and uncertainty associated with permitting a new project (or, for that matter, relicensing an existing project) as major hurdles to new development. These concerns encompassed both federal and state regulatory processes. At the federal level, there is little the State of Maine can do to modify the Federal Power Act or other statutes that define FERC's regulatory authority and process requirements. Nor is there much that the state can do to modify FERC's licensing and permitting regulations, although some states, such as Colorado, have attempted to reduce the federal regulatory burden by entering into agreements with FERC aimed at streamlining approvals for certain types of projects by consolidating federal and state project review.

However, the state is a major player in the FERC licensing process, and state resource agencies have significant influence on both the licensing process and its outcome through several mechanisms, including FPA Section 10(j) fish and wildlife recommendations, CWA Section 401 water quality certification, and Coastal Zone Management Act approval. For any given licensing process, the state may be represented by several different state agencies, each with diverging perspectives and mandates. This situation can add both delay and uncertainty to the licensing process, and occasionally results in the State providing inconsistent or even contradictory direction to hydropower developers. Survey respondents consistently identified this as a concern, and several respondents gave specific examples of their experience with this problem.

To help with this situation, several survey respondents specifically recommended that the state consider establishing a "hydropower coordinator."[6] The role of this individual or office would be to act as a coordinator for all of the state agencies on hydropower licensing and related regulatory reviews. The hydropower coordinator would also serve as a single voice for the State of Maine on any hydropower licensing/permitting proceedings, including the State's review of water quality 401 certification. However, to be effective, the hydropower coordinator would have to do more than just serve as a clearinghouse for state agency comments (as is done in other states), and instead would need to be empowered to make final decisions on the State's positions on issues related to the project licensing/permitting, to ensure that these positions are consistent with the State's policy goals of balancing hydropower and non-hydropower uses of Maine's waters.

[6] While the former State Planning Office once maintained a similar position, only one of the respondents specifically pointed to this historical position, and even then did not consider that position an effective model.

At the state level, survey respondents consistently noted that Maine's 401 certification process needs to be reviewed and "overhauled." Most of the developers indicated that Maine's criteria for evaluating whether a project meets state water quality standards are not clear, and must be reevaluate and revised, not only to clarify the criteria, but to also define exactly when and where such criteria apply. Just as importantly, the criteria must be established at the outset of the 401 certification/FERC licensing process and cannot be revised, modified, or reinterpreted along the way. To address this concern, the State should consider conducting an in-depth review of its water quality standards, and the criteria used to evaluate whether hydropower projects meet state standards, including both numeric and narrative standards, as well as designated uses. To be effective, the review might also need to consider Maine's historically broad interpretation of the application of Section 401 to hydropower projects, since in part the uncertainty associated with the criteria used to assess whether a project meets water quality standards is driven by Maine's past consideration of water quality impacts other than those directly attributable to the "discharge" from a hydropower project.

Finally, with respect to the 401 certification process, several survey respondents noted that some of the uncertainty associated with the current 401 review process, is the open-ended timeline associated with state 401 certification. As noted earlier, a state has one year to act on a 401 certification application. If a state fails to act within a year, then certification is deemed waived under the FPA. In Maine, it is common for MDEP's review of a 401 application to exceed a year. However, to avoid the potential of having 401 certification deemed waived as a result of inaction within a year, the historic practice of the MDEP has been to "act" within the year by issuing a request to the applicant to withdraw and refile its application, thereby resetting the 1-year clock. As noted by several of the survey respondents, this practice adds considerably to the uncertainty surrounding project licensing and permitting, and should be part of the State's 401 certification review.

4.1.3 FINANCING AND ECONOMIC INCENTIVES

Survey respondents all agreed that with respect to financing, improved certainty in the regulatory process and outcome, as well as certainty in pricing in the form of long-term power purchase agreements (PPAs), at attractive rates, are critical. While the State cannot directly affect the price of power, which in an open market drives purchase rates and pricing agreements, there are ways that a state can affect the value of hydropower generation such that it is eligible for renewable energy price premiums that may be established in the market through RPSs or through mandated pricing structures.

While there was no consensus among the survey respondents about how to approach this particular issue, several respondents suggested that the State review and revise its RPS and eligibility requirements such that more new conventional hydropower development, if not all hydropower development, is classified as a Class1 renewable. A specific suggestion provided by one of the survey respondents was that Maine's RPS program should be modified to be more like New Hampshire's, and allow all in-state hydropower that meets current fish passage requirements and is under 1.5 MW to be eligible for Class I treatment.

Another specific suggestion could be having legislation that allows for the Public Utilities Commission to solicit pricing for long-term contracts for existing and new hydro facilities, and if the price is deemed prudent, to direct the utilities to enter into agreements for this power.

Other more direct approaches to overcoming the project financing conundrum suggested by survey respondents included the development of a State-sponsored hydropower project financing authority and funding mechanism; a State-sponsored and funded pilot and/or partnership program to attract new hydropower technologies to the State; and potential modifications to Maine's existing capital investment programs to better support the capital and financing needs of the private sector, in addition to municipalities.

One survey respondent specifically suggested that the State amend Chapter 329. This law, enacted in 2009, established a pilot program to provide incentives for the development of "community based" renewable projects. To qualify for the program, facilities must be "locally owned electricity generating facilities," such that at least 51% of the facility is owned by a resident of the state or a Maine municipality. The suggestion is to remove the 51% resident ownership requirement to allow more projects being pursued by companies or corporations to qualify for the program.

4.1.4 INFRASTRUCTURE

As the focus of this part of the study was on the development of conventional hydropower projects at existing dams, consideration of necessary infrastructure requirements was somewhat limited. However, grid interconnection was one aspect of infrastructure that has been identified as a significant potential hurdle to hydropower development in Maine. Some of the issues associated with grid connection are related to the cost associated with lack of consistency in grid tie-in requirements, depending on the location and ownership of the transmission facilities. In Maine, a potentially bigger problem associated with grid connection is the remoteness of potential project sites and the lack of existing transmission within the immediate vicinity of these sites.

Two specific examples of this problem are the Middle Dam and Flagstaff Dam sites identified in the inventory. Although both of these dams are FERC-licensed storage projects, neither of these dams support generation, primarily because they are located in remote areas, far from the nearest transmission lines. Thus, any development of these sites would have to support the cost of significant new transmission facilities, in addition to the cost of the actual hydropower development; an economic burden that few small hydropower projects can support. As a result, while these sites are two of Maine's most promising sites from a hydraulic, hydrologic, and potential generation perspective, they remain undeveloped [7]. Other sites identified as part of the inventory may also lack proximity to existing transmission rendering them uneconomical as well. If the State of Maine is serious about making such sites more attractive to hydropower developers, it may need to consider what actions can be taken to overcome the grid connectivity issues in these and other remote locations.

4.1.5 PROMOTION OF HYDROPOWER

The survey respondents touched on several themes repeatedly in discussing the hurdles facing potential hydropower development in Maine. One common theme was the idea that Maine is not seen as a hydropower "friendly" state. Some of this perception is a result of the State's long history with hydropower, including some highly controversial projects that gained national notoriety. Some of the perception is a result of Maine's broad interpretation of 401 Certification requirements, and the national attention gained by some prominent court cases regarding 401 certification of Maine hydropower projects.

Other sources of this perception include highly active chapters of national NGOs that have long been opponents of hydropower as a source of electric generation including American Rivers,

[7] Note that transmission interconnection costs were not included in the screening-level analysis described in Section 2.1.

American Whitewater, the Nature Conservancy, and Trout Unlimited. In recent decades these national organizations have led the charge to defeat new hydropower projects around the country and in Maine have served as a catalyst for local opposition to hydropower. Again, the combined result of these and other factors is the general perception that Maine is a difficult state hydropower development.

Although perception should not be equated with reality, nearly all of the hydropower developers surveyed suggested that state and local support of a potential hydropower project weighs heavily in their decision about whether to pursue a particular project or not. One developer stated that just by conducting this study and issuing this report, Maine will be sending important positive signals to the hydropower community about their support of and interest in new hydropower development in Maine. Other suggestions for ways Maine could change how the state is perceived by the hydropower development community included:

- Establish a state hydropower office that would work with potential developers interested in pursuing hydropower projects in Maine;
- Establish a state-wide education and public relations campaign that promotes hydropower and the benefits of hydropower as a renewable energy source;
- Work with national and local NGOs to reconsider the value of hydropower to Maine, New England, the U.S. and the world, particularly in the context of other forms of electric generation, and to emphasize the compatibility of hydro development with environmental goals of combating climate change, river restoration, and fish passage;
- Issue and periodically update an inventory of conventional hydropower development sites in Maine, and make the this information readily available to the development community; and
- Work with the U.S. Department of Energy to promote Maine as a hydropower friendly state by actively participating in ongoing and upcoming DOE initiatives to promote hydropower development nationwide.

4.2 MARINE AND HYDROKINETIC

4.2.1 SITE RESOURCE VALIDATION

The inventory of hydrokinetic sites conducted as part of this effort was hampered by a lack of consistent data necessary to fully evaluate site potential. A process and funding should be developed to properly assess priority tidal and river sites. Review of available information indicates the State of Maine resources are conducive to marine and hydrokinetic development. However, measurements to quantify the resource have not been made at many sites. For tidal energy sites, measurements typically are made through the use of instruments called Acoustic Doppler Current Profilers (ADCPs) deployed over the course of a lunar cycle.

ADCP's can also be utilized to measure river resources for potential hydrokinetic development. This step is critical in order correlate flow data, which is historically available, to velocity data. The University of Alaska Anchorage developed a regression analysis to determine river velocities for the purpose of hydrokinetic development potential.

4.2.2 FURTHER RESEARCH AND DEVELOPMENT OPPORTUNITIES

The State is well positioned to play a leadership role in the development of the national marine and hydrokinetic industry. The Cobscook Bay Tidal Energy Project, Maine Maritime Academy's test site and the University of Maine's Monhegan offshore test site all offer accelerated development opportunities based on available site information and infrastructure. In addition, proven industry/academic partnerships and existing supply chain position the state well for further development.

4.2.2.1 ADDRESSING COMMUNITIES WITH HIGH COST OF POWER

Maine islands pay some of the highest costs for electricity in the United States. By identifying marine and hydrokinetic sites in proximity to these communities it could allow for high power costs to be reduced while offering opportunities for market entry by technology developers.

4.2.2.2 COUPLING WITH INFRASTRUCTURE PROJECTS

Similar to communities with high costs of power, the identification of infrastructure projects at or in the vicinity of marine hydrokinetic resources could offer the opportunity for reduced installation and maintenance costs. In particular, bridge sites located where tidal or river resources are present could be designed or retrofitted to incorporate hydrokinetic technologies.

4.2.2.3 COUPLING WITH CONVENTIONAL HYDROPOWER

A potentially attractive location for deployment of hydrokinetic units would be in the tailraces of existing conventional hydropower developments. As many of these projects will be undergoing FERC relicensing in the next 15 years, incorporating the addition of new hydrokinetic units into the relicensing might offer efficiencies to reduce cost and increase overall generation capacity.
Regulatory Process

The Cobscook Bay Tidal Energy Project demonstrated successful permitting and licensing of a marine hydrokinetic project in the State of Maine as well as at the federal level. It is recommended that the Adaptive Management Plan process governing the project's licensing requirements be used as a model for other MHK projects. The Memorandum of Understanding (MOU) established between FERC and the State of Maine served as a catalyst for bring state and federal regulators together. In addition, the lessons learned from permitting the Cobscook Bay project offer opportunities to further improve the regulatory process to make it more efficient and cost effective.

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