Maine Tidal In-Stream Energy Conversion (TISEC): Survey and Characterization of Potential Project Sites

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Phase:	1 – Project Definition Study
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Two special acknowledgements are also extended; one to Michael Mayhew of the Maine PUC and the other to Robert Judd, citizen of Lubec Maine and Sacramento, CA, for there tireless work in helping the EPRI team with local knowledge and resources.

If, despite our best efforts, errors survive in the pages of this summary report or in our referenced technical reports, the fault rests entirely with the EPRI E2I Global Project Team. And if I inadvertently omitted the names of any persons or organizations that should have been acknowledged, I offer my sincere apologies.

Roger Bedard

Organization(s) that prepared this document

Electric Power Research Institute

Virginia Polytechnic Institute and State University

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1. Introduction

The purpose of this report is to identify and characterize sites in Maine that have significant development potential for tidal in-stream energy conversion (TISEC). This report provides the basis for selecting the most promising sites for a feasibility demonstration project, notionally rated at 500 kW (producing 1,500 MWh annually at 40% capacity factor) and for a first commercial plant, notionally rated at 10 MW (producing 30,000 MWh annually at 40% capacity factor). Sufficient data is provided to enable the Maine State Advisory Group to select a single site for a subsequent concept-level design, performance analysis and cost estimate.

1.1 Geological and Oceanographic Setting

The Gulf of Maine, including the Bay of Fundy, is one of the world's most biologically productive environments. Its marine waters and shoreline habitats host some 2,000 species of plants and animals. The coastlines of Massachusetts, New Hampshire, Maine, New Brunswick, and Nova Scotia make up its western and northern boundaries. As shown in the figure below, Georges and Brown Banks define the seaward edge of the Gulf of Maine, forming a barrier to the North Atlantic Ocean. Between these banks is the Northeast Channel, a deepwater conduit that brings dense, high-salinity, nutrient-rich water from the North Atlantic into the Gulf.

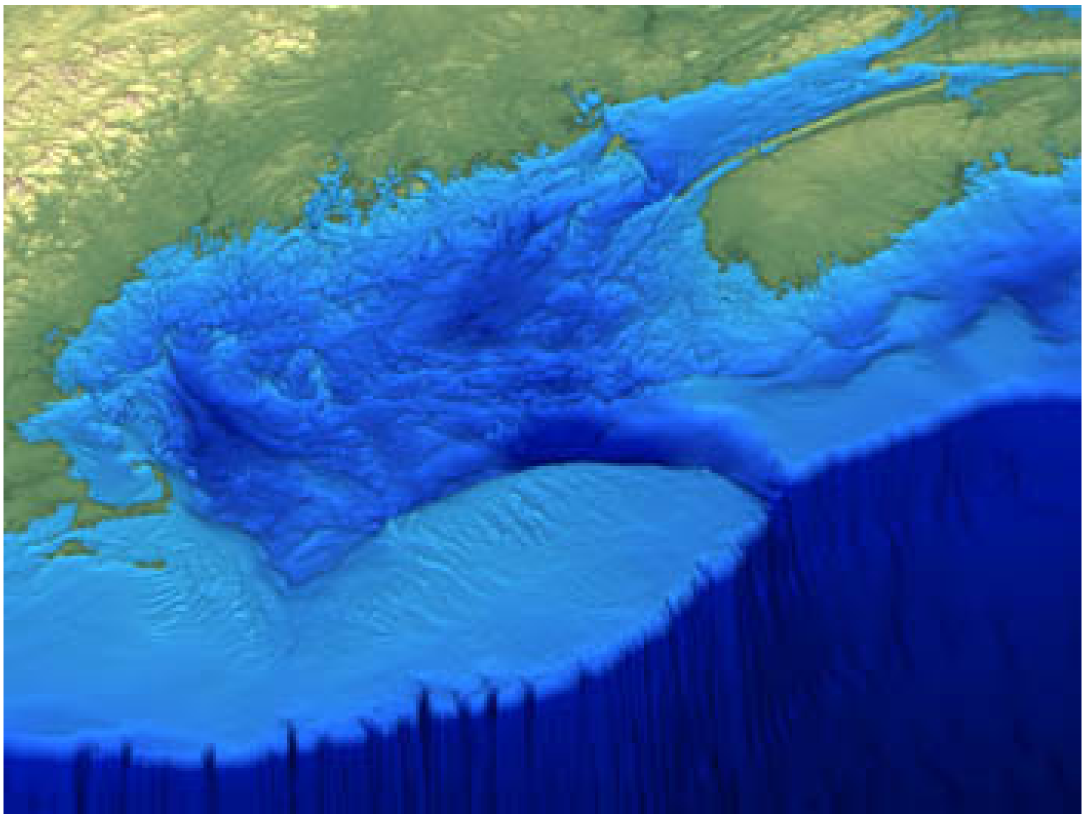


Figure 1-1. Three-dimensional rendering of seafloor bathymetry in the Gulf of Maine and Bay of Fundy, with vertical depth exaggerated by a factor of 75 to enhance bottom features. (Source: www.gulfofmaine.org/knowledgebase/aboutthegulf/maps/mapsandphotos.asp)

Tides in the Gulf of Maine and Bay of Fundy are forced by tides in the North Atlantic Ocean rather than directly by the sun and moon. The North Atlantic tide enters the Gulf of Maine via the Northeast Channel and then spreads as a refracted wave across the Gulf (Reference 1). After entering the channel, this wave travels 335 km to reach the shelf edge between Bar Harbor and Jonesport about three hours after entering the Northeast Channel (Figure 1.1-2, below).

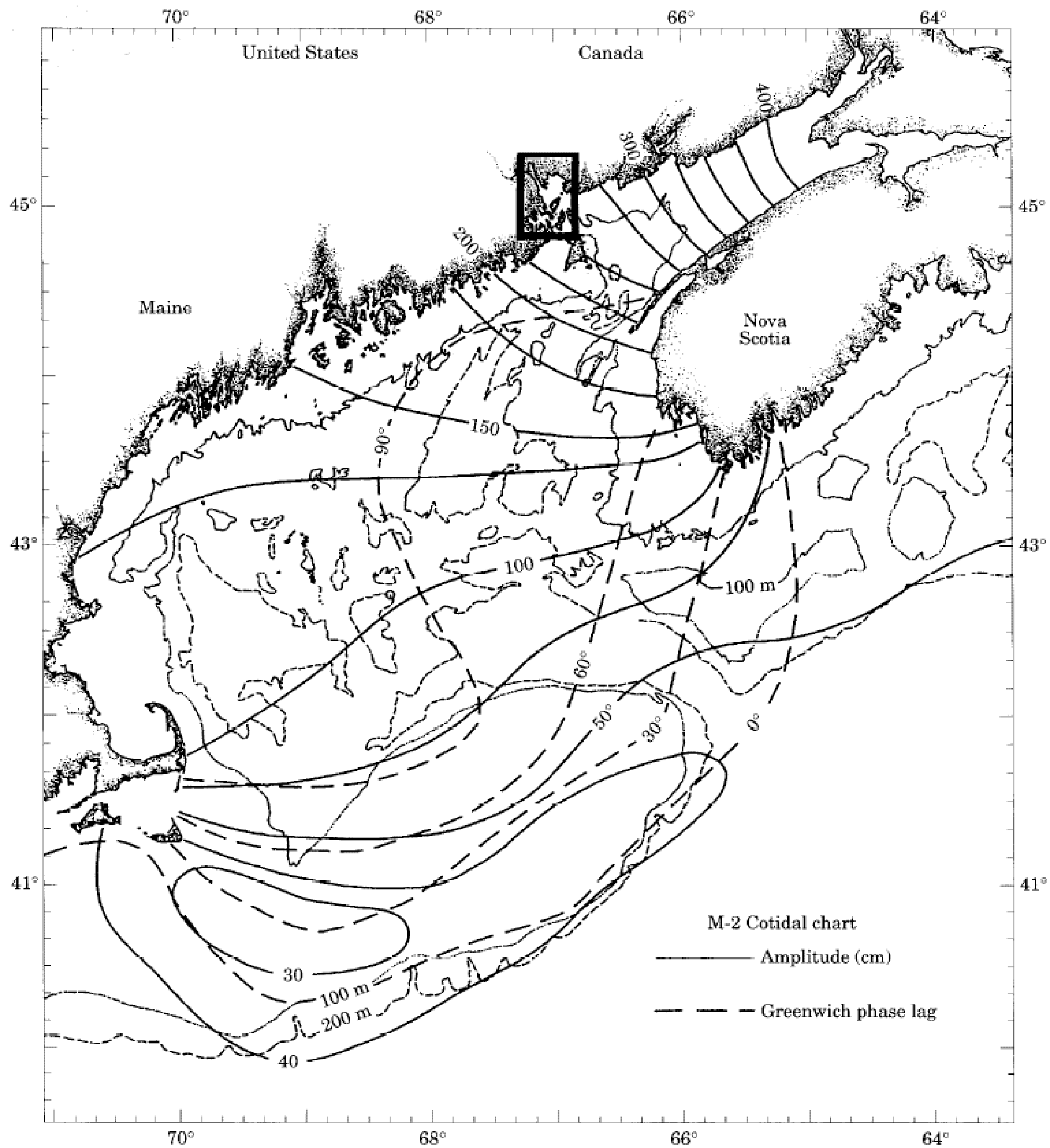


Figure 1.1-2. Behavior of the M-2 (principal lunar semi-diurnal) tidal constituent as it progresses across the Gulf of Maine and into the Bay of Fundy. (Source: Reference 2)

The relatively close spacing of the dashed co-tidal lines in Figure 1.1-2 indicate the progressive nature of the North Atlantic tidal wave as it sweeps along the southern coast of Nova Scotia and refracts toward Cape Cod. In the southern bight of the Gulf of Maine and in the Bay of Fundy, however, its behavior is closer to that of a standing wave, with high and low water levels occurring at approximately the same times around the shoreline (except in the Minas Basin, where there is a lag of about an hour).

The average tidal range at the North Atlantic entrance of Northeastern Channel is 0.9 m, increasing to 3.1 m at Bar Harbor. At the mouth of the Bay of Fundy, the average tidal range is about 5 m, increasing dramatically toward the basins at the head of the Bay.

Two phenomena account for this amplification of tidal range. First, the natural period of the semi-enclosed basin that encompasses the Gulf of Maine and Bay of Fundy is about 13 hours, which is very close to the principal lunar semi-diurnal tide forcing period of 12.4 hours. Second, and of particular importance in the Bay of Fundy, is the effects of shoaling and funneling, which reduce the cross-sectional area of the Bay by a factor of two between Grand Manan Channel at the mouth of the Bay to Saint John, NB, and again by a factor of two near Cape Chignecto, where the Bay of Fundy splits into Minas Channel to the south and Cobequid Bay to the north. Further shoaling and narrowing within these embayments leads to the highest tidal ranges in the world, averaging 12 m, and attaining 15-16 m during the highest spring tides.

1.2 **Survey Approach and Organization of Report**

An initial "long list" of 40 potential TISEC sites (Appendix A) was developed based solely on the potential magnitude of the local tidal in-stream energy resource, as characterized in one or more of the following four references (see Section 4 for full citations):

- Manuscript by Dr. David Brooks, a physical oceanographer at Texas A& M University, who has conducted extensive numerical modeling and circulation studies of Cobscook and Passamaquoddy Bays, submitted for 2005 publication in the journal, *Renewable Energy*. (Reference 2)
- *Tidal Power Inventory of the Maine Coast*, 1985. Prepared by the Maine Office of Energy Resources. (Reference 3)
- *NOAA Tidal Current Tables*, 2005. (Reference 4)
- *Coast Pilot*, 2005 . (Reference 5)

Based on preliminary feedback from the Maine Advisory Group and interested stakeholders, ten potential sites were selected from the initial long list for further characterization in Section 3 of this report. These ten sites are identified on a Maine map in Figure 1.2-1 and listed below, together with the nearest coastal or river town cable of providing maritime support services (as described in Section 2) to a potential tidal in-stream energy conversion project at that site.

Bangor Hydro Electric Service Area

Lubec Narrows, Eastport (potential for joint U.S-Canada collaborative project)

Western Passage, Eastport (potential for joint U.S-Canada collaborative project)

Outer Cobscook Bay entrance, Eastport

Taunton Bay, West Sullivan

Central Maine Power Service Area

Bagaduce Narrows, Castine

Penobscot River, Bucksport

Cowseagan Narrows, Wiscasset

Kennebec River entrance, Bath

Ewin Narrows (northern Harpswell Sound) – Portland

Piscataqua River, Kittery

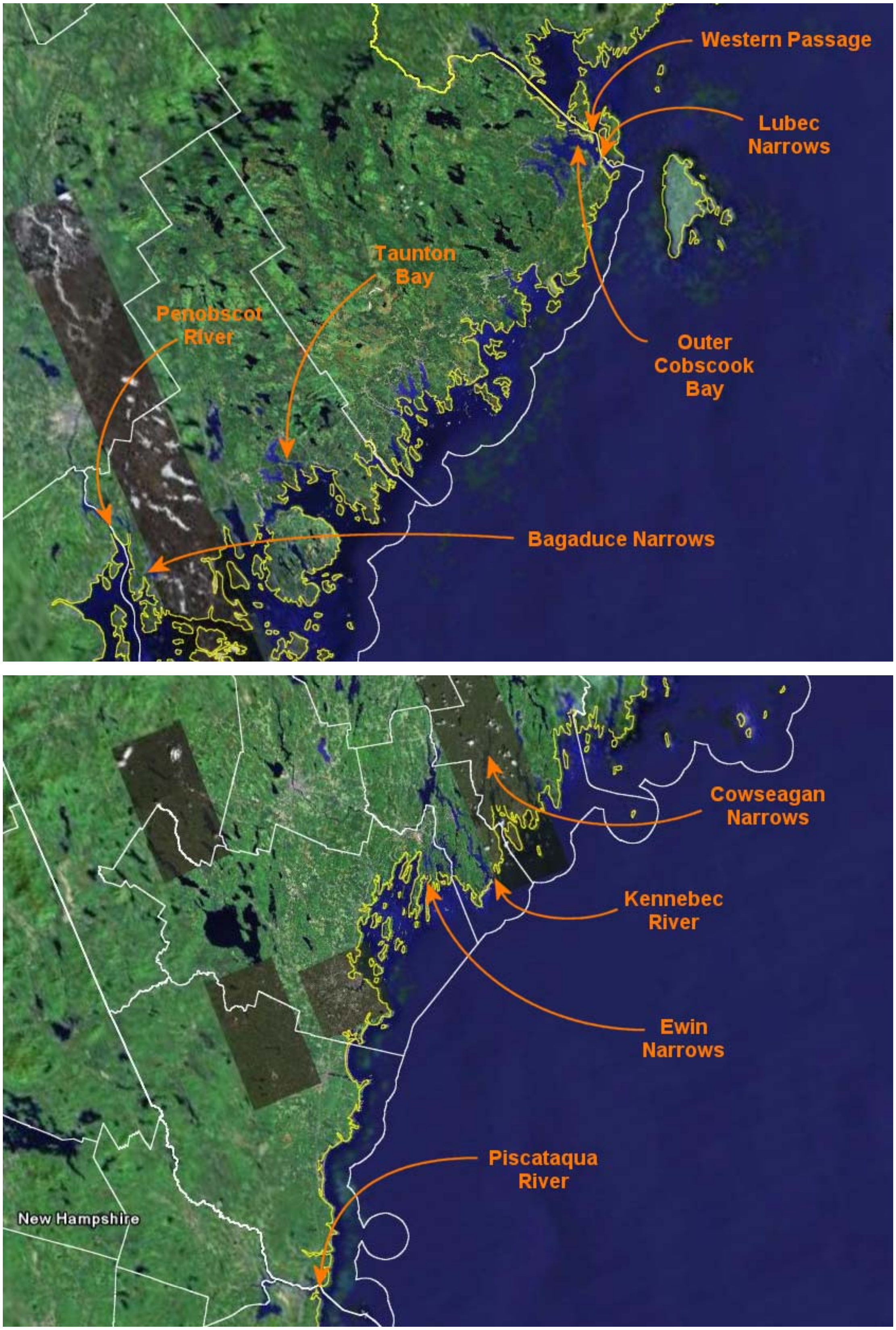


Figure 1-3. Maine map showing ten potential TISEC project sites surveyed in this report.

Section 2 of this report describes the site attributes that were used to characterize each of the above ten sites for Advisory Group evaluation of their potential suitability for a TISEC project. Section 3 characterizes each of these sites according to these attributes, which include magnitude of tidal in-stream energy resource, seafloor geology, grid interconnection, nearby maritime infrastructure and harbor support services, potential conflicts with other uses such as navigation and commercial fishing, environmental issues, and possible unique opportunities associated with a particular site. Finally, a list of references cited is provided as Section 4.

2. Site Selection Criteria

The site selection criteria used in this assessment are:

1. Tidal current energy resource attributes (annual average energy flux per unit aperture area of TISEC device, and in-stream power density at ebb and flood peak flows)

2. Candidate site bathymetry and seafloor geology suitable for TISEC device foundation or anchoring system and submarine cable routing to shore (bottom composition, potential for sediment mobility under severe conditions, and bottom changes over time)

3. Coastal utility grid and substation loads and capacities, and availability of a suitable onshore grid interconnection point with a capability of handling the 500 kW pilot plant supply and with potential for growth to a 10 MW commercial plant.

4. Nearby regional shipyard labor and infrastructure for device fabrication and assembly, with sufficient local maritime infrastructure and harbor service vessels for system deployment, retrieval, and offshore servicing or in-harbor repair

5. Minimal conflict with competing uses of sea space (navigation channel clearance and maintenance dredging activities, commercial and sport fishing, protected marine areas) and likelihood of public acceptance

6. Unique opportunities to minimize project costs and/or attract supplemental funding, such as:
   - Existing utility easement which can be used to route power cable and shore crossing
   - High local demand and growth forecast, where installation of local generation source could eliminate need for distribution or transmission line upgrade
   - Plans for a roadway/railway bridge to cross a tidal channel yielding the opportunity to integrate and "buy down" the capital cost of civil works
   - Local public advocacy for project and highly-visible public education opportunity

In addition to selecting a site that has favorable attributes among the criteria listed above, it also is important that a site be appropriate to the selected device. As described below, water depth and turbine spacing requirements may significantly constrain the number of full-scale devices that can be accommodated within a particular tidal inlet or channel. Indeed, depth and width constraints may limit a site's development potential to a greater degree than constraints on tidal stream energy withdrawal.

It is not the intent of this site survey report to describe the dimensions for every device, as this information is presented in the 003 Device and Technology Survey Report. Instead two examples are used to illustrate the types of device-specific issues that must be considered to ensure that the selected site is well matched to the selected device. Section 2.1 deals with channel depth requirements, and Section 2.2 deals with project area requirements.

2.1. Water Depth Requirements

Two example devices are considered, Marine Current Turbines' 1.2 MW twin-rotor device, which is supported by a monopile foundation, and Lunar Energy's 1.5 MW ducted turbine, which is installed on a gravity base.(note that both MCT and Lunar devices are scaleable in size)

Marine Current Turbines (MCT) employs a monopile foundation, as is commonly used for offshore wind energy projects in Europe. One of MCT's founding investors is Seacore, Ltd., a UK-based company specializing in non-oilfield marine drilling. Seacore has installed monopile foundations for at least five offshore wind energy projects, as well as MCT's Seaflow project.

A search of Seacore's project Web page at http://www.seacore.co.uk/categories.php?pID=86 indicated that their monopile technology has been applied mainly in firm seabeds of rock or hard clay. Any sediment overburden is "drilled through" and the monopile is grouted into a socket of 10 to 15 m penetration depth into the underlying bedrock (see Figure 2.1-1, below).

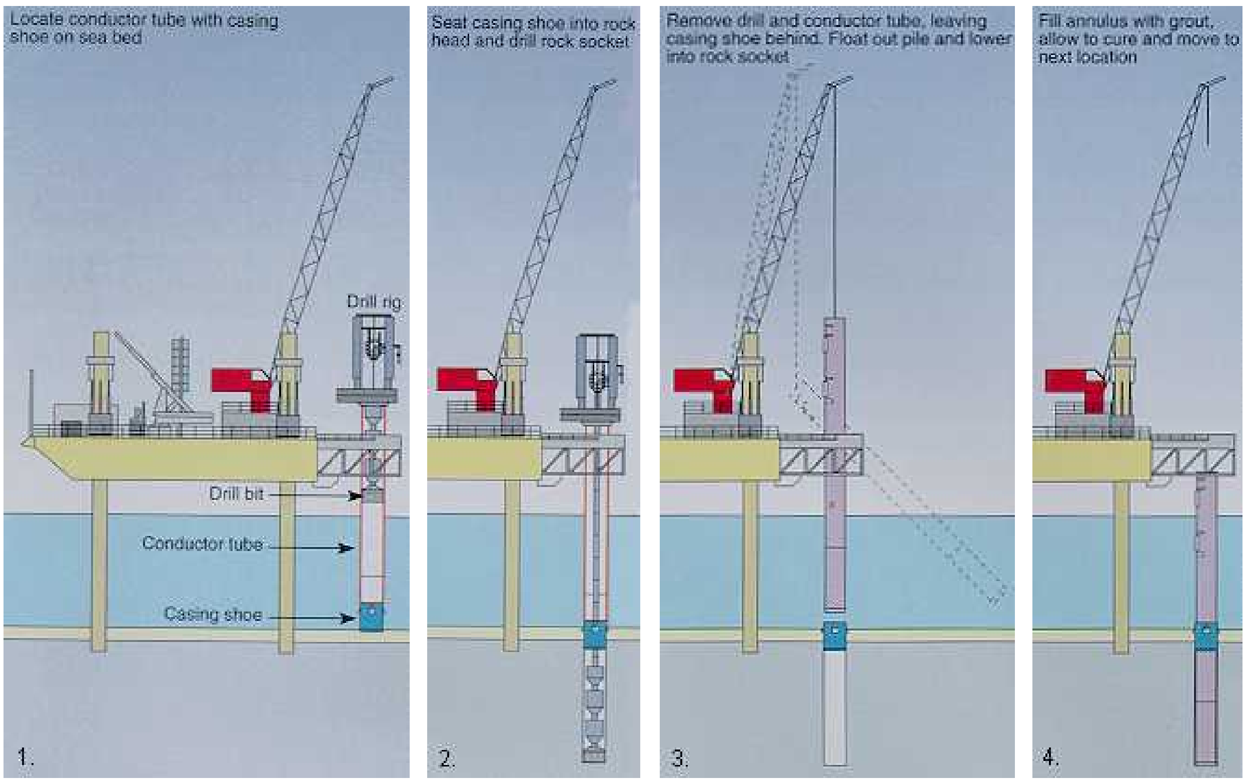


Figure 2.1-1. Monopile foundation installation sequence.

Seacore's jack-up barges can operate in water depths up to 30 m. Offshore wind energy cost models and feasibility studies indicate that monopile material and installation costs increase dramatically in water depths beyond 25 m. In deeper waters, MCT undoubtedly can apply the alternative fixed foundation concepts being investigated for offshore wind energy in 30-50 m water depths, such as the tripod, but these have not yet been proven in the ocean. Therefore, for purposes of the EPRI Phase I study, a monopile foundation concept is assumed.

For the 16-m rotor diameter of MCT's 1.2 MW Seagen device, a minimum water depth of 18 m would be required. MCT's Web site indicates that the required depth range for their commercial device is 20 to 30 m (http://www.marineturbines.com/background.htm), which is consistent with the above analysis.

By comparison, Lunar Energy's 1.5 MW ducted turbine has a minimum water depth requirement of 35 m (http://www.lunarenergy.co.uk/pdf/lunar_energy_brochure.pdf). This PDF brochure indicates the following specifications for their 1.5 MW unit to be as follows:

- Duct inlet diameter: 21 m
- Turbine diameter: 16 m
- Distance from seafloor to lower edge of duct: 8 m
- Minimum depth required: 35 m

These company specifications give an overhead clearance of 6 m, which is more than adequate to accommodate transiting commercial fishing vessels, ferries, most coastal research vessels, recreational motor vessels, and deep-keeled sailing vessels.

For channels and inlets used by oceangoing commercial shipping, including cruise ships and bulk carriers, which can have drafts of 35 to 45 feet, a minimum clearance of 15 m would be required at extreme low water. Thus the depth required to accommodate the Lunar 1.5 MW turbine and oceangoing vessels passing overhead would be 44 m.

For Lunar's 2 MW unit, the following specifications are given in the EPRI 003 Device and Technology Survey Report:

- Duct inlet diameter: 25 m
- Turbine diameter: 19.5 m
- Total height above seafloor: 33 m (109 ft)

These specifications imply that for the 2 MW Lunar turbine, a minimum depth of 38 m would be required in channels or inlets used by transiting commercial fishing vessels, ferries, most coastal research vessels, recreational motor vessels, and deep-keeled sailing vessels. In passages used by oceangoing commercial vessels, the minimum depth requirement would be 48 m.

2.2. Turbine Spacing and Project Area Requirements

According to Reference 6, environmental impact studies of the MCT device assume that turbines with diameters of 15.85-metres would be spaced out some 60-metres apart. This would leave a minimum gap of 44 metres from blade tip-to-tip. The turbines would be positioned 1000-metres downstream from each other in order to reduce the negatives effects on performance caused by turbulence (wake effects) and allow for the tidal streams to restore themselves. These spacings yield an installed capacity density of 21.6 megawatts (18 units x 1.2 MW) per km^2.

No information is available on the cross-channel spacing requirements for Lunar Energy's ducted turbines, but the units should be placed far enough apart on sediment bottoms to avoid excessive scouring due to flow acceleration between the ducts. Pending receipt of device-specific information, an upstream-downstream spacing of 1,000 m is assumed between rows.

3. Site Survey and Characterization

This section describes the attributes of each potential project site. Survey summary tables, listing key attributes in each category, are given first. Table 3-1 estimates the tidal in-stream energy resource and potential installed TISEC project capacity. Table 3-2 characterizes the seafloor geology, grid interconnection distances, and local maritime support infrastructure. Table 3-3 identifies potential conflicts with other uses, and unique opportunities.

Table 3-1. Summary of Site Energy Resources

	Tidal In-Stream Power Density Averages			Channel Cross Sectional Flow Area (= B)	Total Annual In-Stream Energy Base (= A x B x 8766 hrs/yr)	Total TISEC Project Rated Capacity at 15% Energy Withdrawal *
Site Name	Peak Flood Flows Only	Peak Ebb Flows Only	Entire Flow Distribution (= A)			
Lubec Narrows	8 kW/m^2	16 kW/m^2	5.5 kW/m^2	750 m^2	36,000 MWh	1.2 MW
Western Passage	5.1 kW/m^2	4.6 kW/m^2	2.2 kW/m^2	16,300 m^2	314,000 MWh	10.8 MW
Outer Cobscook Bay	4.6 kW/m^2	4.6 kW/m^2	1.64 kW/m^2	14,500 m^2	23,800 MWh	7.1 MW
Taunton Bay	No measured or modeled current data					
Bagaduce Narrows	5.2 kW/m^2	5.2 kW/m^2	1.94 kW/m^2	400 m^2	780 MWh	230 kW
Castine Harbor	No measured or modeled current data			4,300 m^2	No measured or modeled current data	
Penobscot River	0.2 kW/m^2	3.3 kW/m^2	0.73 kW/m^2	5,000 m^2	3,650 MWh	1.1 MW
Cowseagen Narrows	8.7 kW/m^2 (based on *Coast Pilot* anecdotal reports of 5-knot peaks)		No measured or modeled current data			
Kennebec River Entrance	1.0 kW/m^2	1.7 kW/m^2	0.44 kW/m^2	990 m^2	440 MWh	130 kW
Ewin Narrows	No measured or modeled current data					
Piscataqua River	3.3 kW/m^2	5.9 kW/m^2	1.48 kW/m^2	2,300 m^2	3,360 MWh	1.0 MW

* Note: This calculation assumes the project withdraws 15% of the Total Annual In-Stream Energy given in the next-to-last column, 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.

Table 3-2. Summary of Site Geological and Geographic Attributes

	Bathymetry and Geology		Grid Interconnection Distances		Maritime Support Infrastructure in Nearest City or Town on Same Waterway
Site Name	Channel Depth	Seafloor Properties	To 34.5 kV or 115 kV (10 MW Plant)	To 12.5 kV (500 kW Plant)	
Lubec Narrows	18-20 ft	Rock	2.5 miles	Very close	Moderately extensive in Eastport
Western Passage	180-240 ft	Gravel/mud, rock, rock/gravel	0.5 mile	0.5 mile	Moderately extensive in Eastport
Outer Cobscook Bay	60-120 ft	Gravel/mud over rock	1 mile	Very close	Moderately extensive in Eastport
Taunton Bay	18-24 ft	Mud	5 miles	Very close	Needs development
Bagaduce Narrows	9-12 ft in Narrows 60-80 ft off Castine	Mud Mud over rock	16 miles	3 miles	Probably adequate in Castine
Penobscot River	60-70 ft	Mud	3 miles	0.5 mile	Moderately extensive in Bucksport
Cowseagen Narrows	15-30 ft	Mud over rock	3 miles	3 miles	Probably adequate in Wiscasset
Kennebec River Entrance	30-60 ft	Sand over rock	13-15 miles	0.5 mile	Very extensive in Bath
Ewin Narrows	18-20 ft	Mud over rock	14 miles	2.5 miles	Very extensive in Portland
Piscataqua River	35-45 ft	Sand or mud	3 miles	Very close	Very extensive in Portsmouth / Kittery

Table 3-3. Summary of Site Societal Attributes

Site Name	Key Potential Conflicts	Unique Opportunities
Lubec Narrows	Minimal (high currents limit other uses)	Bridge for cable landfall. Possible joint ME-NB project.
Western Passage	May be minimal in central channel due to high currents and depth, but commercial scallop dragging and recreational groundfishing may represent potential conflicts to be resolved early in the planning phase.	Possible joint ME-NB project.
Outer Cobscook Bay	Heavy use by fisheries, aquaculture, and boaters, with particularly high probability of conflict with scallop draggers.	Existing submarine telecomm cable corridor.
Taunton Bay	Existing focus of DMR pilot management project. Access to shellfish flats.	Bridge for cable landfall.
Bagaduce Narrows	Limited lobstering and sport fishing, so less conflict than other sites. Adjacent land to Bagaduce Narrows is privately owned. Castine Harbor very busy mooring area.	Workforce training and international exposure via Maine Maritime Academy.
Penobscot River	Navigation (major port, relatively shallow). Potential conflict with both commercial shipping and recreational boating.	Bridge for cable landfall. Observation tower potential for public visibility and education
Cowseagen Narrows	Heavy use by recreational boaters (shallow). Heavy lobstering and potential for entanglement by traps in heavy flows.	Bridge for cable landfall.
Kennebec River Entrance	Navigation (shipyard traffic, relatively shallow). Maintenance dredging. Busy mooring areas off Popham Beach and Bay Point.	None identified.
Ewin Narrows	Commercial and recreational boat anchorage (shallow). Heavy lobstering and potential for entanglement by traps in heavy flows.	Bridge for cable landfall.
Piscataqua River	Navigation (major port, relatively shallow)	Bridge for cable landfall.

Detailed information supporting the above summary tables is given in the remainder of this section, with about 5 or 6 pages of text and figures per site.

3.1 Lubec Narrows – Eastport

Lubec Channel and Lubec Narrows, between Quoddy Narrows and Friar Roads, have been improved by dredging. In 1977, the controlling mid-channel depth at mean lower low water (MLLW) was 10 feet. The channel is marked by a light and buoys. During spring tides the low water may be 3 or 4 feet below MLLW. A reference map is given below.

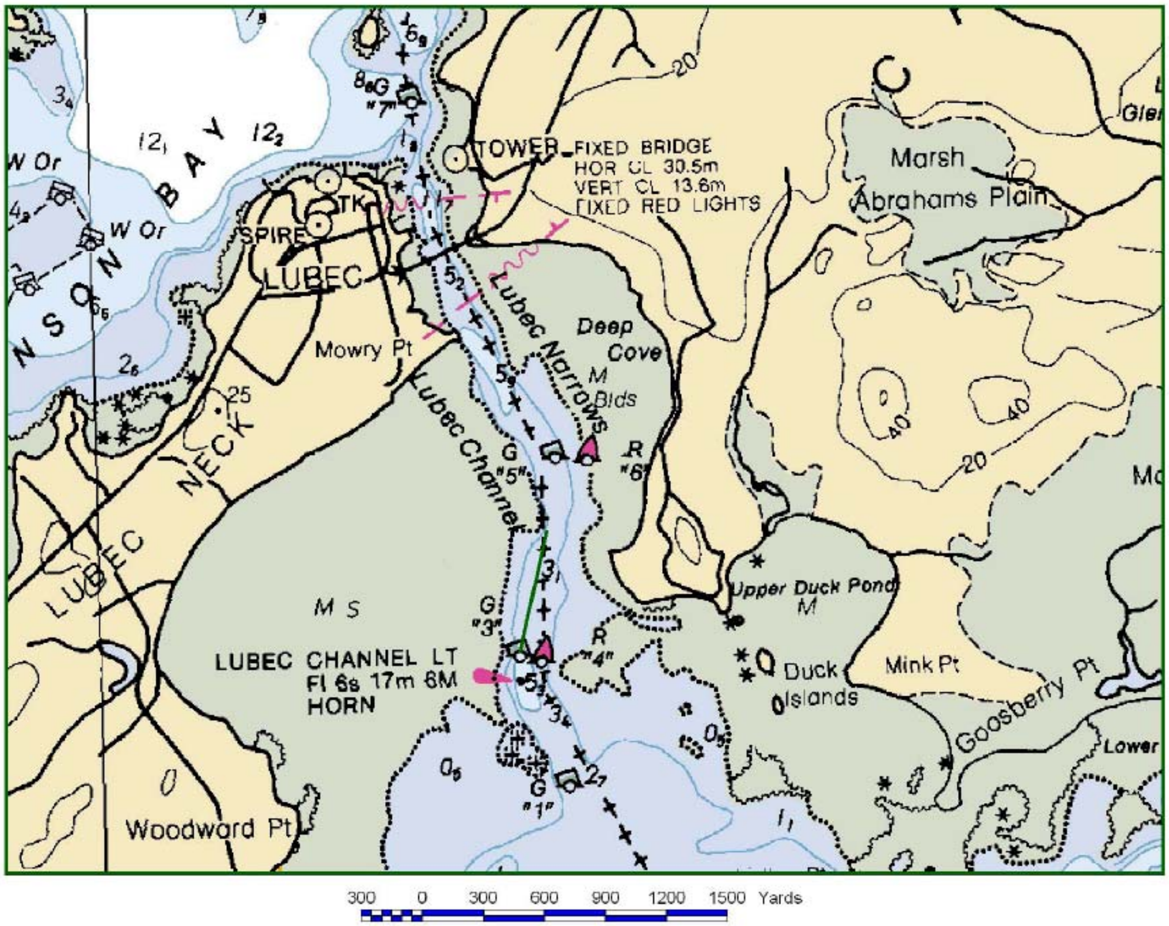


Figure 3.1-1. Location map for Lubec Narrows site (Reference 6).

At low tide, shoals bare on both sides of Lubec Narrows. The Franklin D. Roosevelt Memorial Highway Bridge crosses the narrows from Lubec to Campobello Island at a point about 400 yards southward of the abandoned lighthouse on Mulholland Point. The fixed span has a clearance of 47 feet, with 100 feet between the piers in the channel. Another breakwater extends from the shore to Gun Rock and 75 yards eastward of the rock on the west side of the channel at the north end of the narrows. This breakwater is marked by a white pyramid midway along its length. The breakwater covers at extreme high water. A ledge extending about 150 yards north-northeasterly from Gun Rock has 7 feet over it and is marked on its north end by a buoy.

Lubec is a small town on the west side of Lubec Narrows. Settled in 1785 and incorporated in 1811, Lubec is the easternmost town in the continental United States. Its principal industries are fishing and the canning and smoking of herring. The port has two fish canning factories with wharves that bare alongside at low water.

An L-shaped 250-foot pier about 0.2 mile northward of the Roosevelt Memorial Bridge is used to unload fishing boats. It has 2 feet alongside its outer face, and a suction pump is utilized to unload the boats. There is a 2,400-square-foot storage and transfer shed at the head of the pier. Boats usually unload along the outer end of the southern side of the pier at or near high water.

Another L-shaped commercial fishing wharf, 170-foot-long with a 62-foot face, is on the north Lubec waterfront. The depths alongside are reported to be 14 feet, with 6 feet along the outer face. A public small-craft launching ramp with an adjoining float landing is about 250 yards eastward of this wharf.

3.1.1 Tidal In-Stream Energy Resource

As previously mentioned, Reference 1 describes numerical model results that estimate the tidal in-stream power density in Passamaquoddy and Cobscook Bays, including Lubec Narrows. The results of Reference 1 indicate a marked difference in flow velocity between flood and ebb currents in Lubec Narrows, with flood current peaks averaging 3.3m/sec (6.4 knots), and ebb current peaks averaging 4.2m/sec (8.2 knots). Since in-stream power density is proportional to the cube of flow velocity, this asymmetry results in ebb tidal in-stream power densities that are approximately twice as high as flood power densities, as shown in Figure 3.1-2.

The numerical modeling results of Reference 1 are in general agreement with the 2005 *Coast Pilot* (Reference 5), which offers the following narrative:

> Through Lubec Narrows, the flood current sets northward, following the general trend of the channel; southward of the narrows it has a velocity of about 4 knots at strength, but in the narrows it attains a velocity of about 6 knots during the spring tides. The ebb sets southward, following the general direction of the channel, and in the narrows has a velocity of about 8 knots during spring tides. Below the narrows its velocity is about 4 knots, and the set is in the general direction of the channel. The currents at strength form dangerous eddies on both sides of the channel in the narrows; these are avoided by keeping in midchannel. The duration of slack in the narrows is only 5 to 15 minutes.

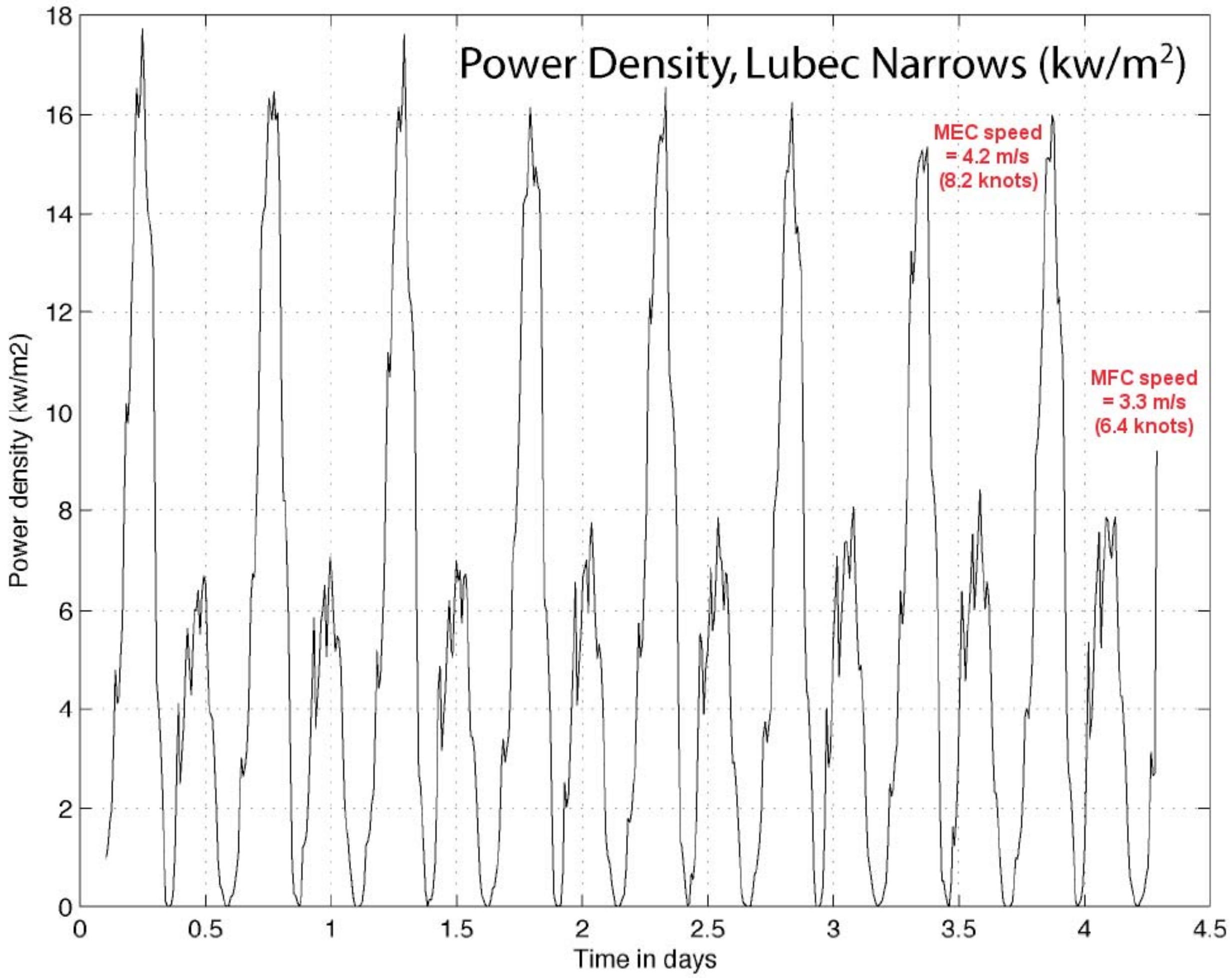


Figure 3.1-2. Tidal in-stream power density in Lubec Narrows under average tidal conditions. Maximum Ebb Current (MEC) speed averages 8.2 knots, and Maximum Flood Current (MFC) speed averages 6.4 knots, but respective power densities differ by a factor of two (Reference 1).

It also should be noted that the numerical model of Reference 1 indicates higher current speeds on the U.S. side of Lubec Narrows because of how Treat and Dudley Islands direct water flow into and out of Cobscook Bay. This is shown for the time of peak flood in Figure 3.1-3.

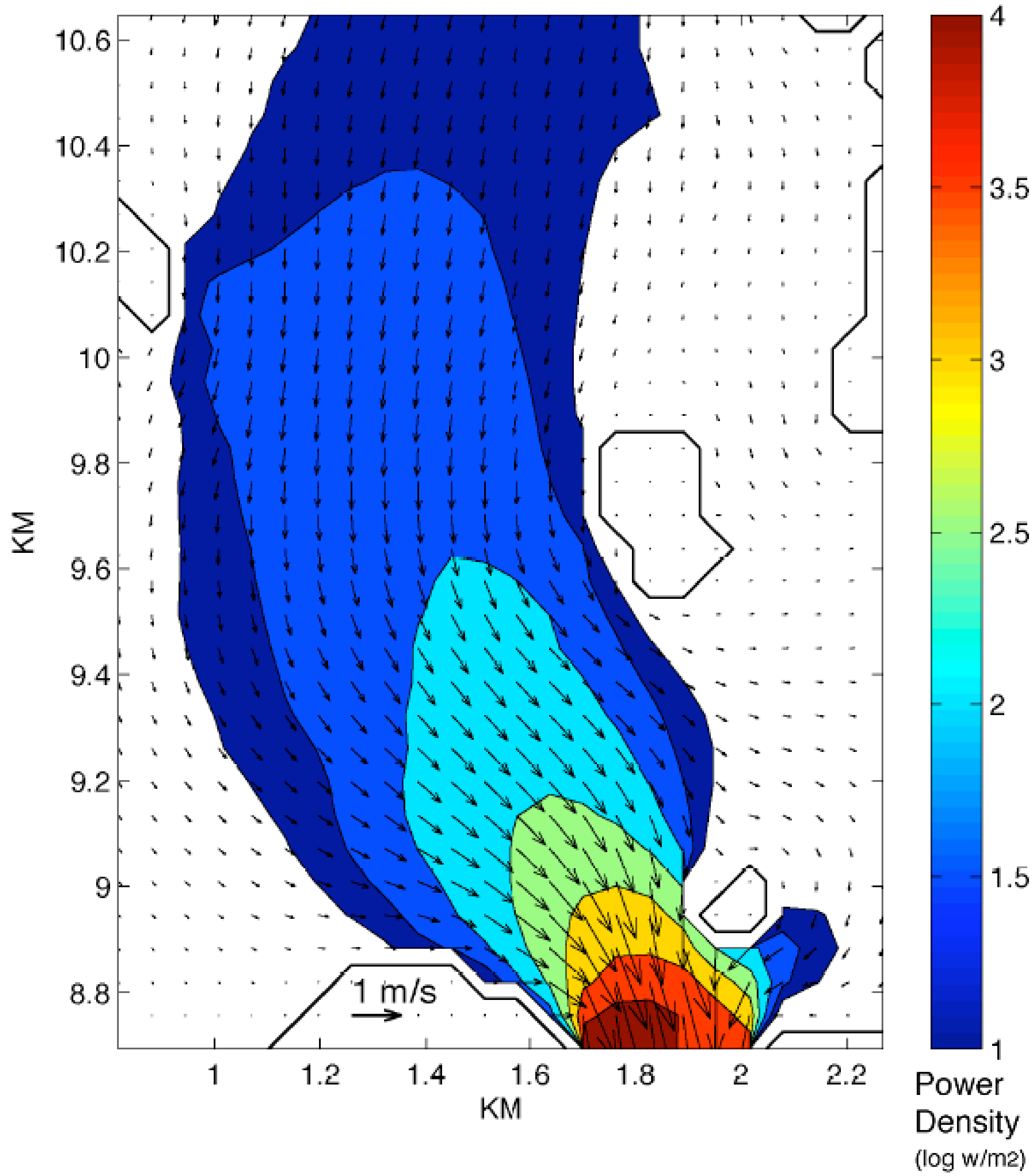


Figure 3.1-3. Tidal in-stream power density, mapped as the base-10 logarithm of watts per square meter of flow cross-sectional area, during peak ebb flow in Lubec Narrows, under average tidal conditions. Note that the peak ebb power density is on the order of 10 kW/m^2 on the American side, compared to 3 kW/m^2 on the Canadian side (Reference 1).

3.1.2 Tidal Channel Bathymetry and Geology

A bathymetric map of Lubec Narrows and Lubec Channel is given below.

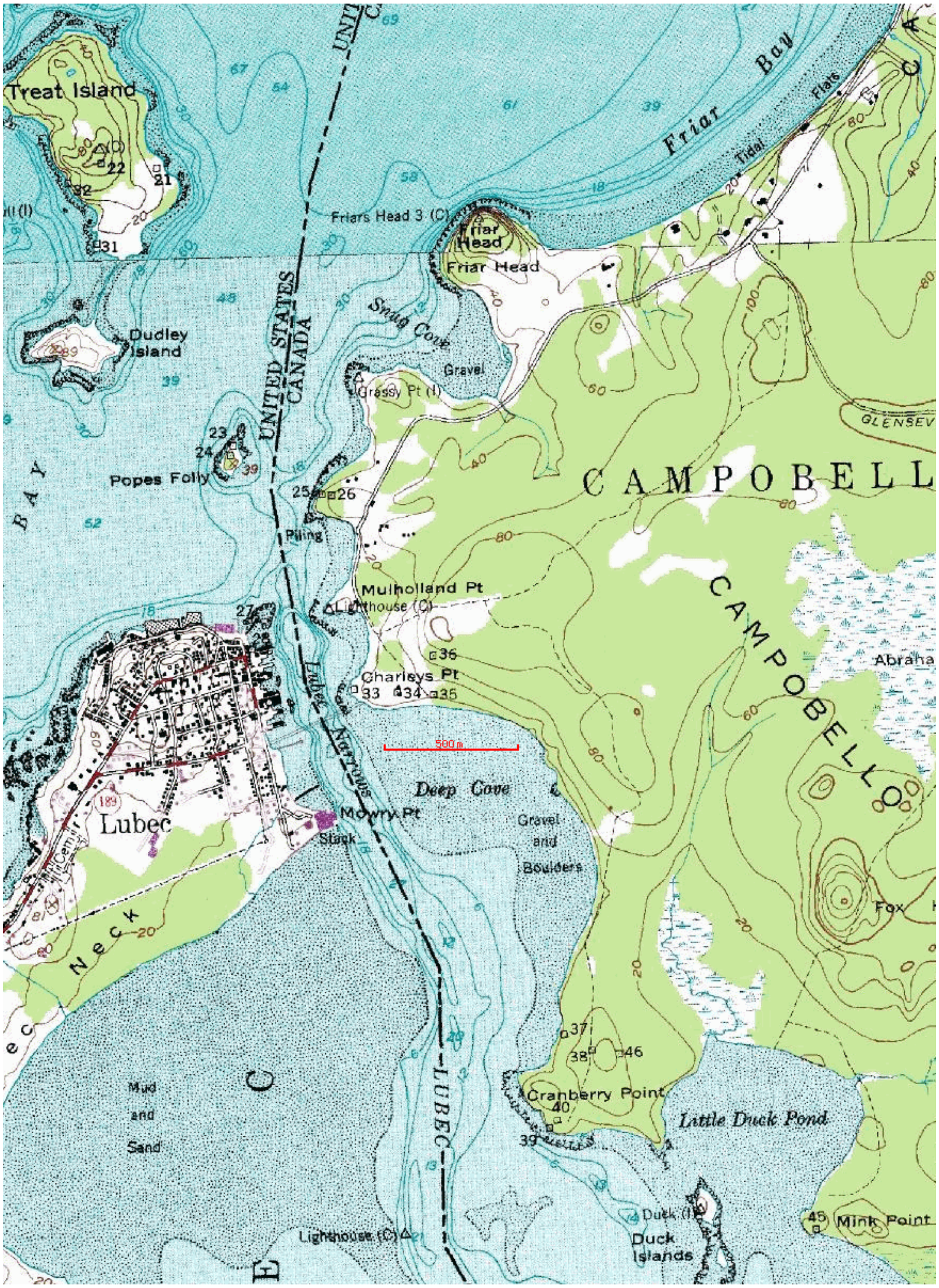


Figure 3.1-4. Bathymetric chart of Lubec Narrows and Lubec Channel as far south as Duck Islands. Note 200 m long deep area between Mulholland Pt. and Charleys Pt., and 800 m long deep area from beneath the Roosevelt Memorial Bridge, extending 300 m south of Mowry Pt. (Reference 7).

A geological map characterizing the surface properties of the seafloor in the northern part of Lubec Narrows and Friar Roads is given below.

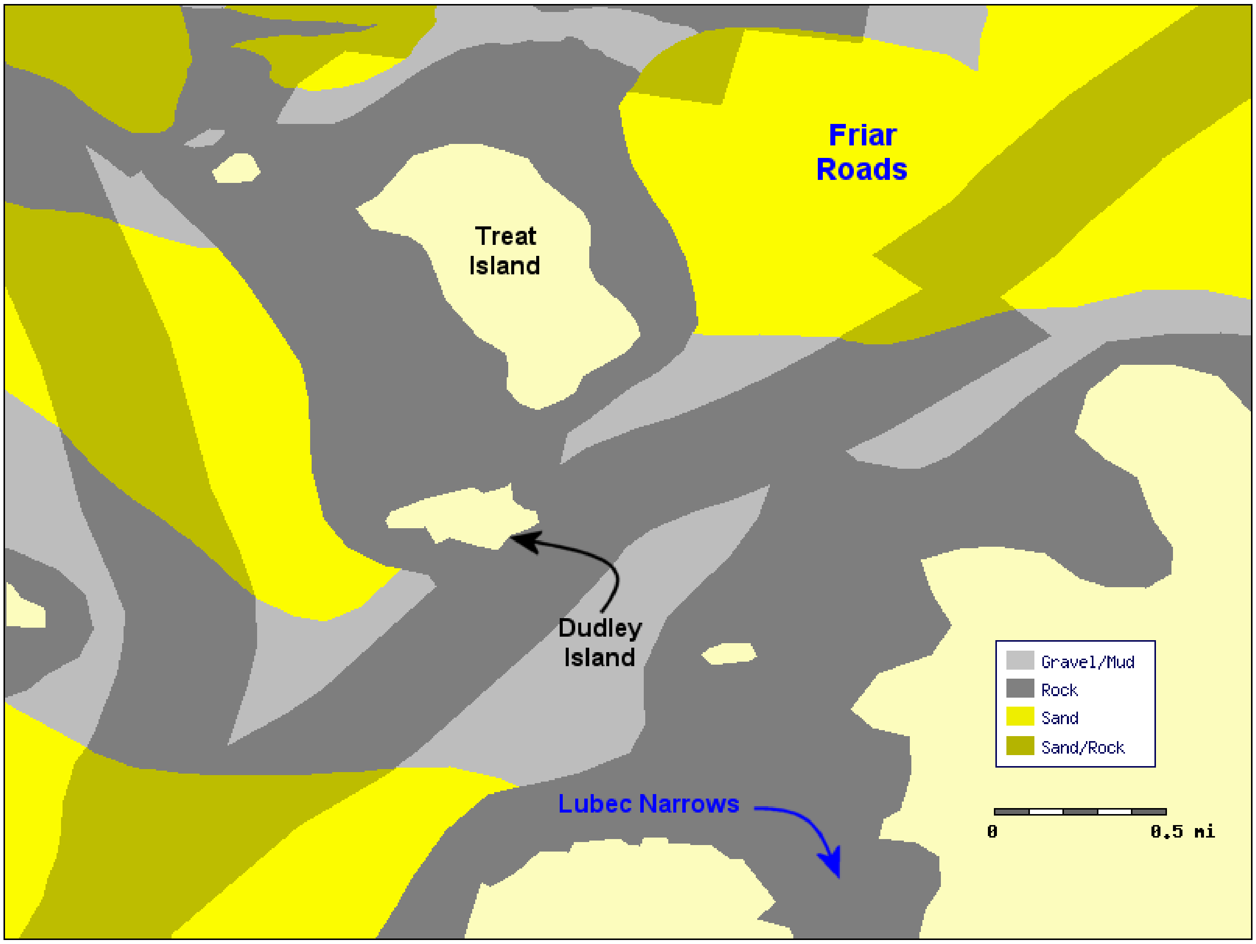


Figure 3.1-5. Surficial geology of northern Lubec Narrows and Friar Roads (Reference 8).

The above map indicates that the seafloor in the northern part of Lubec Narrows is exposed bedrock. A geological map of Lubec Neck and the shoreline south of Lubec Narrows (shown in Figure 3.1.6) indicates that the seafloor in the southern part of the Narrows and in Lubec Channel is likely to be glaciomarine mud and terminal moraine sands and gravels.

The bedrock includes the Quoddy Formation, consisting of dark-colored shale and argillite, and abundant gabbro and diabase intrusions dating back to the Silurian Period, approximately 415 to 440 million years ago. Glacial sediment rests on the bedrock and was deposited by melting ice around 14,000 years ago. Till, a poorly sorted deposit of boulders, cobbles, sand and mud, makes up Lubec Neck and is well exposed at the town gravel pit on Route 189.

Glaciomarine muddy sediments, containing fossils from 14,000 to 12,000 years old, covers the till in most places indicating the flooding of coastal Maine by the sea as the glacier retreated. This glaciomarine mud is now widely exposed along the coast in the faces of eroding bluffs.

In a few places, a layered sand and gravel deposit overlies the glacial-marine sediment. This material is thought to represent coastal beach or nearshore deposit formed when sea level fell across the present shoreline between about 11,000 and 10,000 years ago, reworking the coarser sediments of glacier terminal moraines. Where the marine sand and gravel is absent, a peat deposit often covers the glaciomarine mud. as at Carrying Place Heath.

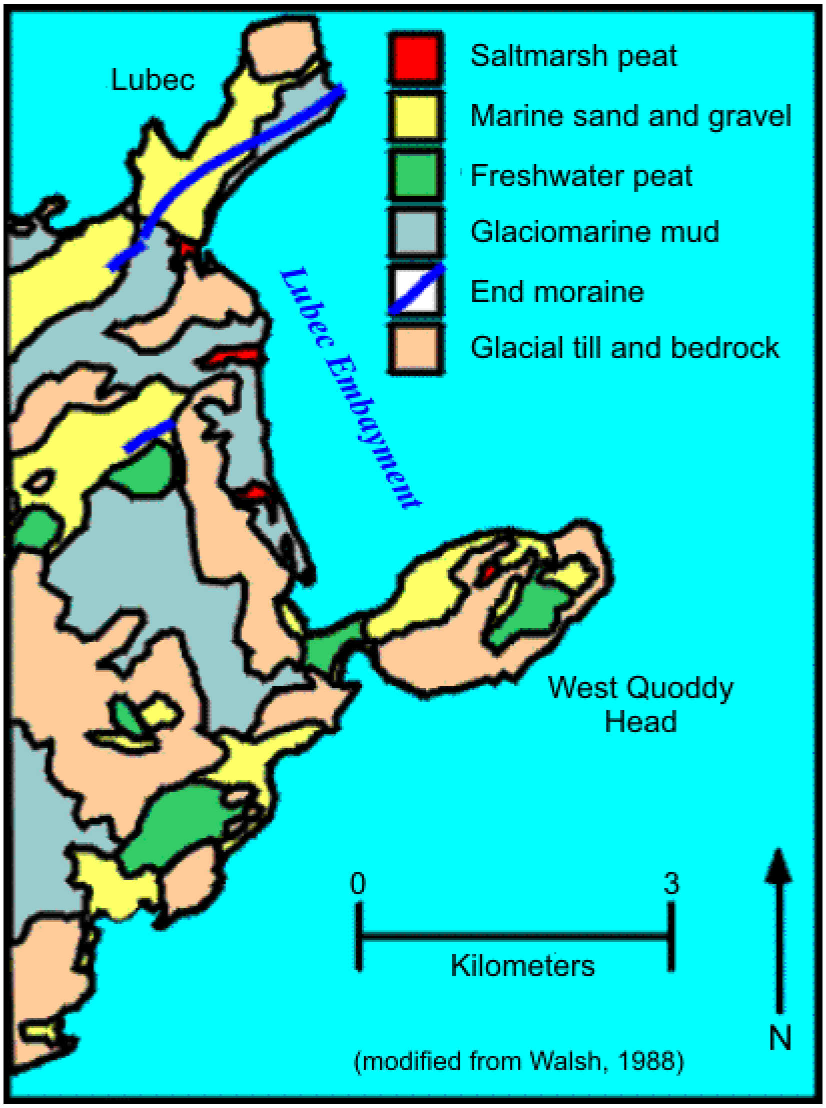


Figure 3.1-6. Geologic map of shoreline bordering the Lubec Embayment between Lubec Neck and West Quoddy Head (Source: Reference 9).

3.1.3 Utility Grid Interconnection

Lubec is served by Bangor Hydro-Electric Company (BHE). A BHE system interconnection map for Lubec is given below. Interconnection points for a 500 kW pilot plant at the 12.5 kV distribution level are readily available onshore. The closest 34.5 kV interconnection point for a 10 MW commercial scale plant is located about 2.5 miles from the Narrows shore side.

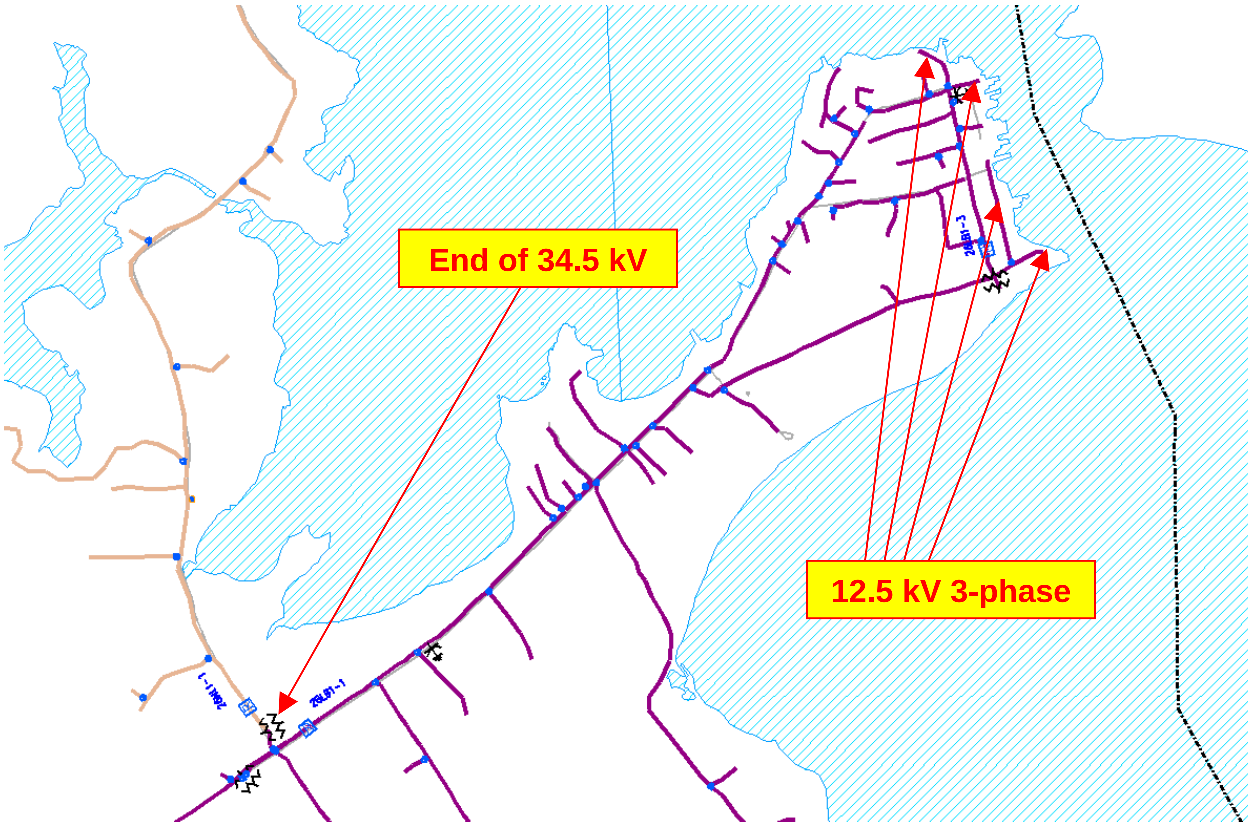


Figure 3.1-7. BHE utility grid in Lubec (Source: Bangor Hydro-Electric Company).

3.1.4 Maritime Support Infrastructure

There are no regular boat repair facilities at Lubec. Due to the large tidal range, boatmen usually ground out their vessels for below-the-waterline repairs at low tide. Diesel fuel is available by truck at the cannery wharf 200 yards north of the bridge. Ice, prov north end of the harbor. Boats usually moor along the inner face of the breakwater. In fair weather, berthing is also possible along the east and north (seaward) faces of the breakwater in depths of 36 feet and 6½ to 10 feet, respectively. Forest products are loaded along the east face. Electricity is available at all the berths, and diesel fuel can be delivered by truck on short notice. The breakwater is floodlighted at night.

The only active cannery along the waterfront, 100 yards north of the breakwater, has a wharf with 65-foot face and 1 to 5 feet alongside. Fresh water is available on the wharf. The Port of Eastport offers general cargo dockage at the Breakwater Pier. The 420-foot facility can accommodate vessels with a draft up to 36 feet.

A machine shop in the port handles repairs to small-craft gasoline or diesel engines. Electrical repairs can be made. Small vessels are usually grounded out at high water for hull repairs after the tide falls. There is a private facility for hauling out craft up to 40 feet in length and a boatbuilder who makes hull repairs.

Pilotage is compulsory for all foreign vessels, and for U.S. vessels registered in foreign trade with a draft of 9 feet or more. Pilotage is optional for fishing vessels and vessels powered predominately by sail. Two tugs up to 2,400 hp are available at Eastport. Additional information about pilotage, towage, and the port can be obtained from Eastport Port Authority at P.O. Box 278, Eastport, ME. 04361, telephone 207-853-4614.

There is no railroad service to Eastport, but a good highway parallels the St. Croix River to Calais. There is a municipal airport at Eastport.

3.1.5 Competing Uses of Sea Space

The most important potential competing uses of sea space in Lubec Narrows and Lubec Channel are interference with small boat navigation, channel maintenance dredging, commercial fishing (lobstering), and aquaculture (salmon farming). The endangered North Atlantic Right Whale is reported to occur in Lubec Narrows, although this does not seem to be a common occurrence. Each of these issues is described briefly below.

Navigation: The principal navigation entrance to Passamaquoddy Bay is around the northern end of Campobello Island through Head Harbour Passage. This passage is deep and generally clear of dangers. The channel through Lubec Narrows is also used, especially at high water, although not by deep-draft oceangoing vessels.

Channel Maintenance Dredging: Sporadic maintenance dredging occurs in the main channel through the center span of the Roosevelt Memorial Bridge.

Lobstering: Unlike southern Maine where it is common to fish trawls of 10-15 pots, lobstermen in the Lubec area fish ‘doubles’ and ‘triples’, i.e., only two or three traps per set of buoys, which is the maximum number that can be effectively handled in the 45-minute window typically available to work traps during slack water. Lobstermen here put up to100 lbs. of weight in a trap to keep it from being moved around by the unusually strong currents (Reference 10). Because slack water in Lubec Narrows lasts only 5 to 15 minutes, traps are more common to the north, in Johnson Bay and Friar Roads, and to the south, in Lubec Channel.

Salmon Farming: Locally-farmed salmon are first reared in a freshwater hatchery for about eighteen months, during which time they go through a physiological change known as smoltification. This makes these anadromous fish ready for life in the sea. As smolts, they are then transferred to farm pens in Johnson, Cobscook and Passamaquoddy Bays, where they spend the next eighteen to twenty-four months growing large enough to harvest for market. Salmon aquaculture first began in Canada and quickly spread to the United States during the mid-1980s. Pen aquaculture succeeded in the region in large part because of the flushing action provided by the unusually high tides and currents in the region (Reference 10).

Although salmon pens are not found in Lubec Narrows, a potential conflict would arise if excessive amounts of tidal current energy were withdrawn from the natural flows that make salmon farming possible. Limiting tidal in-stream energy projects to withdrawing no more than 10 to 15% of the cross-sectional base resource should avoid this potential negative impact.

Endangered Species: The Bay of Fundy is a feeding and nursery area for the endangered North Atlantic Right Whale. Mother and calf pairs and courtship groups of right whales may occur in the following areas: north along the New Brunswick coast, along the Campobello-White Horse coast, the Lubec Narrows, the Wolves, and along the Grand Manan coast (close to shore from White Head to Swallowtail). The peak months for such occurrences are June-July and September-December.

When right whales first arrive in the Bay of Fundy in early summer, their distribution tends to be dynamic, with animals often occurring in shallow water close to shore. Similar spreading out of the population occurs in the fall, when they are sometimes seen in very shallow areas, including Lubec Narrows and the ledges south of Grand Manan (Reference 11).

Conversations with Lubec watermen in August 2005 suggested that the occurrence of right whales in the Narrows must be rare, as nobody could recall seeing one. It is more likely that reported sightings were in the shallows of Lubec Channel, to the south.

3.1.6 Unique Opportunities

Lubec Narrows offers one of the most accessible sites for public visibility among the eight potential sites surveyed in New Brunswick. Although Cape Enrage and the entrance to Cumberland Basin also offer significant opportunities for public education via interpretive displays at existing or planned educational facilities, those sites are comparatively remote from well-traveled highways. By comparison, Lubec Narrows is literally a “stone’s throw” from the only bridge to Campobello Island, with its popular tourist destinations of Roosevelt Campobello International Park, Herring Cove Provincial Park and Golf Course, and East Quoddy Head Lighthouse, as well as the resort and fishing communities of Welshpool, Wilsons Beach, and Head Harbour. Over 100,000 visitors cross the Roosevelt International Memorial Bridge to Campobello Island each year.

Even more importantly, Lubec Narrows offers three possible locations where a public walkway leading out to a demonstration project could be constructed at relatively low cost (Figures 3-8 and 3-9). This would make it possible for the public to actually “see” the device up close, particularly when the water is clear at low slack water. Such a walkway also would provide a grid interconnection cable route as well as low-cost access for inspection, maintenance, and repair in a larger range of weather conditions than would be possible by marine service vessel.

Although the Lubec Narrows tidal stream resource can support up to 1.2 megawatts of generating capacity, its shallow depth would prevent installation of a single device this large. Even in the deeper locations charted in Figure 3-8, the water depth at lowest low tide is only 4 to 7 m.

As described in Section 2.1, a Marine Current Turbines device of 1.2 MW has 16 m diameter rotors and a minimum water depth requirement of 18 m. A demonstration project using this technology in the Lubec Narrows could only have 1/4 to 1/3 this diameter, which would correspond to an installed capacity of only 75 to 130 kW.

The depth constraint would be even more limiting for Lunar Energy’s 1.5 MW ducted turbine, which has a minimum depth requirement of 29 m, assuming that there would be no overhead navigation for a demonstration project located at the end of a breakwater or wharf, as shown for the potential sites depicted in Figure 3-9. A demonstration project using this technology in Lubec Narrows could only have 1/6 to1/4 this diameter, which would correspond to an installed capacity of only 40 to 90 kW.

Although this may seem a “step back” for the developers of these devices, who will be installing 1,000 to 1,2000 kW devices in the United Kingdom during 2006, the ability to have such a visible demonstration of their technologies in an inaugural demonstration project in North America represents a compelling opportunity. It also would demonstrate the “down-scalability” of their technologies for distributed generation applications, which are particularly numerous in Maine and the Passamaquoddy region of New Brunswick, where there are many small and shallow channels that can accommodate devices no larger than a few tens of kilowatts, but where the local electrical load is of similar magnitude.

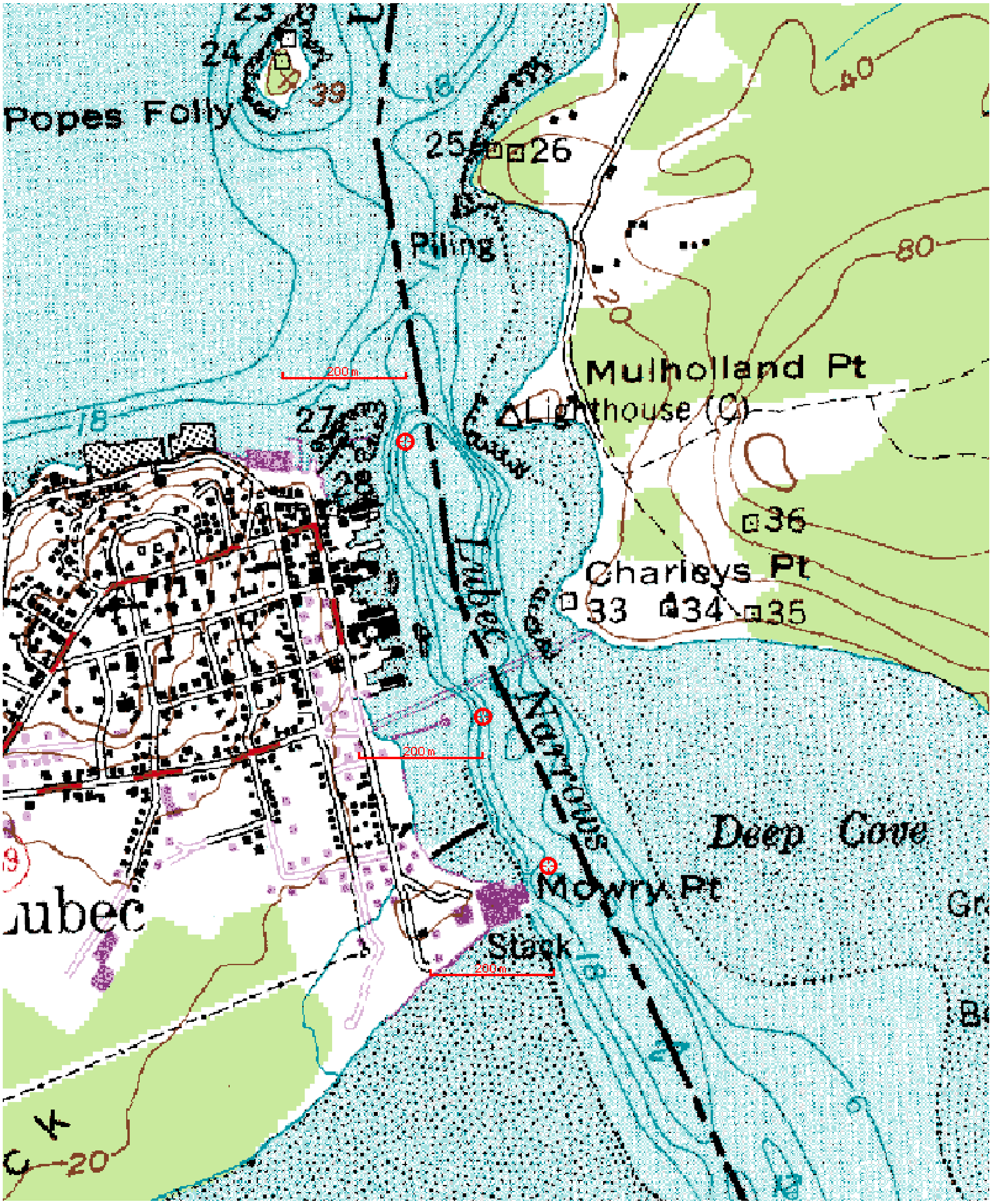


Figure 3.1-8. Bathymetric chart of potential demonstration project sites in LubecNarrows that could be made accessible from shore by extending existing breakwaters or wharfs by 50-100 m (Reference 7).

Figure 3.1-9. Aerial photograph of potential demonstration project sites in Lubec Narrows that could be made accessible from shore by extending existing breakwaters or wharfs by 50-100 m (Reference 7).

3.2 Western Passage – Eastport

Western Passage cuts between Moose Island on the U.S. side and Deer Island, the next large Canadian island northwest of Campobello Island, and connects Friar Roads with Passamaquoddy Bay. It is entered between Deer Island Point, which is at the south end of Deer Island, and Dog Island, which lies off the east side of Moose Island.

As shown in the figure below, Western Passage is the western conduit for waters from the St. Croix River and Passamaquoddy Bay. As such, it is known for its strong currents and eddies, including "Old Sow," the largest tidal whirlpool in the Western Hemisphere.

Figure 3.2-1. Location map for Western Passage site (Reference 12)

The hydrodynamic driving force behind the Old Sow is the conjunction of two tidal currents that meet at a right angle off Deer Island Point. While the flood current flows generally northwest (at a heading of about 305°, per Reference 2) through Western Passage, the flood current between Deer Island and Indian Island flows south-southwest (at a heading of about 195°). The turbulence generated by the collision of these two currents is enhanced by the plunging bottom profile south of Deer Point, which deepens from 120 to 300 feet at a slope of more than 45°.

The whirlpool is most active during flood current, 2 to 3 hours before high water, when the vortex can attain a diameter of up to 250 feet (Reference 13) and a depth of up to 40 feet (Reference 13). It is less pronounced during ebb flows. The Old Sow is pictured in the figure below. More detailed information can be found in References 13 through 16.

Figure 3.2-2. Aerial photo of Old Sow tidal whirlpool, with Deer Island Point at upper right. The 90° collision of the flood current out of Indian River (coming from right side of photo) and the flood current in Western Passage (heading toward left side of photo) is clearly visible.

According to Reference 15, the Old Sow is one of five significant whirlpools worldwide; the others being the Corryvreckan in Scotland; the Saltstraumen and Moskstraumen in Norway, and the Naruto in Japan. It vies with the Moskstraumen for title of the world's most powerful whirlpool, with both having vortex current speeds up to 15 knots!

Since the first whirlpool drowning reported in 1817, the Old Sow has claimed at least ten lives (Reference 16), and it still presents a hazard for small boats. According to Reference 17, the least turbulent tidal flows are "about 275 m north of Dog Island, where the current is more direct between the whirlpools and eddies on either side." The bathymetric map presented later in this section shows this least turbulent location to lie along the 180-foot depth contour, where tidal in-stream devices could be installed with ample navigation clearance even for deep-draft vessels.

3.2.1 Tidal In-Stream Energy Resource

As previously mentioned, Reference 1 describes numerical model results that estimate the tidal in-stream power density in Passamaquoddy and Cobscook Bays, including Western Passage. Screen shots of peak tidal in-stream power densities in Passamaquoddy and Cobscook Bays are given below, based on animations of the Reference 1 numerical model posted at Reference 18.

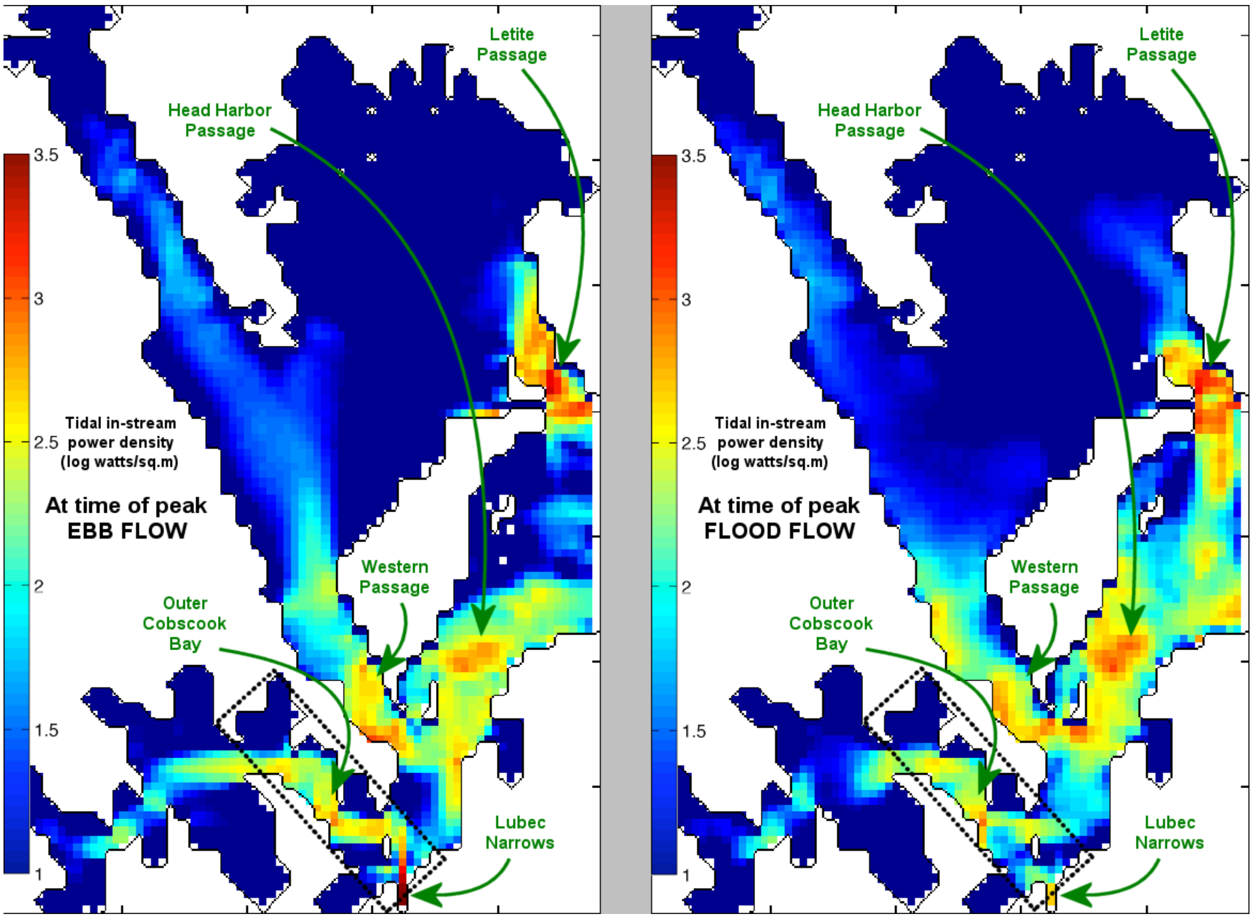
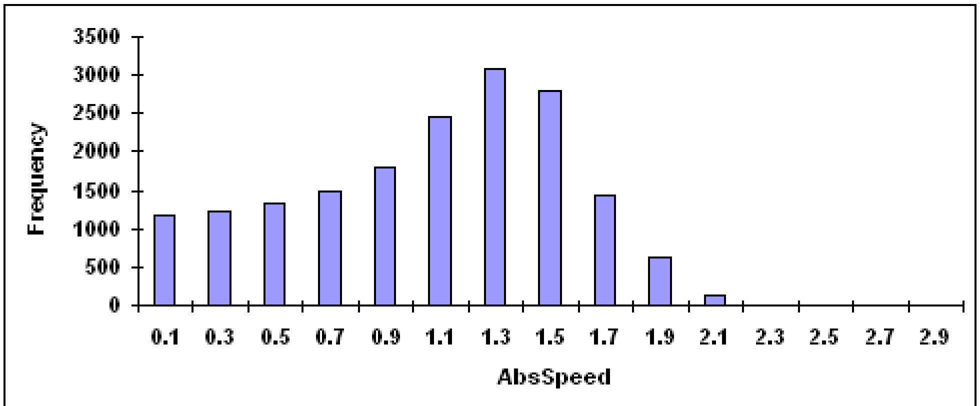


Figure 3.2-3. Tidal in-stream power density, mapped as the base-10 logarithm of watts per square meter of flow cross-sectional area, during peak ebb and flood in Passamaquoddy and Cobscook, under average tidal conditions. Note that where Western Passage widen, north of its narrow entrance, the tidal in-stream power density drops by one-half to one order of magnitude (Source: Reference 18).

Note that under average tidal conditions, Figure 3.2-3 indicates peak ebb and flood tidal stream power densities ranging from 300 watts (yellow-colored squares = $10^{2.5}$ watts) to 1 kilowatt (orange-colored squares = 10^3 watts) per square meter of channel cross-section area in southern Western Passage, where it is narrowest.

NOAA has a secondary tidal current prediction station off Kendall Head, and a full calendar year (2005) of predicted tidal current speeds at this station was used to construct a tidal power density histogram, which is given in Figure 3.2-4, below. This estimates an annual average tidal stream power density of very nearly 1 kW/m^2, but this is not in the fastest part of the passage.



Speed Bin Mid-Point (m/sec)	Tidal Stream Power Density (watts/sq.m)	Number of Cases	Proportion of Cases	Number of Hours	Tidal Stream Energy Density (kWh/sq.m)
0.1	0.5	1183	0.067523	591.5	0.3
0.3	13.8	1219	0.069578	609.5	8.4
0.5	64.1	1330	0.075913	665.0	42.6
0.7	175.8	1478	0.084361	739.0	129.9
0.9	373.6	1812	0.103425	906.0	338.5
1.1	682.1	2452	0.139954	1226.0	836.3
1.3	1,126.0	3076	0.175571	1538.0	1,731.7
1.5	1,729.7	2794	0.159475	1397.0	2,416.4
1.7	2,517.9	1427	0.081450	713.5	1,796.5
1.9	3,515.2	617	0.035217	308.5	1,084.5
2.1	4,746.3	132	0.007534	66.0	313.3
2.3	6,235.6	0	0	0.0	0.0
2.5	8,007.8	0	0	0.0	0.0
2.7	10,087.5	0	0	0.0	0.0
2.9	12,499.4	0	0	0.0	0.0
		17520	**1**	**8760**	**8,698.4**
		8760	hours		**0.993 kW/sq.m**
					Annual Average
		1025	kg/cu.m		Power Density

Figure 3.2-4. Tidal in-stream power density histogram off Kendall Head.

The average peaks predicted by the NOAA Tidal Current Tables off Kendall Head are 3.1 knots (1.59 m/sec) for the maximum ebb current, corresponding to a tidal in-stream power density of 2.1 kW per square meter, and 3.2 knots (1.65 m/sec) for the maximum flood, corresponding to a tidal in-stream power density of 2.3 kW per square meter. As noted earlier, the numerical model of Brooks indicates peak tidal power densities of 1 kW per square meter in the narrowest parts of Western Passage. This much lower power density is probably due to the coarse resolution of the model, with power densities averaged over large areas.

As shown in Figure 3.2-5, below, the Dog Island transect in Western Passage is much narrower than the transect where the NOAA tidal current prediction station is located. This would be the preferred location of any TISEC project located in Western Passage. To estimate the power density at this much narrower part of the transect, the NOAA-predicted velocities off Kendall Head were multiplied by the ratio of cross-sectional areas, assuming that the velocities must be proportionally greater in the Dog Island transect in order to preserve continuity of flow.

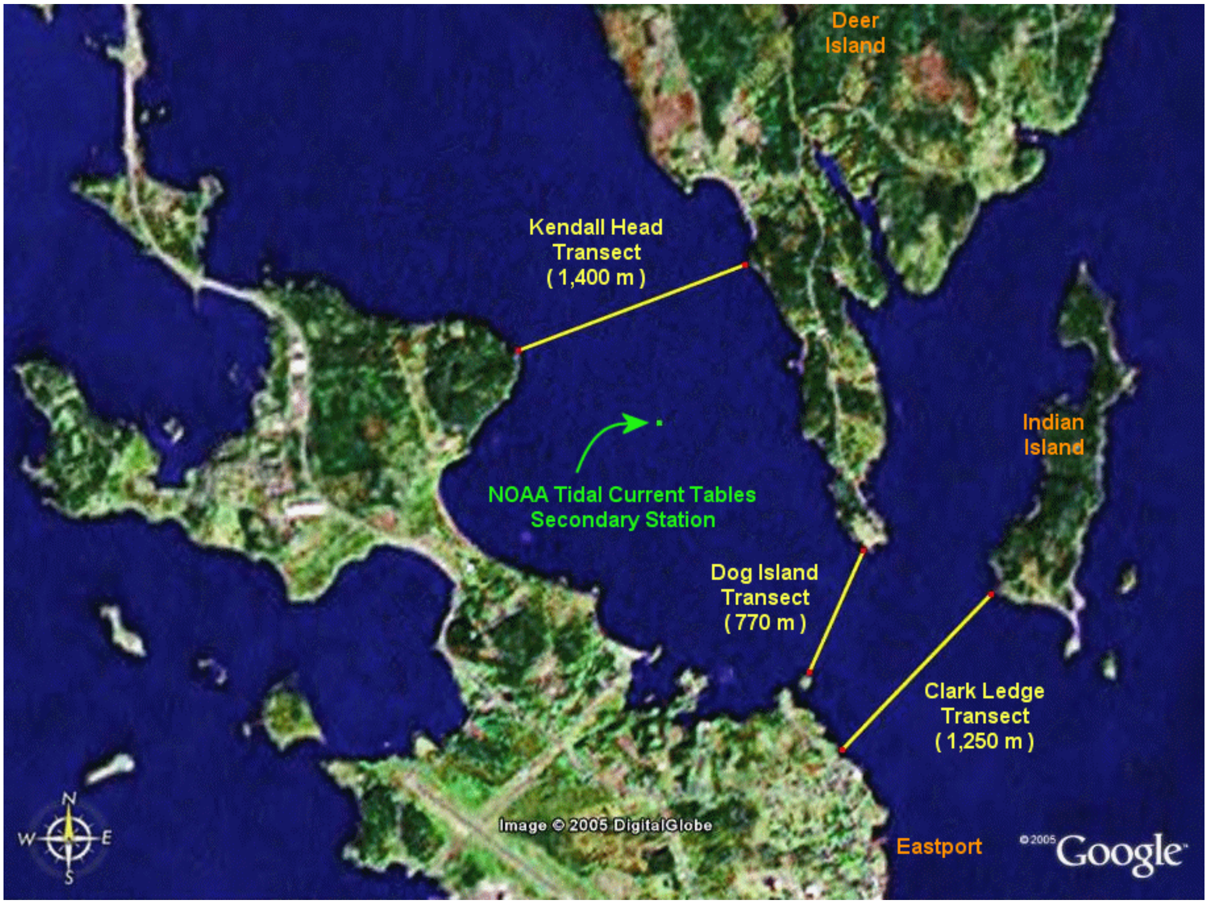


Figure 3.2-5. Aerial photograph from an altitude of approximately 20,000 ft, showing the numerically modeled transects in Western Passage (Reference 7).

The Dog Island transect area is 35,860 square meters, as compared with 56,580 square meters in the section through the NOAA tidal current prediction station off Kendall Head. Applying the ratio of the channel cross-sectional area between these two sites, gives an average peak flood power density of 5.1 kW/m^2, an average peak ebb power density of 4.6 kW/m^2, and an annual average in-stream power density of 2.2 kW/m^2.

3.2.2 Tidal Channel Bathymetry and Geology

A bathymetric contour chart of Western Passage is given below.

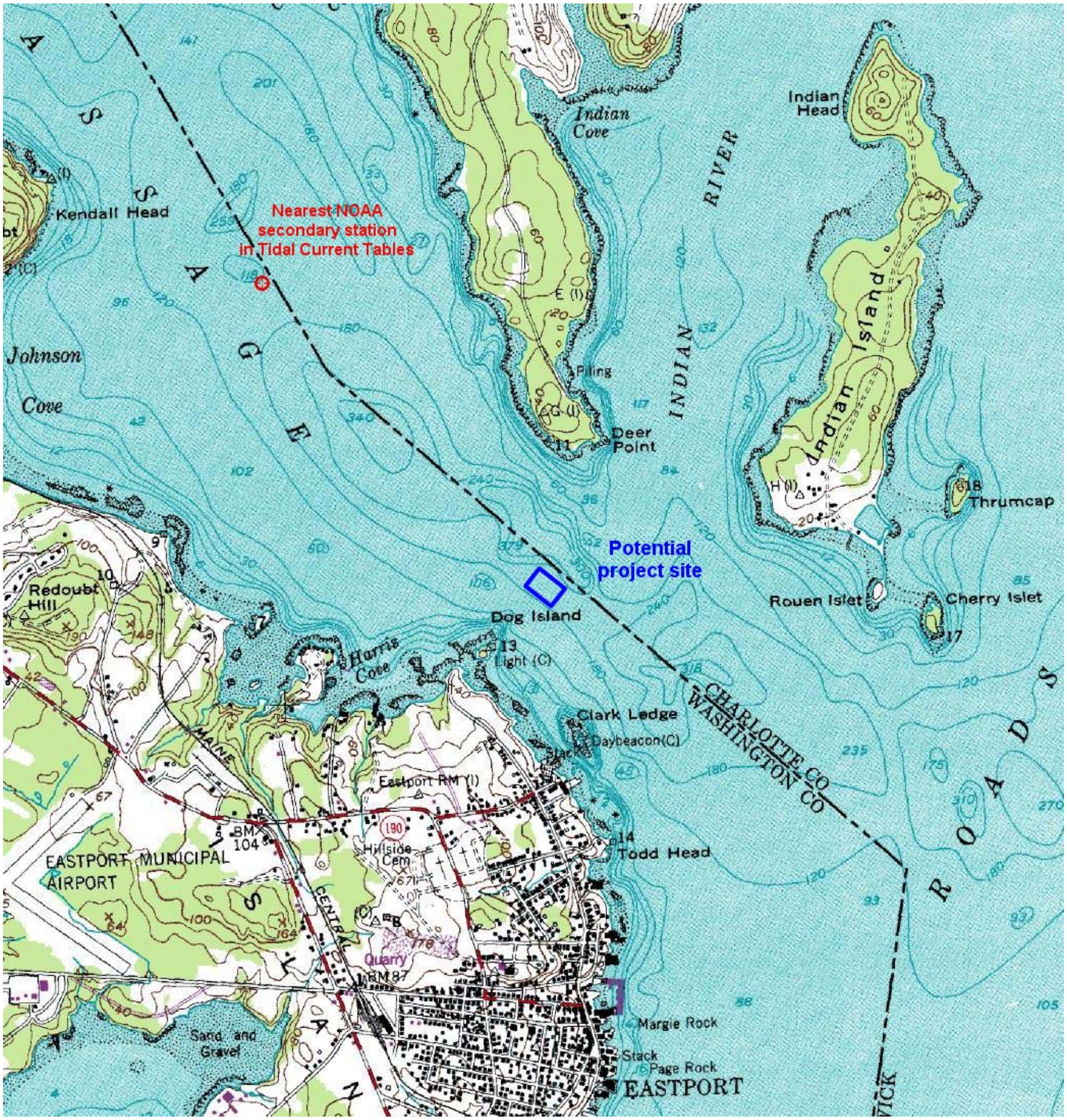


Figure 3.2-6. Bathymetric chart of Western Passage. A potential deep project site for a tidal in-stream device such as Lunar Energy's ducted turbine is indicated by the blue rectangle between the 180- and 240-foot depth contours just northeast of Dog Island. Monopile foundations for a device such as Marine Current Turbines units are feasible along the 60-ft depth contours either on the New Brunswick side of Western Passage, by the southwest shore of Deer Island, or on the Maine side, between Dog Island and Clark Ledge. (Source: Reference 7).

A geological map characterizing the surface properties of the seafloor in the northern part of Lubec Narrows and Friar Roads is given below.

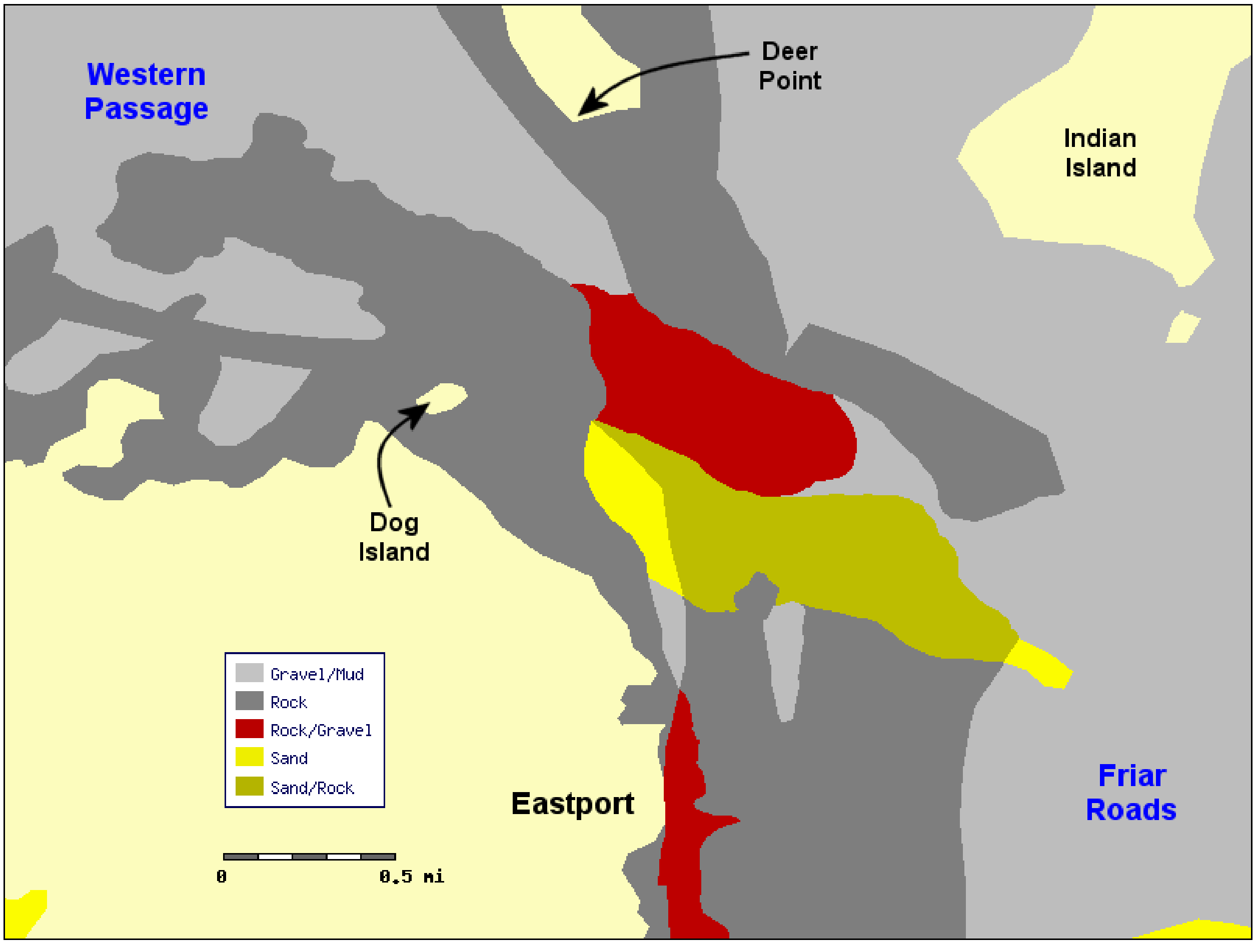


Figure 3.2-7. Surficial geology of Western Passage (Reference 8).

3.2.3 Utility Grid Interconnection

The U.S. onshore interconnection point for a tidal energy project in Western Passage would be to the Bangor Hydro-Electric Company utility grid. A 34.5 kV transmission line runs adjacent to state Route 190, and 12.5 kV distribution lines run throughout the island, which minimizes the overland distance for grid interconnection to either a 500 kW demonstration or a 10 MW commercial scale TISEC project. Due to the rocky nature of the Eastport shoreline in the vicinity of Dog Island and the residential zoning there, a submarine power cable from a project in Western Passage probably would be landed into the rural residential area north of Harris Cove, where it is about 0.5 miles to both 34.5 and three-phase 12.5 kV distribution lines.

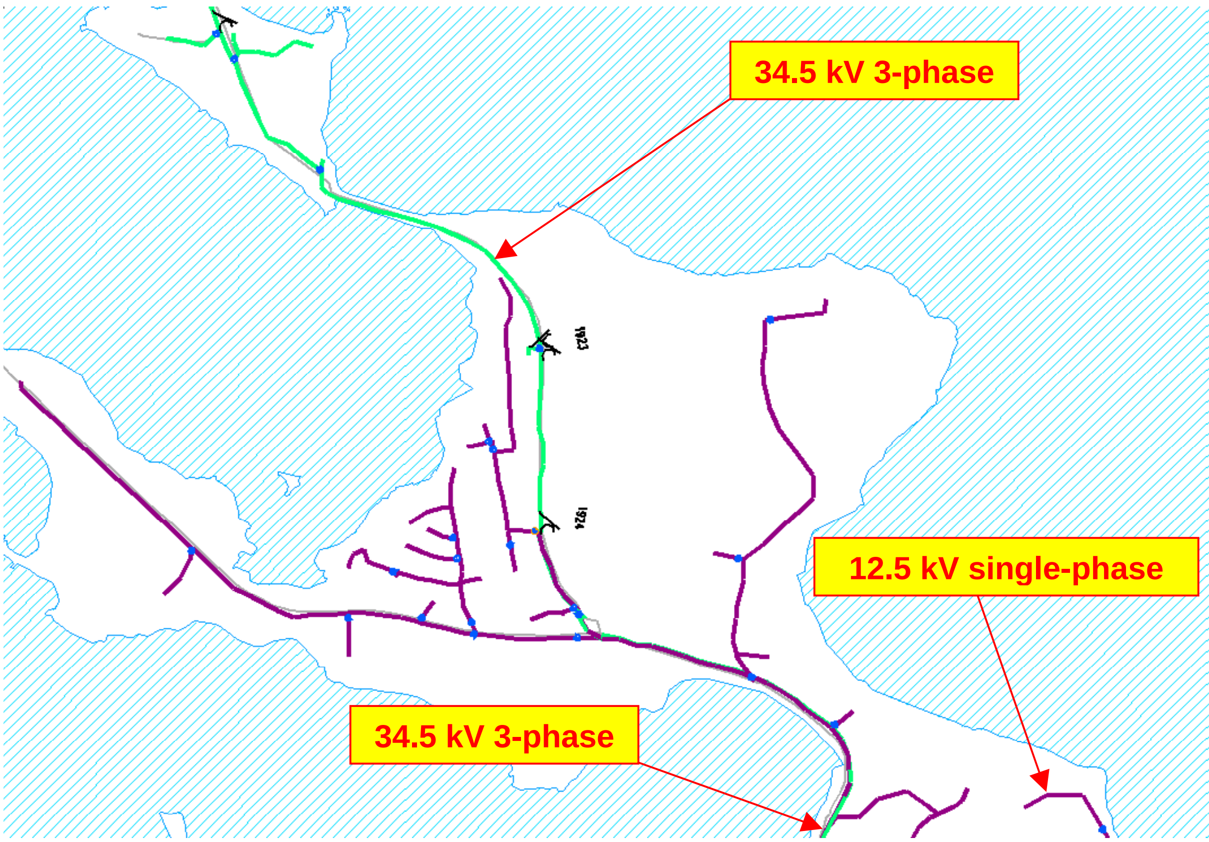


Figure 3.2-8. BHE utility grid on Kendall Head in Eastport (Source: Bangor Hydro-Electric Company).

3.2.4 Maritime Support Infrastructure

Eastport would be the nearest coastal town for basing inspection, maintenance and repair activities. Section 3.1.4 fully describes the maritime infrastructure of Eastport, and the reader should consult that section for details.

3.2.5 Competing Uses of Sea Space

The most important potential competing uses of sea space in Western Passage is interference with navigation, commercial fishing and salmon farming. Western Passage is naturally quite deep, and therefore not subject to maintenance dredging.

Navigation: The principal navigation entrance to Passamaquoddy Bay is around the northern end of Campobello Island through Head Harbour Passage. This passage is deep and generally clear of dangers. South of Deer and Indian Islands, incoming vessels enter Friar Roads before turning north to approach the entrance to Western Passage. The safest route for navigation is toward the U.S. side of the entrance, which is free of turbulence. This also is the best location for a tidal in-stream energy project, but as previously mentioned, the depth here is 180 feet, which allows ample clearance for navigation, even by deep-draft commercial shipping.

Commercial Fishing: According to the Maine Marine Patrol (Reference 19), Western Passage is highly fished for lobsters (April through November), scallops (December through mid-April), and urchins (October through March). The faster currents and deeper water in the center of the passage may limit lobstering activity as compared with the shallower, nearshore areas, but scallop draggers do operate in the deep channel. During summer months there is a high level of recreational groundfishing, but as with lobstering, this is not as great a potential conflict in the faster, deeper waters of the central channel.

Salmon Farming: Salmon farms are found along the shores of Western Passage (Figure 3.2-7), and a potential conflict would arise if excessive amounts of tidal current energy were withdrawn from this flow, reducing the natural flushing action through salmon-rearing pens. Limiting tidal in-stream energy projects to withdrawing no more than 10 to 15% of the cross-sectional base resource should avoid this potential negative impact.

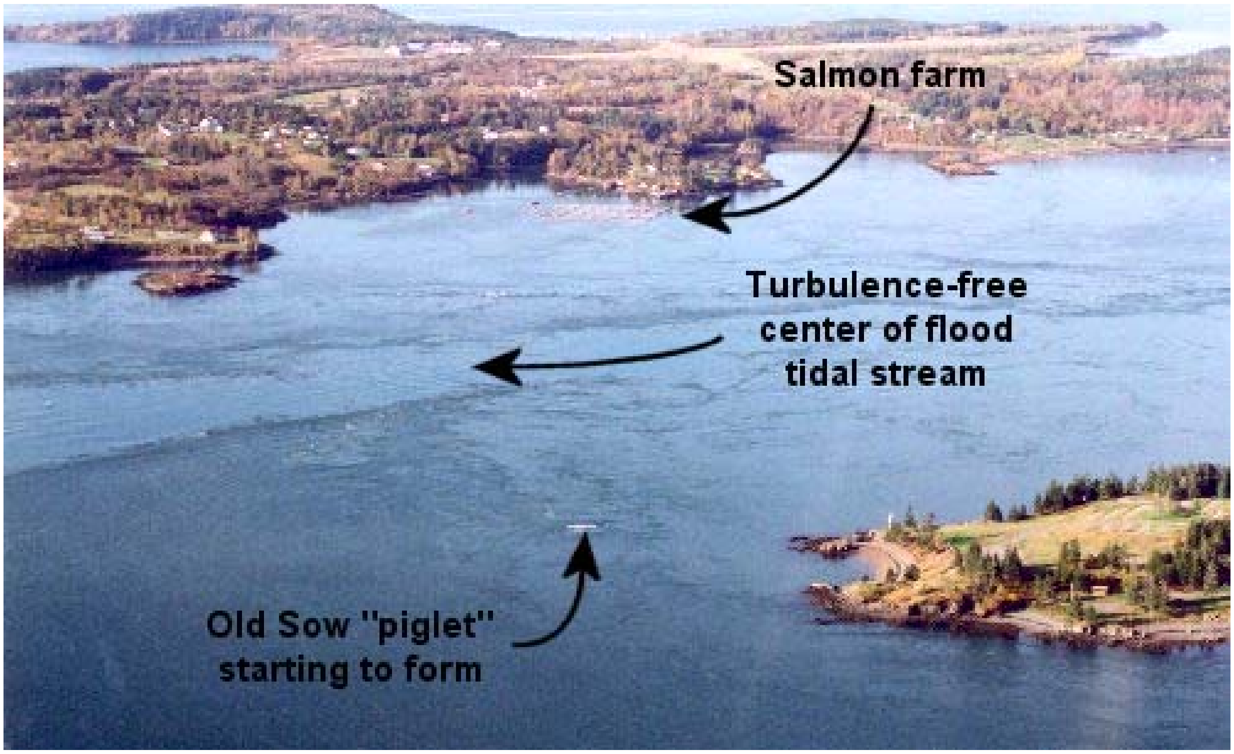


Figure 3.2-9. Salmon farming operation on the eastern shore of Moose Island, well-removed from the central tidal stream flow where a TISEC project would be located. (Source: http://easternmaineimages.com/WPaerial10.jpg)

3.2.6 Unique Opportunities

As with Lubec Narrows, Western Passage represents a potential site for an international collaborative project between New Brunswick and Maine.

Eastport is at the end of a 34.5 kV transmission line, and the installation of local distributed generation might defer the need for upgrade of this line. For a TISEC project to have this benefit, however, additional generation or energy storage would be required to provide firm capacity during slack water and slow current speeds on either side of slack water.

3.3 Outer Cobscook Bay – Eastport

Cobscook Bay, extending westward from Moose Island, is large and irregular and has several arms. The approach channel is between Shackford Head, which separates Broad Cover from Deep Cove on the western shore of Moose Island, and Seward Neck. As shown in the figure below, all of the water entering or leaving Cobscook Bay passes through this channel.

Figure 3.3-1. Location map for Outer Cobscook Bay site (Reference 12)

3.3.1 Tidal In-Stream Energy Resource

Screen shots of peak tidal in-stream power densities in Outer Cobscook Bay are given below, based on numerical simulations described in Reference 1.

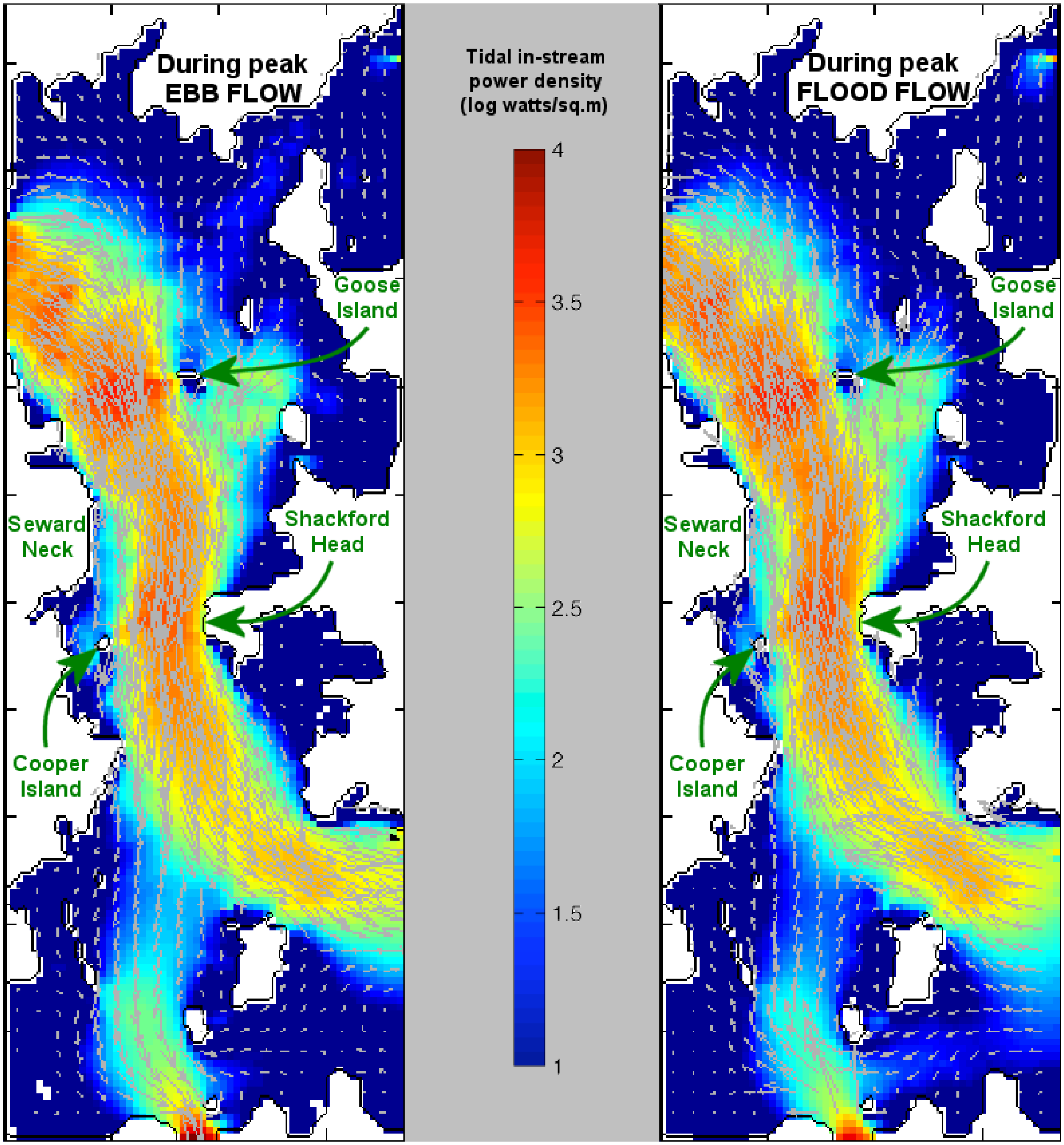


Figure 3.3-2. Tidal in-stream power density, mapped as the base-10 logarithm of watts per square meter of flow cross-sectional area, during peak ebb and flood in Outer Cobscook Bay, under average tidal conditions. Note that there are two centers of maximum power density in this channel: between Shackford Head and Cooper Island Ledge, and due south of Goose Island, where the flow is constricted before it bends around Seward Neck (Reference 17).

The Physical Oceanography Group of the School of Marine Sciences at the University of Maine maintain a current meter mooring in 35 m water depth, 10 m below the surface, at Station J in the Gulf of Maine Ocean Observing System (GoMOOS). The location of this buoy is mapped in Figure 3.3-3. Additional information about the buoy deployments at this station can be found at http://gyre.umeoce.maine.edu/GoMoos/site_history.phtml?region=J.

As shown in Figure 3.3-3, the current meter in Station J is not in the narrowest part of Outer Cobscook Bay. The narrowest section is between Shackford Head and Cooper Island Ledge. The cross-sectional area of the channel here is only 60% of that at Station J. This ratio was applied to the tidal current speeds measured at Station J in a manner similar to the resource estimate for Western Passage.

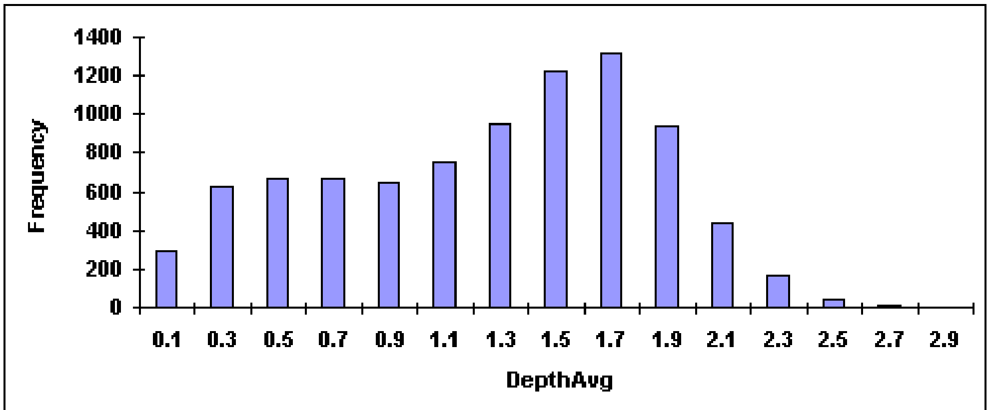
Twelve months of data area available from two closely spaced buoy deployments at GoMOOS Station J for the period 16 May 2004 to 15 May 2005:

J0208: 2004-May-13 to 2004-Oct-03: 44° 53.39´N, 067° 00.76´W

J0209: 2004-Oct-03 to 2005-May-19: 44° 53.33´N, 067° 00.70´W

The average peak current speed in the above record was 1.3 m/sec. Doubling this to 2.8 m/sec yields an estimate for the peak tidal stream power density of 4.6 kW per square meter.

The annual current speed histogram and tidal stream power density for this site are given in Figure 3.3-3, on the next page.



Speed Bin Mid-Point (m/sec)	Tidal Stream Power Density (watts/sq.m)	Number of Cases	Percentage of Cases	Number of Hours	Tidal Stream Energy Density (kWh/sq.m)
0.1	0.5	294	3.4%	294.5	0.2
0.3	13.8	624	7.1%	625.0	8.6
0.5	64.1	672	7.7%	673.1	43.1
0.7	175.8	670	7.7%	671.1	118.0
0.9	373.6	652	7.5%	653.0	244.0
1.1	682.1	748	8.6%	749.2	511.1
1.3	1,126.0	947	10.8%	948.5	1,068.0
1.5	1,729.7	1220	13.9%	1222.0	2,113.6
1.7	2,517.9	1317	15.1%	1319.1	3,321.4
1.9	3,515.2	943	10.8%	944.5	3,320.2
2.1	4,746.3	436	5.0%	436.7	2,072.7
2.3	6,235.6	165	1.9%	165.3	1,030.5
2.5	8,007.8	42	0.5%	42.1	336.9
2.7	10,087.5	14	0.2%	14.0	141.5
2.9	12,499.4	2	0.0%	2.0	25.0
		8746	**1**	**8760**	**14,354.6**
14,500	sq.m section area	8760	hours		**1.639 kW/sq.m**
					Annual Average
23.8	**MW resource base**	1025	kg/cu.m		Power Density

Figure 3.3-3. Tidal in-stream power density histogram for Outer Cobscook Bay.

3.3.2 Tidal Channel Bathymetry and Geology

A bathymetric contour chart of Outer Cobscook Bay off Shackford Head is given below.

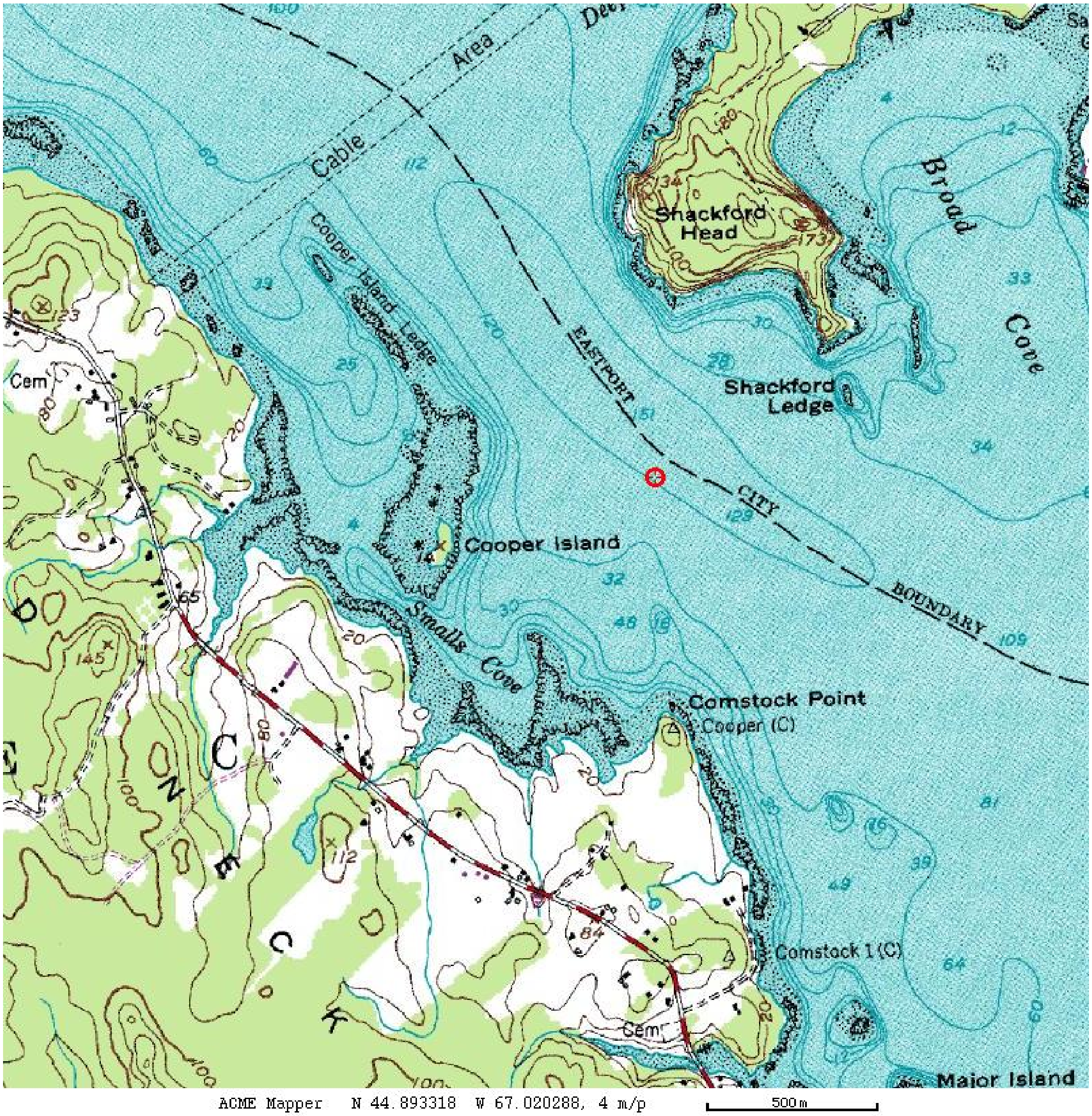


Figure 3.3-4. Bathymetric chart of Outer Cobscook Bay off Shackford Head and Goose Island. Red circle indicates location of GoMOOS monitoring buoy, Station J (Source: Reference 7).

A geological map characterizing the surface properties of the seafloor in Outer Cobscook Bay off Shackford Head and Goose Island is given below.

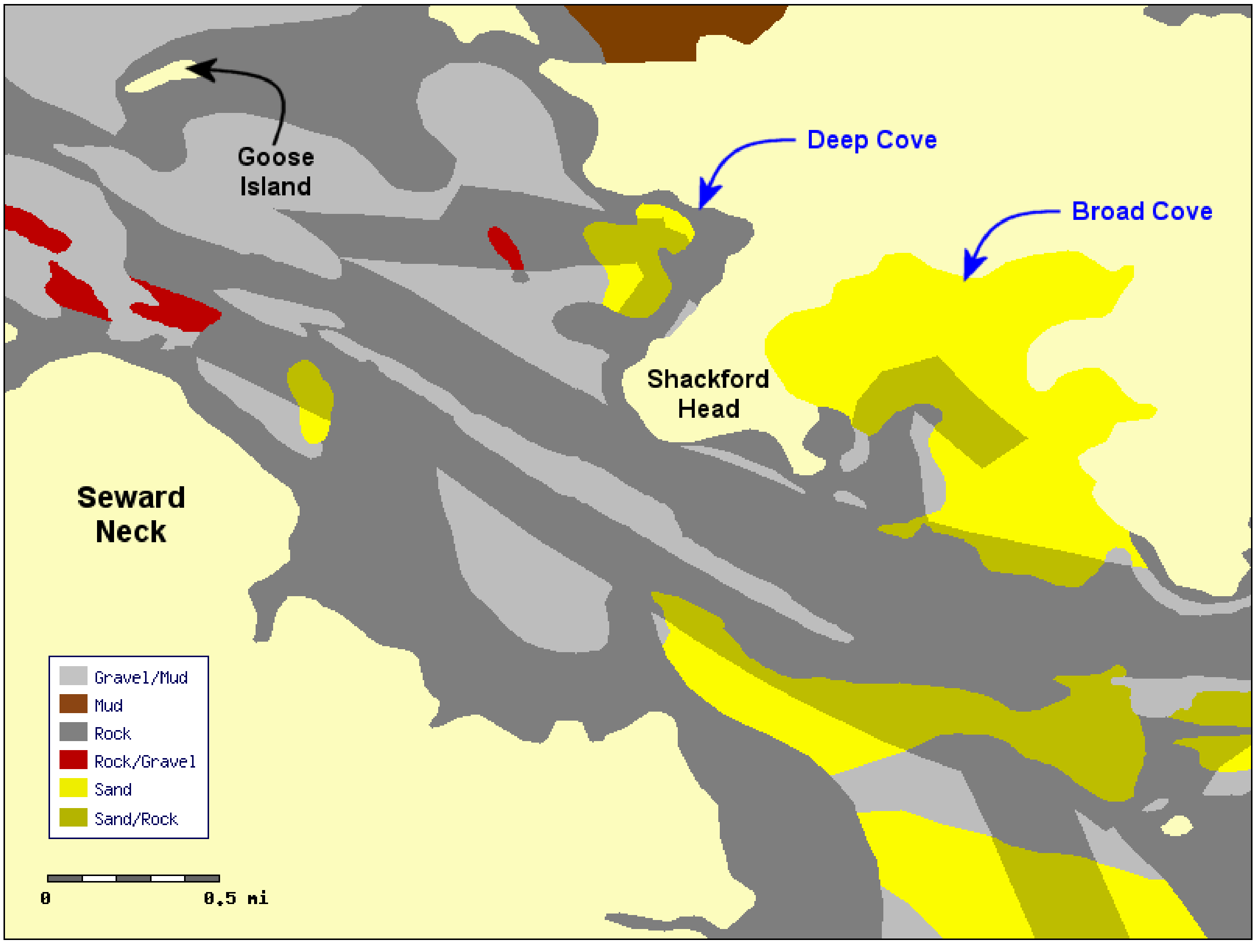


Figure 3.3-5. Surficial geology of Outer Cobscook Bay off Shackford Head (Reference 8).

The outer area of Cobscook Bay is erosional, with truncated reflectors of glacial-marine sediment and bedrock cropping out extensively. The bedrock structure, a plunging anticline, provides numerous constrictions to water movement, generating modeled current velocities of 2m/sec and leaving the seafloor bare rock in many places. Bedrock crops out in random locations throughout the bay, causing many scour holes, abrupt facies shifts and creating localized concentrations of carbonate sediment. Most of the remainder of the subtidal region is a gravel/sand lag deposit resting over glacial-marine mud. Tidal current lineations are the dominant sedimentary structures, with fishing drag marks also common. Fine sediment is most common on tidal flats, which abruptly transition to the coarse-grained subtidal areas.

3.3.3 Utility Grid Interconnection

The onshore interconnection point for a tidal energy project in Outer Cobscook Bay would be to the Bangor Hydro-Electric Company utility grid mapped below. As previously noted, a 35.4 kV transmission line runs adjacent to state Route 190, and a 12.5 kV lines run out around the airport, providing very close interconnection for submarine power cables making landfall in Deep Cove, where there already is a submarine cable crossing to Seward Neck.

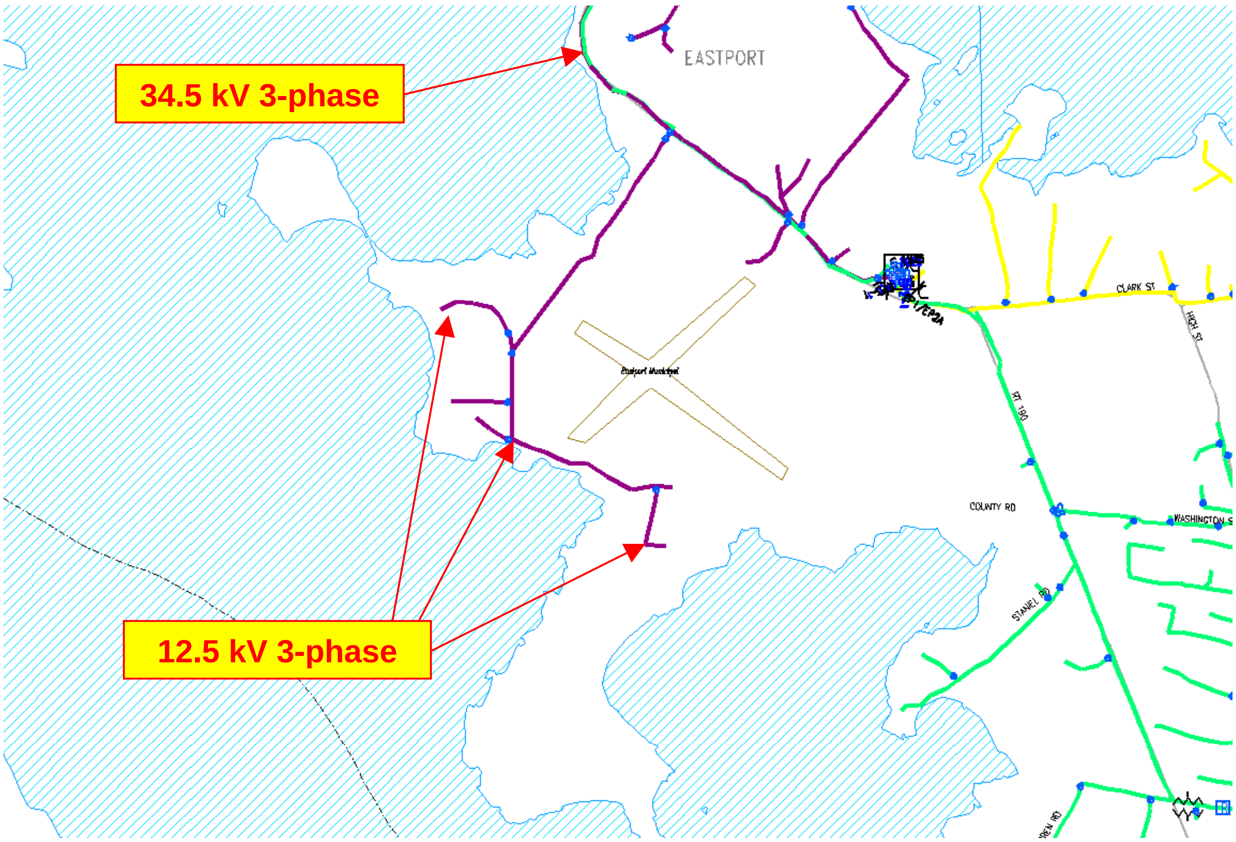


Figure 3.3-6. BHE utility grid on Shackford Head (Source: Bangor Hydro-Electric Company).

3.3.4 Maritime Support Infrastructure

Eastport would be the nearest coastal town for basing inspection, maintenance and repair activities. Section 3.1.4 fully describes the maritime infrastructure of Eastport, and the reader should consult that section for details.

3.3.5 Competing Uses of Sea Space

According to Reference 4, the deepest drafts carried into Cobscook Bay are 14 feet, which provides ample clearance for any tidal energy project located in the deep waters between Cooper Island Ledge and Shackford Head, and due south of Goose Island, where the depth ranges between 100 and 150 feet (refer back to Figure 3.3-3). Thus no conflicts with navigation are anticipated, and the entrance to Outer Cobscook Bay is naturally deep, so there would be no conflict with maintenance dredging.

Discussions with watermen in August 2005 indicated that a monopile-based device located against the steep channel boundary at Shackford Head would have minimal conflict with scallop dragging and lobstering.

The most important potential conflicts with other uses of sea space in Outer Cobscook Bay are with commercial and recreational fishing, and with salmon farming. These are described below.

Commercial and Recreational Fishing: Reference 19 reports a high level of lobstering effort here (April-November) and very high levels of commercial fishing for sea urchins (October-March) and scallops (December-15 April). Outer Cobscook Bay also is a very active area for recreational fishing. The potential conflict with scallop draggers is particularly high, since they already have lost significant bottom area to salmon pens.

Salmon Farming: Salmon farms are found within Cobscook Bay, and a potential conflict would arise if excessive amounts of tidal current energy were withdrawn from this flow, reducing the natural flushing action through salmon-rearing pens. Limiting tidal in-stream energy projects to withdrawing no more than 10 to 15% of the cross-sectional base resource should avoid this potential negative impact.

3.3.6 Unique Opportunities

There is a submarine power cable crossing located between the southern and northern maxima of tidal power density, making landfall at Deep Cove, by the municipal airport. Ownership of this cable route and “piggyback” permitting of shore crossing from a tidal in-stream energy project will be investigated during August trip.

In addition, the Eastport Comprehensive Development Plan (Reference 20) promotes expansion of maritime industries and specifically identifies the Deep Cove waterfront as a growth area for such development.

3.4 Taunton Bay – West Sullivan

Sullivan Harbor is an arm on Frenchman Bay making northward from its north end. It is the approach to the villages of Hancock Point, Mount Desert Ferry, Sullivan, and Franklin. The least depth to the falls just above Sullivan is about 25 feet. The channel to Sullivan is marked by a daybeacon and buoys to near Ferry Point.

Sullivan is a small village on the north side of Sullivan Harbor, 3 miles above the entrance. The channel is unmarked above Ferry Point, has dangerous ledges on both sides, and is unsafe without local knowledge.

Sullivan Falls are reversing tidal falls in the constricted reach below Preble Cove, about 0.5 mile upstream of Ferry Point (Figure 3.3-1). The channel through the falls is reported to have a depth of 10 feet, but is obstructed by ledges, with swift and dangerous tidal currents.

Figure 3.4-1. Location map for Taunton Bay site (Reference 12)

Navigation through the falls is safe only at slack water. Most craft go up on the last of the flood, but come out only at high-water slack, as there is great turbulence when the current is running at strength. The mean tidal range is about 10.5 feet below Sullivan Falls, and about 6.5 feet above. Ice obstructs navigation in Taunton Bay and Sullivan Harbor from January through March.

West Sullivan, on the north side of the bay just above Sullivan Falls, has several abandoned quarry wharves at which vessels were formerly loaded. The U.S. Route 1 highway bridge crosses the bay about 0.5 mile above the falls and connects West Sullivan with Hancock. The bridge has a fixed span with a clearance of 17 feet.

3.4.1 Tidal In-Stream Energy Resource

No tidal current measurements, modeling, or predictions are available for this site. In the 1985 Maine Tidal Power Inventory (Reference 3), this site was identified as having a potential power generation capacity of 14.0 megawatts using conventional hydro equipment and a single-effect, ebb generation scheme with an impoundment dam. Potential in-stream generation capacity is expected to be less than this number.

It may be possible to find current data used in the design of the Route 1 bridge.

3.4.2 Tidal Channel Bathymetry and Geology

A bathymetric contour chart Taunton Bay is given below.

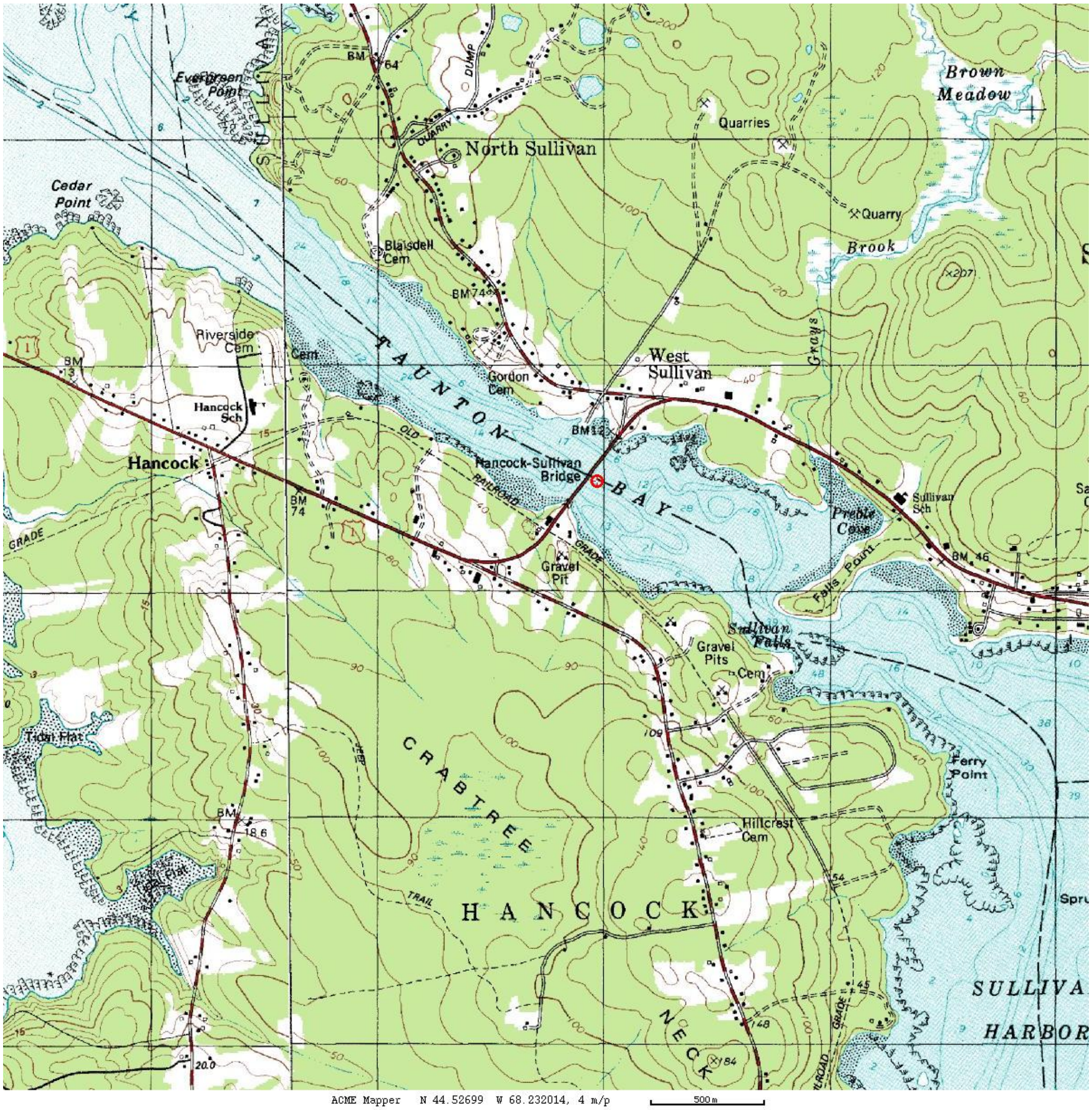


Figure 3.4-2. Bathymetric chart of Taunton Bay site (Reference 7).

Reference 8 indicates a homogeneous surficial geology of muddy sediments in Taunton Bay.

3.4.3 Utility Grid Interconnection

The onshore interconnection point would be to the Bangor Hydro-Electric Company utility grid mapped below. A 34.5 kV transmission line runs adjacent to U.S. Route 1, and there is a dense 12.5 kV distribution network along the entire passage to Taunton Bay.

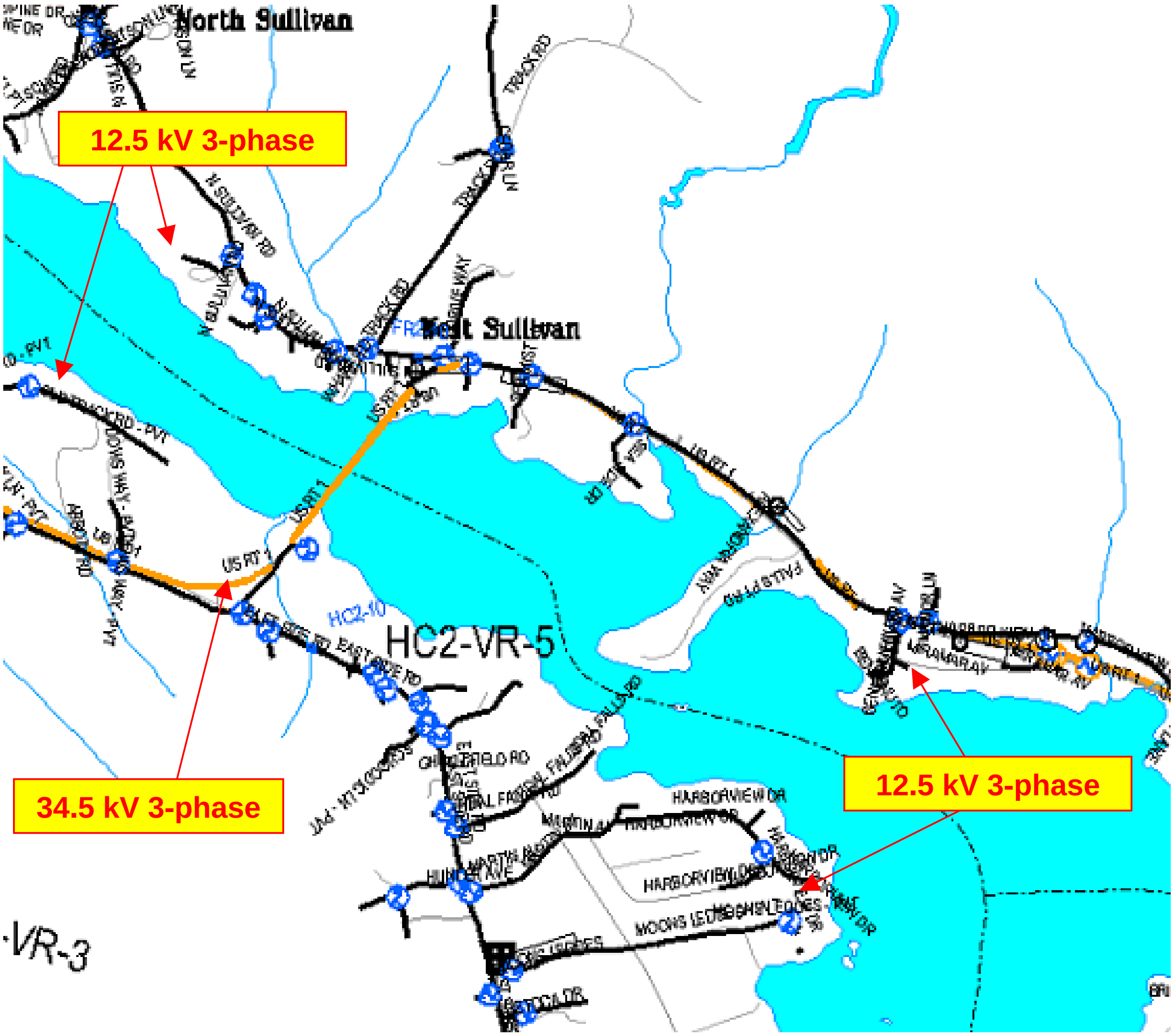


Figure 3.4-4. BHE utility grid in West Sullivan (Source: Bangor Hydro-Electric Company).

3.4.4 Maritime Support Infrastructure

Given the challenging nature of navigating Sullivan Falls, it would be preferable to have a project servicing facility in West Sullivan. A maritime support infrastructure does not exist there at this time, but perhaps economic redevelopment funds might be sought to refurbish one or more of the abandoned quarry wharves on the north shore of Taunton Bay.

3.4.5 Competing Uses of Sea Space

According to Reference 19, there is a relatively light lobstering effort here and Taunton Bay is closed to scallop dragging. Thus a pilot project would have minimal conflict with commercial fisheries. Sufficient navigation clearance must be provided, however, for small boats to access the productive shellfish flats in Egypt and Hog Bays. Additional environmental management concerns are noted in the table below.

Table 3.4-1 Taunton Bay Pilot Management Project

Applicant Friends of Taunton Bay
Geographic Area Taunton Bay (at the head of Frenchman Bay), includes Hog and Egypt Bays
Major Activities Planned 1. Identify and bring together stakeholder groups to identify areas of conflict and agreement. *Purpose*: Clarify issues of importance; Work towards conflict resolution; Promote education, information sharing and relationship building among stakeholders. 2. Develop suite of indicators of ecosystem health. *Purpose*: Provide information on the current state of the bay in order to track changes in the future. 3. Conduct a socioeconomic inventory and analysis of watershed resources. *Purpose*: Provide an assessment of the importance of a healthy Taunton Bay to local communities. 4. Create GIS maps of study area that indicate locations of existing and historical uses, important marine habitats, areas of economic significance and sources of pollution. *Purpose*: Provide graphic representation of data and findings. 5. Develop a potential new model of decision-making for bay management. *Purpose*: Compare different models of management and propose a design that works best in the Taunton Bay region.
Governance Model to be Explored The Friends of Taunton Bay would like to explore establishing an ongoing, interaction relationship between their local group and state agencies for information sharing, problem solving and decision-making. Two of the specific ideas they suggested were: 1) Drafting uniform shellfish and worm ordinances for regional towns; and 2) Establishing zones of allowable activities in specific areas.

3.4.6 Unique Opportunities

The Route 1 bridge over Taunton Bay may provide a lower-cost route for the shore connection cable, minimizing the length of the underwater segment and avoiding the need for a separate shore crossing, by using the bridge's landfall to reach the onshore utility grid.

3.5 Bagaduce Narrows – Castine

The Bagaduce River empties into the eastern side of East Penobscot Bay near its head. The town of Castine is located on its north shore, just inside the entrance, and is home to the Maine Maritime Academy. There is no commerce by water except some fishing and much yachting. The town has a hospital, grocery store, restaurants, guest houses, a bank, and other conveniences.

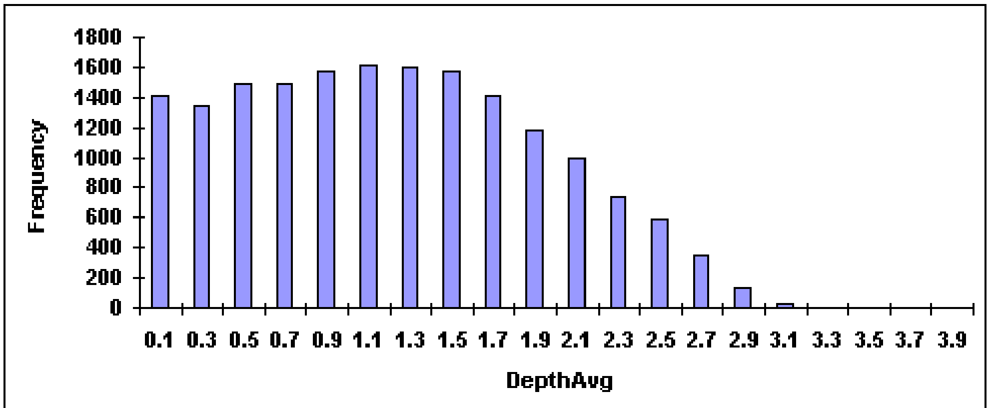
The channel in the river for is buoyed for five miles above Castine Harbor and is used by small craft. At the Narrows, however the channel is so constricted that navigation is possible only at slack water, on account of the fast currents.

Figure 3.5-1. Location map for Bagaduce Narrows site (Reference 12)

The mean range of tide is 9.7 feet at Castine. The river is usually free from ice at Castine and for some distance above, but in very severe winters the river can be entirely closed. Tidal currents of nearly 5 knots have been observed at Jones Point, about four miles above the entrance.

3.5.1 Tidal In-Stream Energy Resource

Bagaduce Narrows is a secondary station in the NOAA Tidal Current Tables (Reference 4), and so a year of tidal current predictions is available for this site, and this was used to construct a tidal power density histogram, which is given below. Unfortunately, no measured, modeled, or predicted tidal current data is available for the entrance to Bagaduce River at Castine.



Speed Bin Mid-Point (m/sec)	Tidal Stream Power Density (watts/sq.m)	Number of Cases	Percentage of Cases	Number of Hours	Tidal Stream Energy Density (kWh/sq.m)	
0.1	0.5	1413	8.1%	706.5	0.4	
0.3	13.8	1343	7.7%	671.5	9.3	
0.5	64.1	1496	8.5%	748.0	47.9	
0.7	175.8	1497	8.5%	748.5	131.6	
0.9	373.6	1568	8.9%	784.0	292.9	
1.1	682.1	1613	9.2%	806.5	550.1	
1.3	1,126.0	1593	9.1%	796.5	896.8	
1.5	1,729.7	1578	9.0%	789.0	1,364.7	
1.7	2,517.9	1404	8.0%	702.0	1,767.6	
1.9	3,515.2	1177	6.7%	588.5	2,068.7	
2.1	4,746.3	994	5.7%	497.0	2,358.9	
2.3	6,235.6	740	4.2%	370.0	2,307.2	
2.5	8,007.8	594	3.4%	297.0	2,378.3	
2.7	10,087.5	349	2.0%	174.5	1,760.3	
2.9	12,499.4	137	0.8%	68.5	856.2	
3.1	15,267.9	24	0.1%	12.0	183.2	
3.3	18,417.7	0	0.0%	0.0	0.0	
3.5	21,973.4	0	0.0%	0.0	0.0	
3.7	25,959.7	0	0.0%	0.0	0.0	
3.9	30,401.0	0	0.0%	0.0	0.0	
		17520	**1**	**8760**	**16,974.1**	
400	sq.m section area	8760	hours		**1.938 kW/sq.m**	
					Annual Average	
0.8	**MW resource base**	1025	kg/cu.m		Power Density	

Figure 3.5-2. Tidal in-stream power density histogram for Bagaduce Narrows.

In the 1985 Maine Tidal Power Inventory (Reference 3), this site was identified as having a potential power generation capacity of 10.4 megawatts using conventional hydro equipment and an ebb generation scheme with an impoundment dam. Potential in-stream generation capacity is expected to be significantly less than this number.

A larger project would be possible in the river entrance channel between Castine and Nautilus Island, through which a much larger volume of the Bagaduce River flows than passes through the Narrows. A TISEC project in Castine Harbor also would harness the flow from Smith Cove, which the Maine Tidal Power Inventory estimated to have an impoundment tidal power capacity of 4.1 MW.

3.5.2 Tidal Channel Bathymetry and Geology

A bathymetric contour chart Bagaduce Narrows is given below, showing the potential site for a 500 kW demonstration project at the location of the NOAA tidal current secondary station.

Figure 3.5-3. Bathymetric chart of Bagaduce Narrows site (Reference 7).

A bathymetric chart of Castine Harbor is given below, showing the potential site for a 10 MW commercial project.

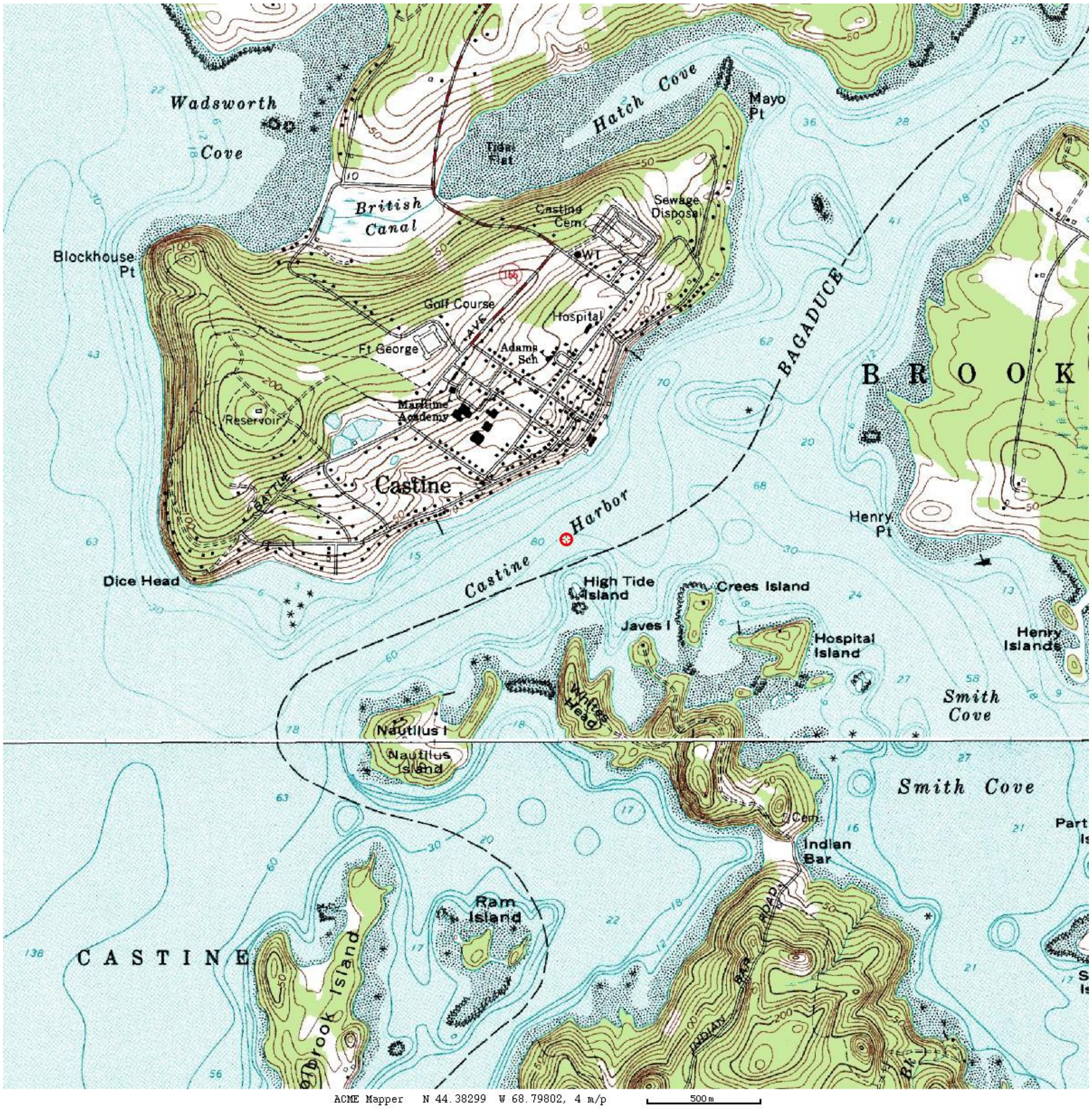


Figure 3.5-4. Bathymetric chart of Castine Harbor site (Reference 7).

A map showing the surficial geology of Bagaduce Narrows and Castine Harbor is given below.

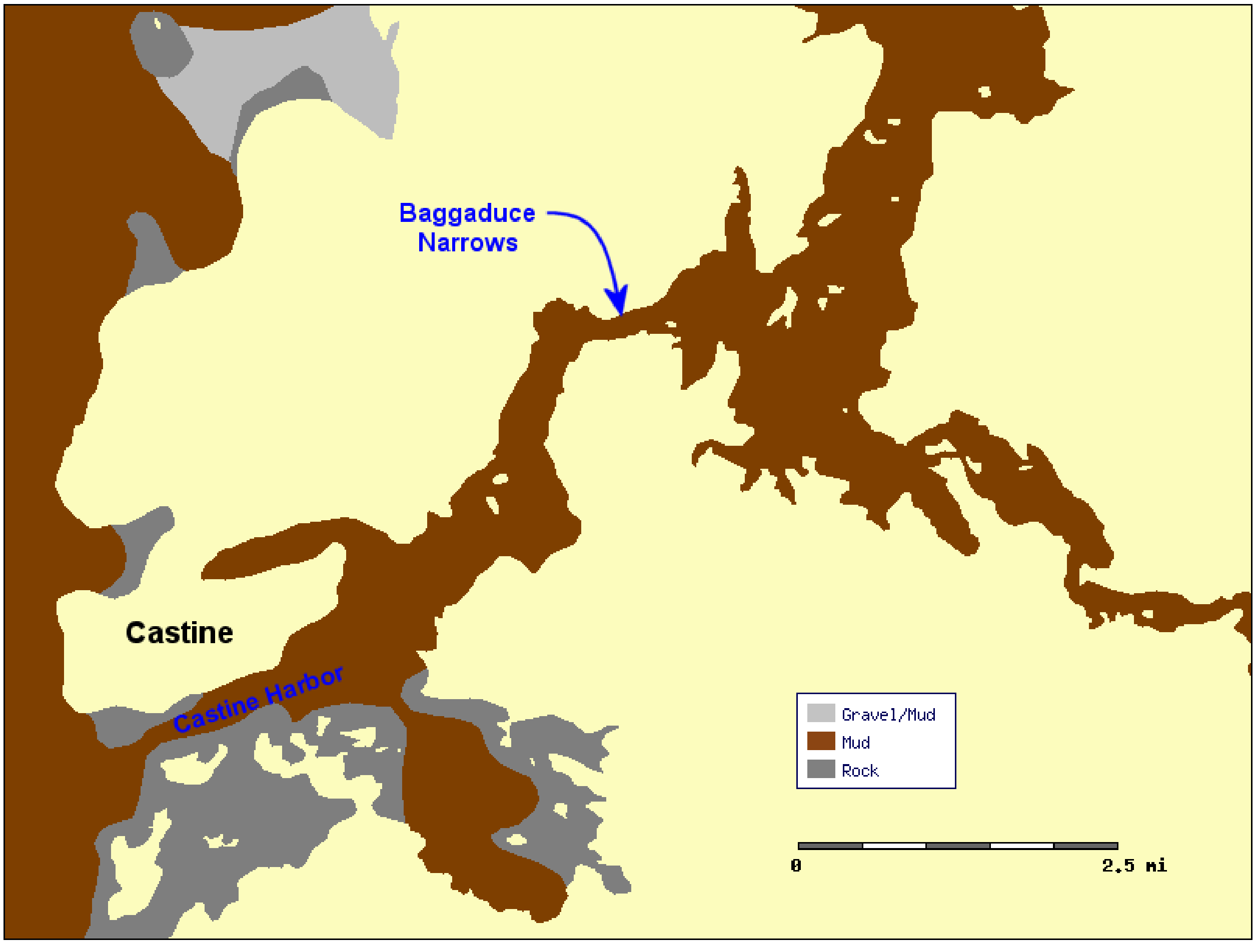


Figure 3.5-5. Surficial geology of Bagaduce Narrows and Castine Harbor (Reference 8).

3.5.3 Utility Grid Interconnection

Castine is served by Central Maine Power Company. The nearest 34.5 kV transmission connection is in Bucksport, which is about 16 miles from Bagaduce Narrows and 20 miles from Castine Harbor. The nearest 12.5 kV connection point is in Castine, which is immediately adjacent to the harbor and about 3 miles from Bagaduce Narrows.

3.5.4 Maritime Support Infrastructure

There are no commercial shipping facilities in Castine Harbor. The Maine Maritime Academy, at the western end of the Castine waterfront, maintains an excellent wharf with 26 feet alongside at which a large training vessel moors. The town wharf and float landing, just eastward of the Academy wharf, has 12 feet reported alongside.

A boatyard is 150 yards northeast of the town wharf. A 20-ton marine railway at the yard can handle craft up to 45 feet long for hull or engine repairs or dry open and covered winter storage.

3.5.5 Competing Uses of Sea Space

There is limited commercial lobstering and recreational fishing for striped bass and mackerel. Bagaduce Narrows provides boat access to productive shellfish flats further upstream (Reference 19). The shoreline adjacent to the Narrows is privately owned. Although the landowner expressed an interest in utilizing the tidal stream resource for powering his residence and a seasonal marina that he owns, this site would not be suitable for a utility project.

Castine Harbor has busy mooring areas, and potential conflict with boaters is high. Sufficient clearance would have to be provided for the *State of Maine* merchant marine training vessel.

3.5.6 Unique Opportunities

A demonstration project here could form the basis of a new curriculum at the Maine Maritime Academy, focused on workforce training in the deployment and servicing of ocean-based renewable energy systems in general and tidal in-stream energy conversion systems in particular.

This opportunity is well described in the 2000 book authored by Lincoln Paine, *Down East: A Maritime History of Maine* (Reference 21):

> In the town of Castine overlooking the Bagaduce there is a store called The Four Flags, a name that alludes to the town's occupation by French, English, Dutch, and American forces. Thanks to the Maine Maritime Academy, Castine is now home to a student body that may represent the flags of more than twenty different countries in a given year.

The next paragraph ends with the following sentence:

> Just as ships launched from Maine yards in the nineteenth century secured Maine's reputation for excellence in ports worldwide, graduates of the Maine Maritime Academy maintain the state's reputation as a center of maritime enterprise.

Thus, a tidal in-stream energy project at this site would showcase a new ocean enterprise to the world, an enterprise based on harnessing the immense energies of the sea.

3.6 Penobscot River – Bucksport

Penobscot River, emptying into the head of Penobscot Bay, forms the approach to the towns of Bucksport, Winterport, and the cities of Bangor and Brewer; the last two are at the head of navigation about 24 miles above Fort Point Light at the entrance. The deepest draft ordinarily trading to Bangor is about 16 feet.

About 2.5 miles above Fort Point Light, Penobscot River is divided by Verona Island into two channels. The principal channel is on the west side of the island, and the Eastern Channel (Eastern River) is on the east side. The channels unite north of Verona Island at the town of Bucksport (see Figure 3.6-1, below).

Figure 3.6-1. Location map for Penobscot River site (Reference 12)

The Penobscot River is unusual in that tidal range increases farther upstream, being greater at Bangor than near the river entrance. The mean range of tide varies from 10.3 feet at Fort Point to 13.1 feet at Bangor. Currents of 3 knots are not unusual from Odom Ledge to Orrington, and during spring runoff, currents reported to exceed 5 knots may be encountered.

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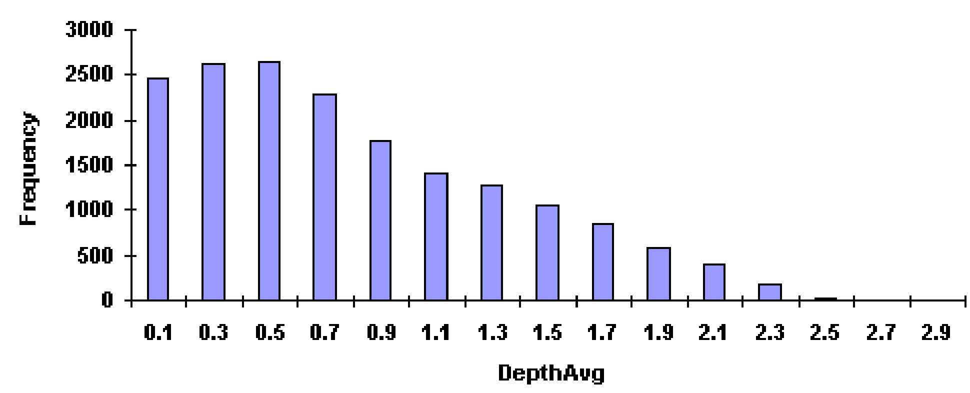
3.6.1 Tidal In-Stream Energy Resource

The NOAA Tidal Current Tables (Reference 4) have a secondary station in the Penobscot River west of Verona Island and so a year of tidal current predictions is available for this site. These predictions were used to construct a tidal power density histogram, which is given below.



Speed Bin Mid-Point (m/sec)	Tidal Stream Power Density (watts/sq.m)	Number of Cases	Percentage of Cases	Number of Hours	Tidal Stream Energy Density (kWh/sq.m)
0.1	0.5	2456	14.0%	1228.0	0.6
0.3	13.8	2625	15.0%	1312.5	18.2
0.5	64.1	2638	15.1%	1319.0	84.5
0.7	175.8	2273	13.0%	1136.5	199.8
0.9	373.6	1758	10.0%	879.0	328.4
1.1	682.1	1407	8.0%	703.5	479.9
1.3	1,126.0	1273	7.3%	636.5	716.7
1.5	1,729.7	1050	6.0%	525.0	908.1
1.7	2,517.9	860	4.9%	430.0	1,082.7
1.9	3,515.2	589	3.4%	294.5	1,035.2
2.1	4,746.3	410	2.3%	205.0	973.0
2.3	6,235.6	169	1.0%	84.5	526.9
2.5	8,007.8	12	0.1%	6.0	48.0
2.7	10,087.5	0	0.0%	0.0	0.0
2.9	12,499.4	0	0.0%	0.0	0.0
		17520	**1**	**8760**	**6,402.0**
5,000	sq.m section area	8760	hours		**0.731 kW/sq.m**
					Annual Average
3.7	**MW resource base**	1025	kg/cu.m		Power Density

Figure 3.6-2. Tidal in-stream power density histogram for Penobscot River.

3.6.2 Tidal Channel Bathymetry and Geology

A bathymetric contour chart of the Penobscot River around Verona Island is given below.

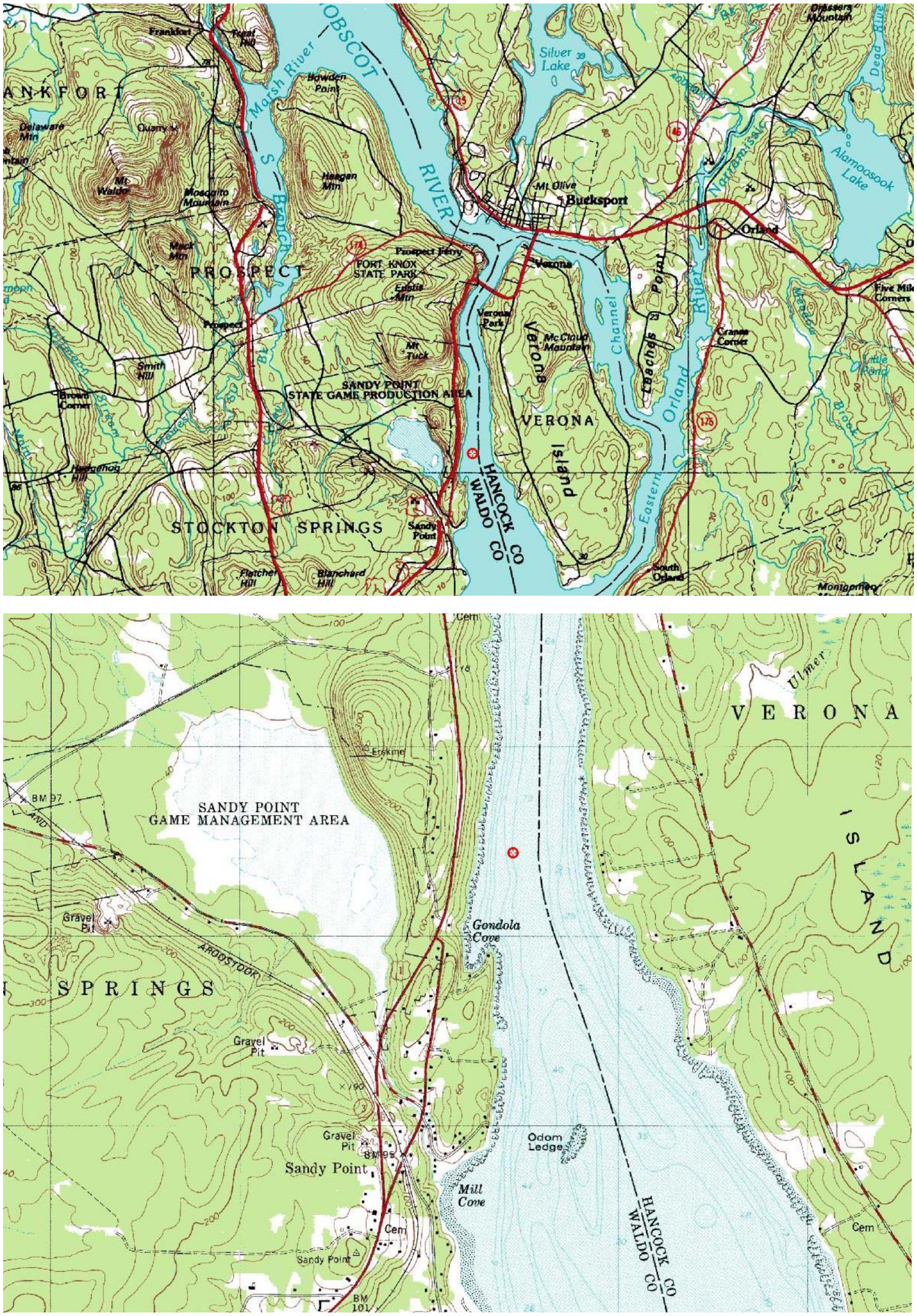


Figure 3.6-3. Bathymetric chart of Penobscot River site (Reference 7).

Reference 8 indicates a homogeneous surficial geology of muddy sediments in the Penobscot River around Verona Island.

3.6.3 Utility Grid Interconnection

Bucksport is served by Central Maine Power Company. For the potential project sites around Verona Island, the distance to the nearest 34.5 kV transmission connection is about 3 miles and the distance to the nearest 12.5 kV connection point is about half a mile.

3.6.4 Maritime Support Infrastructure

There is one deep-draft facility at Bucksport in general use. Most of the other wharves are in ruins with only broken pilings and stone foundations remaining. The paper mill wharf on the southeast side of the point just northwest of the town, has about 400 feet of berthing space with depths of 5 to 24 feet reported alongside. It is used principally to load small vessels and barges with paper.

A petroleum handling berth, consisting of nine concrete pile clusters supporting a handling platform, extends from a former railway wharf and provides a 700-foot berth with depths of 35 feet alongside and can accommodate vessels up to 65,000 DWT. A one-foot under-keel clearance is required when alongside Penobscot Bay and River oil facilities.

Three tugs up to 1,800 hp are available at Belfast. Arrangements for tugs are usually made through ships' agents; advance notice of 24 hours is required. Large oceangoing vessels require the use of tugs for docking at Searsport and at most of the ports on Penobscot River. A tug usually accompanies large vessels bound upriver to Brewer and other river ports; tugs meet vessels off Fort Point.

3.6.5 Competing Uses of Sea Space

Reference 19 reports very little commercial fishing activity here, but frequent sport fishing for striped bass July through September. This stretch of the river has moderately high recreational boating all summer.

The greatest potential conflict would be with commercial shipping navigation. This area is transited by large vessels and barge tows up to 600 feet, serving Bangor and the pulp and paper mill in Bucksport. The river is relatively shallow with insufficient beneath-keel clearance available for tidal turbines in the main channel.

Navigation Clearance Requirements: Approach and mooring criteria for Bucksport deepwater facilities are as follows: Large commercial vessels should engage the services of ship-assist tugs for inbound and outbound transits. For inbound transits, the assist tugs should be engaged in the vicinity of Fort Point. Ship-to-tug communication is established below Fort Point. Minimum visibility requirements for the Penobscot River are ½ mile. Maximum wind speed for docking and undocking in Bucksport are at the master and pilot's discretion. Maximum vessel capacity for Bucksport is 65,000 DWT; the maximum draft at MLW is 35 feet.

3.6.6 Unique Opportunities

The Maine Department of Transportation is replacing the Waldo-Hancock Bridge with a new suspension bridge, with construction well underway. The new bridge will open to traffic in the fall of 2006 (http://www.waldohancockbridge.com/waldo-county-bridge/). Included in the design is a 420-ft tall observation tower, which could represent an opportunity for a public education exhibit about tidal in-stream energy, as well as a good vantage point for local TISEC projects in the Penobscot River west of Verona Island.

Figure 3.6-4. Artist renderings of viewing observatory and entrance to observation tower by new suspension bridge over the Penobscot River west of Verona Island. (Source: http://www.waldohancockbridge.com/waldo-county-bridge/sim.php)

For a project located near the bridge, it also may provide a lower-cost route for the shore connection cable, minimizing the length of the underwater segment and avoiding the need for a separate shore crossing, by using the bridge's landfall to reach the onshore utility grid.

3.7 Cowseagan Narrows – Wiscasset

North of Hockomock Bay a natural channel leads through Montsweag Bay and Cowseagan Narrows, separating Westport Island from the mainland, and joins Sheepscot River just below Wiscasset (see Figure 3.7-1, below). This thorofare is hazardous because of currents which are reported to reach 5 knots on the ebb and flood. A fixed bridge at Cowseagan Narrows has a vertical clearance of 48 feet.

Figure 3.7-1. Location map for Cowseagan Narrows site (Reference 12)

3.7.1 Tidal In-Stream Energy Resource

Currents are strong (reported to reach 5 knots on the ebb and flood) in the vicinity of the fixed bridge that crosses Cowseagan Narrows about 2 miles south of Wiscasset. The ledges and shoals in the narrows make the channel quite narrow at this point. Mariners are advised that passage through the narrows should not be attempted without local knowledge, and then only by small boats at slack water.

Unfortunately, no measured, modeled, or predicted tidal current data is available for Cowseagan Narrows beyond the above report from the *Coast Pilot* (Reference 5). It may be possible to find current data used in the design of the bridge.

3.7.2 Tidal Channel Bathymetry and Geology

A bathymetric contour chart Cowseagan Narrows is given below.

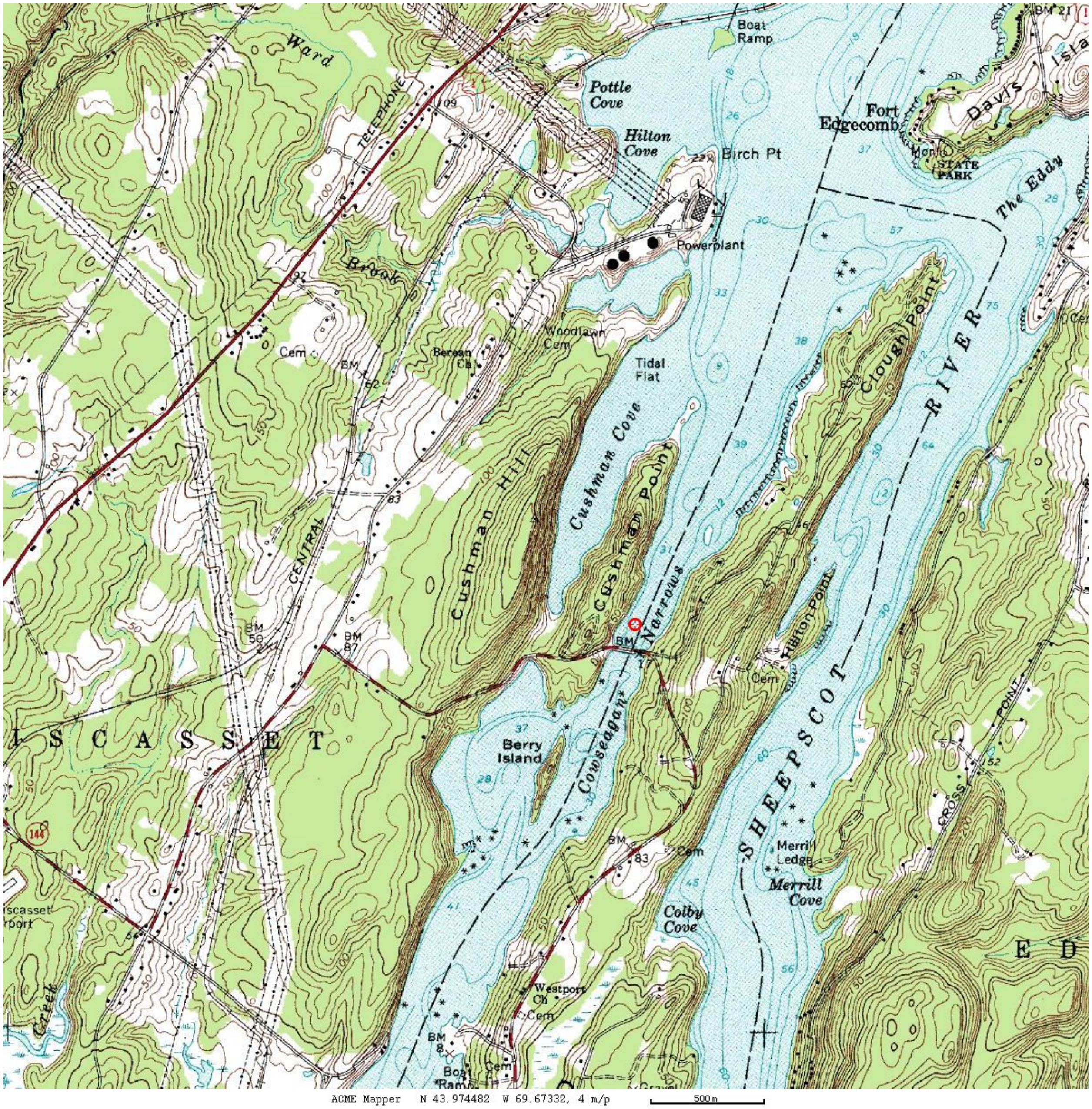


Figure 3.7-3. Bathymetric chart of Cowseagan Narrows site (Reference 7).

A map showing the surficial geology of Cowseagan Narrows is given below.

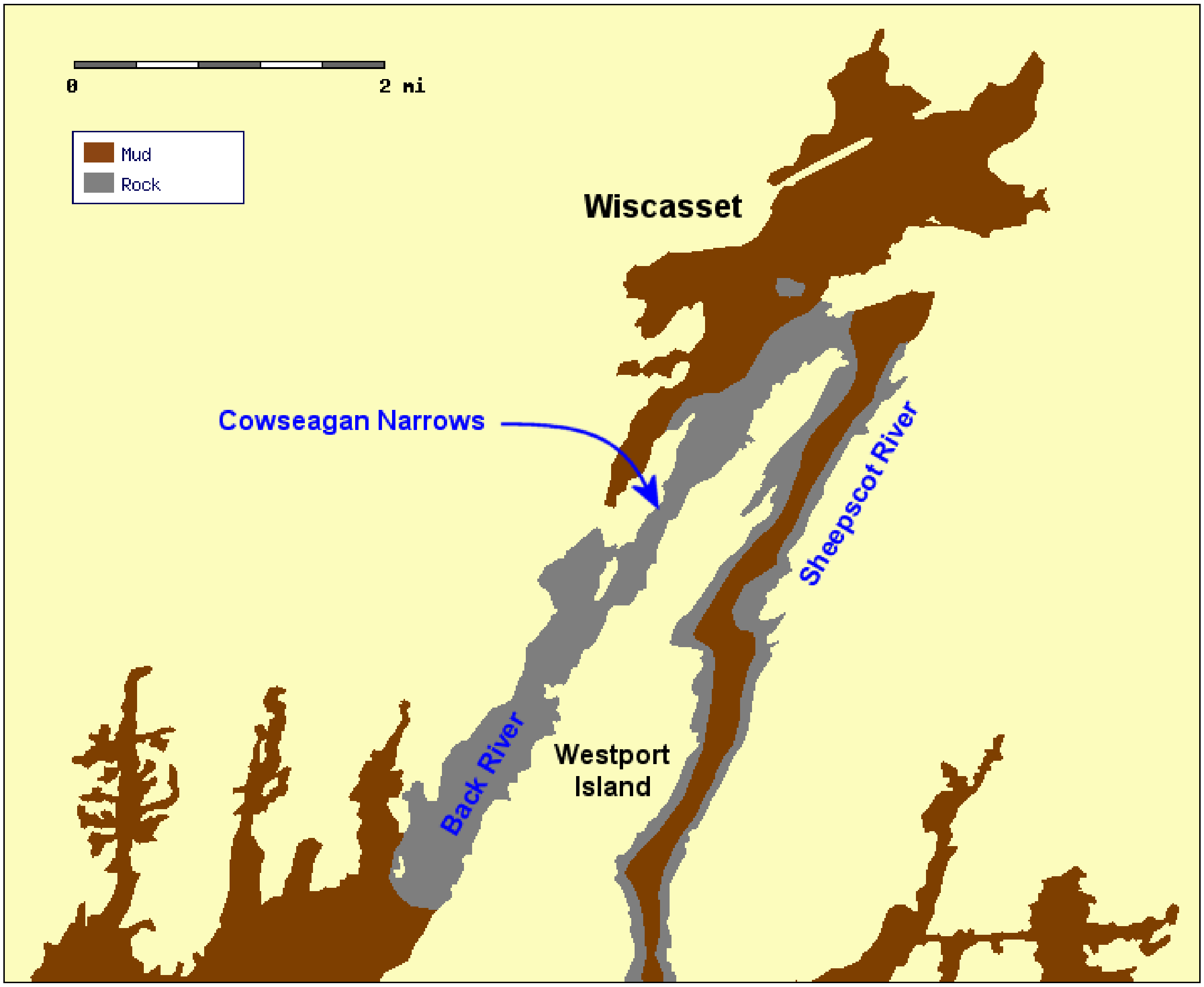


Figure 3.7-4. Surficial geology of Cowseagan Narrows. (Reference 8).

3.7.3 Utility Grid Interconnection

Wiscasset is served by Central Maine Power Company. The distance from the potential project site to the nearest 34.5 kV transmission connection is about 3 miles, and the distance to the nearest 12.5 kV connection point is also about 3 miles. If planned distribution upgrades are implemented, the distance to the 12.5 kV line will be even less.

3.7.4 Maritime Support Infrastructure

The Central Maine Power Company operates a large electric plant and a good pier with coal crane on Birch Point, 0.7 mile southwestward of the bridge at Wiscasset. The pier has reported depths of 31 to 33 feet alongside for a length of 750 feet, rock and mud bottom. Large tankers and occasionally a collier discharge at the pier. Vessels dock at high water slack without the assistance of tugs, and normally portside-to using the starboard anchor; fishing boats assist with the mooring lines. Fresh water is available at the pier.

An outboard engine repair shop is on a wharf at the west end of the bridge at Wiscasset; the wharf dries out at low water. Hull and engine repairs can be made at a boatyard on the southeast side of Davis Island, across the bridge from Wiscasset. The marine railway at the yard can handle craft up to 40 feet in length; winter storage is available.

3.7.5 Competing Uses of Sea Space

Reference 19 reports heavy lobstering gear concentrations here July through November and potential for entanglement by dragging traps during heavy flows. There also is heavy use by recreational boaters, with several landings and an anchorage area on the Westport shore.

3.7.6 Unique Opportunities

The bridge over Cowseagan Narrows may provide a lower-cost route for the shore connection cable, minimizing the length of the underwater segment and avoiding the need for a separate shore crossing, by using the bridge's landfall to reach the onshore utility grid.

3.8 Kennebec River Entrance – Bath

There are two approaches to the Kennebec River entrance (see Figure 3.8-1, below). The eastern, east of Seguin Island, which leads between Whaleback Rock and Pond Island, is the main channel. The western, west of Seguin Island, leads between Pond Island Shoal gong buoy and the shoals eastward. The eastern channel has a depth of 29 feet, and the western has minimum depths of 19 to 29 feet on the sailing lines. Both are used, but vessels drawing more than 18 feet usually enter by the eastern channel. The entrance has strong tidal currents, and if the wind is opposed to the current an ugly chop sea is encountered which is at times dangerous for small craft.

Figure 3.8-1. Location map for Kennebec River site (Reference 12)

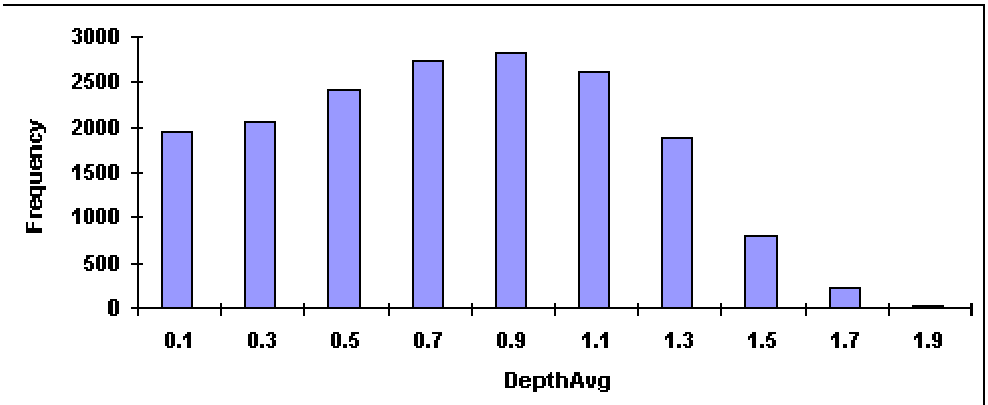
Popham Beach is a summer resort on the west side of Kennebec River just inside the entrance. An abandoned Coast Guard station is on the beach; its L-shaped wharf is located close westward of Fort Popham and has 9 feet alongside. In 1979, only ruins of some cribbing remained of an old wharf in the bight southwestward of the fort; and the long Government pier extending northward from Sabino Head was also in ruins.

The mean range of tide is 8.4 feet at Fort Popham in the entrance, and 6.4 feet at Bath. Atkins Bay, a large bay west of Hunnewell Point, dries out for most of its length at low tide.

3.8.1 Tidal In-Stream Energy Resource

Kennebec River has several secondary stations in the NOAA Tidal Current Tables (Reference 4), with the strongest currents predicted farther upstream, south of Doubling Point and west of Bluff Head. Neither of these sites was thought to be suitable, however, due to the narrowness of the river at these points and associated potential conflicts with navigation, which already is challenging for vessels heading downstream from Bath.

The NOAA Tidal Current Tables predictions for the secondary station northeast of Hunniwell Point were used to construct a tidal power density histogram, which is given below.



Speed Bin Mid-Point (m/sec)	Tidal Stream Power Density (watts/sq.m)	Number of Cases	Percentage of Cases	Number of Hours	Tidal Stream Energy Density (kWh/sq.m)	
0.1	0.5	1957	11.2%	978.5	0.5	
0.3	13.8	2050	11.7%	1025.0	14.2	
0.5	64.1	2409	13.8%	1204.5	77.2	
0.7	175.8	2724	15.5%	1362.0	239.4	
0.9	373.6	2818	16.1%	1409.0	526.4	
1.1	682.1	2613	14.9%	1306.5	891.2	
1.3	1,126.0	1884	10.8%	942.0	1,060.7	
1.5	1,729.7	812	4.6%	406.0	702.3	
1.7	2,517.9	224	1.3%	112.0	282.0	
1.9	3,515.2	29	0.2%	14.5	51.0	
		17520	**1**	**8760**	**3,844.8**	
990	sq.m section area	8760	hours		**0.439 kW/sq.m**	
					Annual Average	
0.4	**MW resource base**	1025	kg/cu.m		Power Density	

Figure 3.8-2. Tidal in-stream power density histogram for Kennebec River entrance.

3.8.2 Tidal Channel Bathymetry and Geology

A bathymetric contour chart for the Kennebec River entrance is given below.

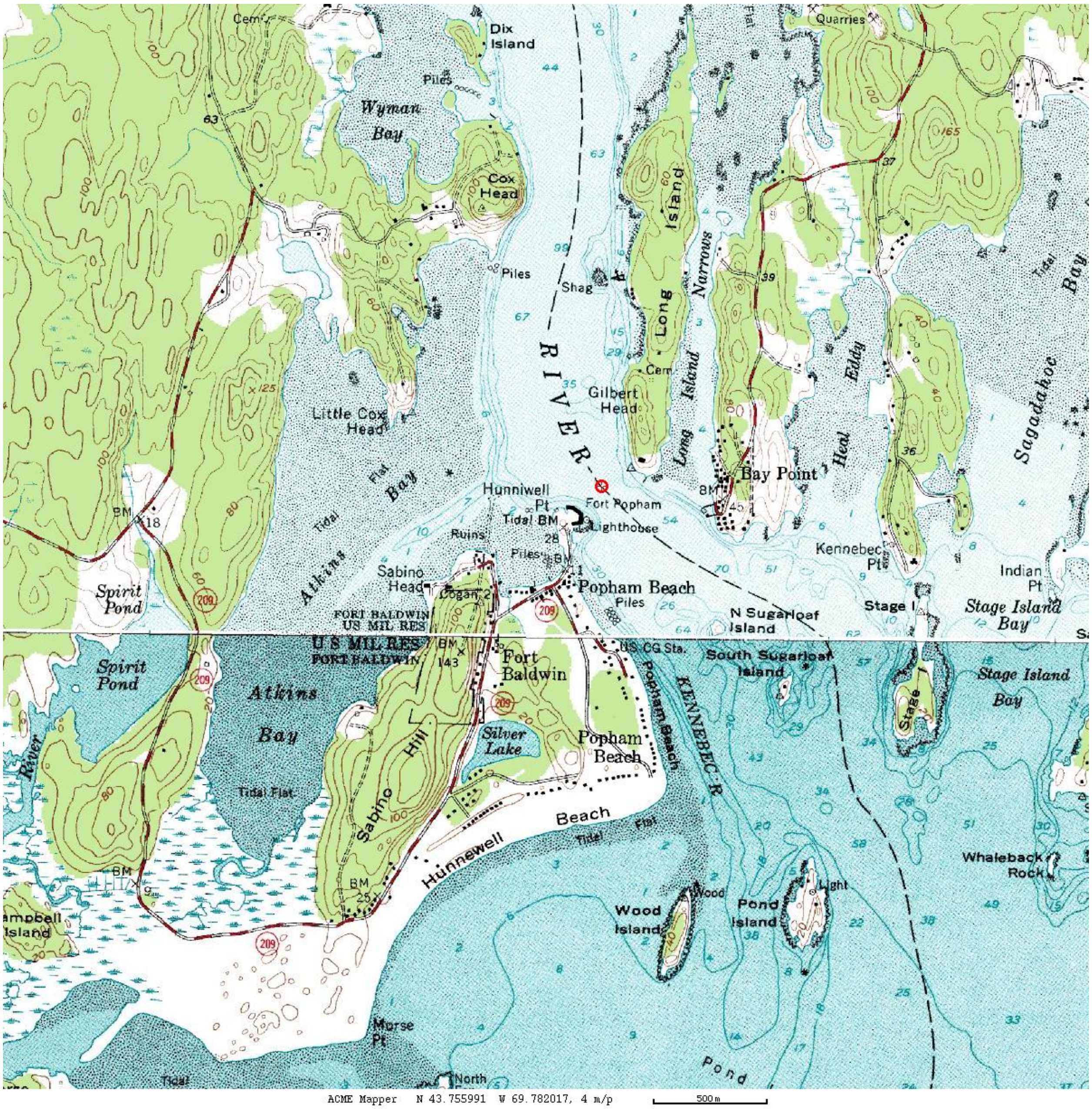


Figure 3.8-3. Bathymetric chart of Kennebec River site (Reference 7).

A map showing the surficial geology of the Kennebec River entrance is given below.

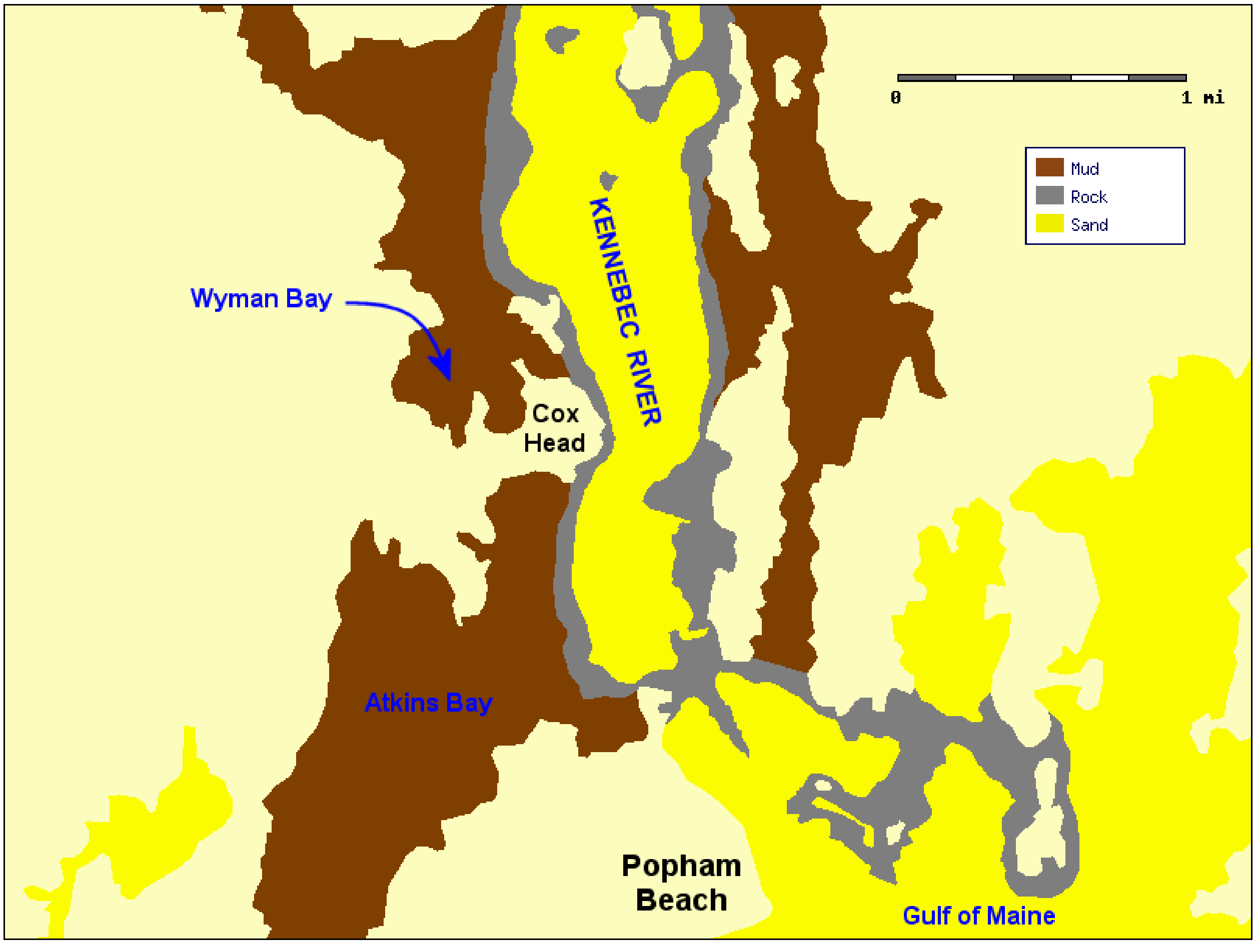


Figure 3.8-4. Surficial geology of Kennebec River and Castine Harbor (Reference 8).

3.8.3 Utility Grid Interconnection

The Fort Popham area is served by Central Maine Power Company. The distance from the potential project site to the nearest 34.5 kV transmission connection is about 5-6 miles and the distance to the nearest 12.5 kV connection point is about 1 mile.

3.8.4 Maritime Support Infrastructure

Due to its long history of shipbuilding, Bath has an extensive maritime support infrastructure, with five deep-draft facilities on the west side of the Kennebec River. All the facilities described below have highway connections and, except Stinson Canning Co., have railway connections.

Bath Iron Works, Outfitting Pier: 733 yards below U.S. Highway 1 Bridge; 600 feet of berthing space; 26 to 50 feet alongside; deck height, 10 feet; one 94-ton traveling gantry crane, one 30-ton wingwall crane and three additional cranes with capacities of 30 to 50 tons; one 8,400-ton floating drydock; mooring vessels for outfitting and repair; owned and operated by Bath Iron Works.

Bath Iron Works, South Wharf: 460 yards below U.S. Highway 1 Bridge; 26 feet alongside; deck height, 9 feet, one 25-ton traveling gantry crane, one fixed 97 to 220-ton crane; three shipbuilding ways; mooring vessels for outfitting; owned and operated by Bath Iron Works.

Bath Iron Works, North Wharf: below U.S. Highway 1 Bridge; 32 feet alongside; deck height, 8 feet; one 25-ton traveling gantry crane, one 5-ton crane; mooring vessels for repair; owned and operated by Bath Iron Works..

Marine Minerals Corp., Coal Pocket Dock: 0.5 mile above U.S. Highway 1 Bridge; 450 feet of berthing space; 27 feet alongside; deck height, 9 feet; one electric conveyor belt, rate 500 tons per hour; open storage for 50,000 tons of material; receipt of miscellaneous bulk materials including coal and salt; owned and operated by Marine Minerals Corp.

Stinson Canning Co., Bath Dock: 1.5 miles above U.S. Highway 1 Bridge; 260 feet of berthing space; 15 feet alongside; deck height, 12 and 14 feet; two 12-inch suction pipelines; receipt of fish; owned and operated by Stinson Canning Co.

A shipyard on the east side of the river at Woolwich, about 500 yards north of the bridge, builds steel vessels up to 120 feet long. A boatyard, on the west side of the river about 1.3 miles below the bridge, has a marine railway that can handle craft up to 50 feet in length.

Tugs are available at Bath. Bath shipyard tug handles primarily shipyard traffic. If desired, commercial tugs can be obtained from Bath, Southport, Boothbay Harbor, Belfast, or Portland; arrangements for this service should be made in advance through ships' agents.

3.8.5 Competing Uses of Sea Space

Reference 19 reports lobstering July through November, shellfish harvesting year-round, and eel fishing in summer. There also is recreational fishing for striped bass and bluefish. Large concentration of moorings off Popham Beach and Bay Point.

Maintenance Dredging: The Federal project for Kennebec River provides for a channel 27 feet deep from the entrance to a point about 0.6 mile above the bridge at Bath.

Potential Hazards: During freshets, pulp logs are sometimes washed over the dam above Augusta and present a serious navigational hazard, especially to small craft. Log booms are maintained at Brown Island and on the east side of the river below Shepard Point to facilitate recovery of the drifting logs. The booms are not lighted, but are outside the navigation channel. The presence of deadheads, known locally as tide walkers, are a constant hazard in the river, especially to small craft. These water-logged boom logs, weighted at one end by parts of mooring chains, with one end down and the other end at the surface or just under, and shift position with the tidal or river currents.

3.8.6 Unique Opportunities

No unique opportunities have been identified for this site.

3.9 Ewin Narrows – Portland

There is a small craft passage from the north end of Harpswell Sound through Ewin Narrows, Prince Gurnet, Long Reach, and Gurnet Strait to New Meadows River. It is occasionally used by local boats. The channel is narrow, has a least depth of only about 6 feet, and has many dangers, with strong tidal currents. A fixed highway bridge with a clearance of 30 feet crosses the southern part of Ewin Narrows (see Figure 3.9-1, below).

Figure 3.9-1. Location map for Ewin Narrows site (Reference 12)

3.9.1 Tidal In-Stream Energy Resource

Unfortunately, no measured, modeled, or predicted tidal current data is available for the entrance for Ewin Narrows beyond the report of "strong currents" in the *Coast Pilot* (Reference 5). It may be possible to find current data used in the design of the bridge here.

3.9.2 Tidal Channel Bathymetry and Geology

A bathymetric contour chart Ewin Narrows is given below.

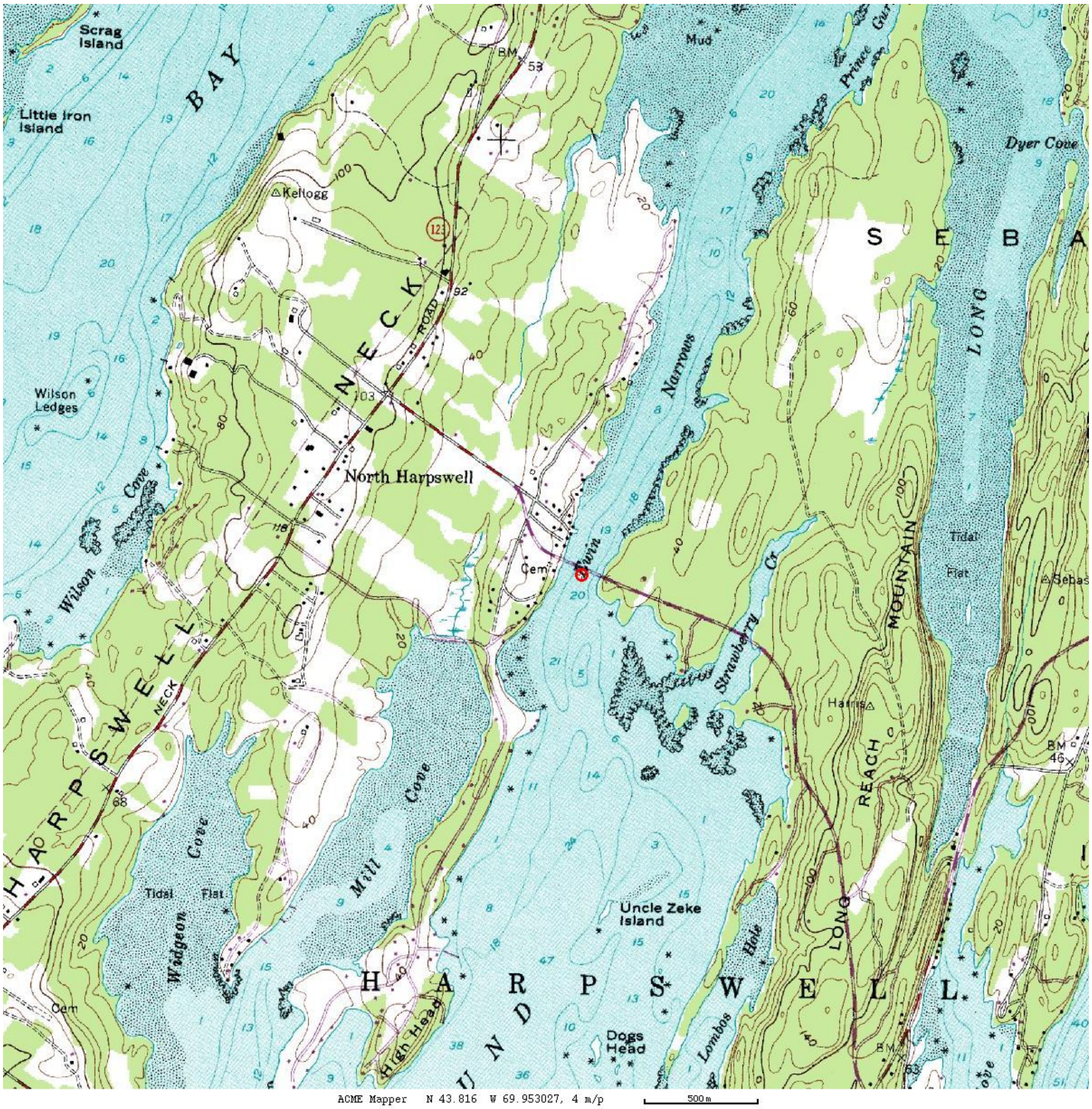


Figure 3.9-2. Bathymetric chart of Ewin Narrows site (Reference 7).

Reference 8 indicates a homogeneous surficial geology of muddy sediments in Ewin Narrows.

3.9.3 Utility Grid Interconnection

The Harpswell area is served by Central Maine Power Company. The distance from the potential project site to the nearest 34.5 kV transmission connection is about 14 miles (assuming a land route) and the distance to the nearest 12.5 kV connection point is about 2.5 miles.

3.9.4 Maritime Support Infrastructure

Portland Harbor, at the western end of Casco Bay, is the most important port on the coast of Maine. The ice-free harbor offers secure anchorage to deep-draft vessels in all weather. There is considerable domestic and foreign commerce in petroleum products, wood pulp, paper, seafood products, and general cargo. It is also the Atlantic terminus of pipeline shipments of petroleum products to Canada.

The outer harbor comprises the area westward of Cushing, Peaks, House, and Great and Little Diamond Islands from the entrance at Portland Head to the entrance of Fore River at Fish Point, including the three deepwater general anchorages and the oil discharging berth westward of Spring Point. The Coast Guard Captain of the Port, Portland advises the minimum visibility requirements for deep draft vessels for Portland Outer Harbor are ½ mile.

The inner harbor is considered to be in two sections; the outer part or Main Harbor, extending from the entrance of Fore River to the Casco Bay Bridge; and the inner part, or Fore River, from Casco Bay Bridge to the head of deepwater navigation at the combined fixed railroad and highway bridge. The Coast Guard Captain of the Port, Portland advises the minimum visibility requirements for deep draft vessels for Portland Inner Harbor are ¼ mile.

Deepwater facilities at Portland include seven petroleum terminals, one general cargo terminal, and one international ferry terminal. All of these have highway connections and most have railroad connections.

A shipyard at Portland has an 80,000-ton drydock, 844 feet long, with a clear inside width of 137 feet and a depth of 47 feet over the keel blocks. The drydock has two wing-wall 25-ton cranes. A repair pier with 37 feet reported alongside is available for above-the-waterline repairs. The pier has two cranes, 25 tons and 60 tons. A complete array of shops is at the yard.

A boatyard at South Portland, about 0.7 mile northeastward of the Casco Bay Bridge has three marine railways, the largest of which can handle craft up to 210 feet long, 1,200 tons displacement, and 16-foot draft for practically any type of repair work. A machine shop is at the yard; rental mobile cranes can be obtained.

There are several ship repair firms in the port that have fully equipped machine, pipe, joiner, and welding shops and can handle above-the-water hull and engine repairs. A 100-ton fixed derrick, floating cranes up to 20 tons, and a 65-ton mobile crane are available in the port.

3.9.5 Competing Uses of Sea Space

Reference 19 reports commercial lobstering July through November, with potential for entanglement by dragging traps during heavy flows. There is clamming year-round and sport fishing for striped bass. Another potential conflict here is anchorage by both commercial and recreational vessels off the western shore.

3.9.6 Unique Opportunities

The bridge over Ewin Narrows may provide a lower-cost route for the shore connection cable and avoid the need for permitting a separate shore crossing.

3.10 Piscataqua River – Kittery

Portsmouth Harbor is at the mouth of Piscataqua River and is the approach to the cities of Portsmouth and Dover, and the towns of New Castle, Kittery, Newmarket, Durham, Newington, and Exeter. Several U.S. Navy activities, including Portsmouth Naval Shipyard and a regional medical clinic, are on Seavey Island at Kittery.

Portsmouth, NH is located on the south bank of Piscataqua River about 4 miles above the entrance to the harbor. Foreign trade is in petroleum products, gypsum, frozen fish, fish products, and salt. Oil shipments in tankers, drawing as much as 35 feet, arrive frequently, except during the summer. Kittery is a town on the north bank of the river, opposite Portsmouth.

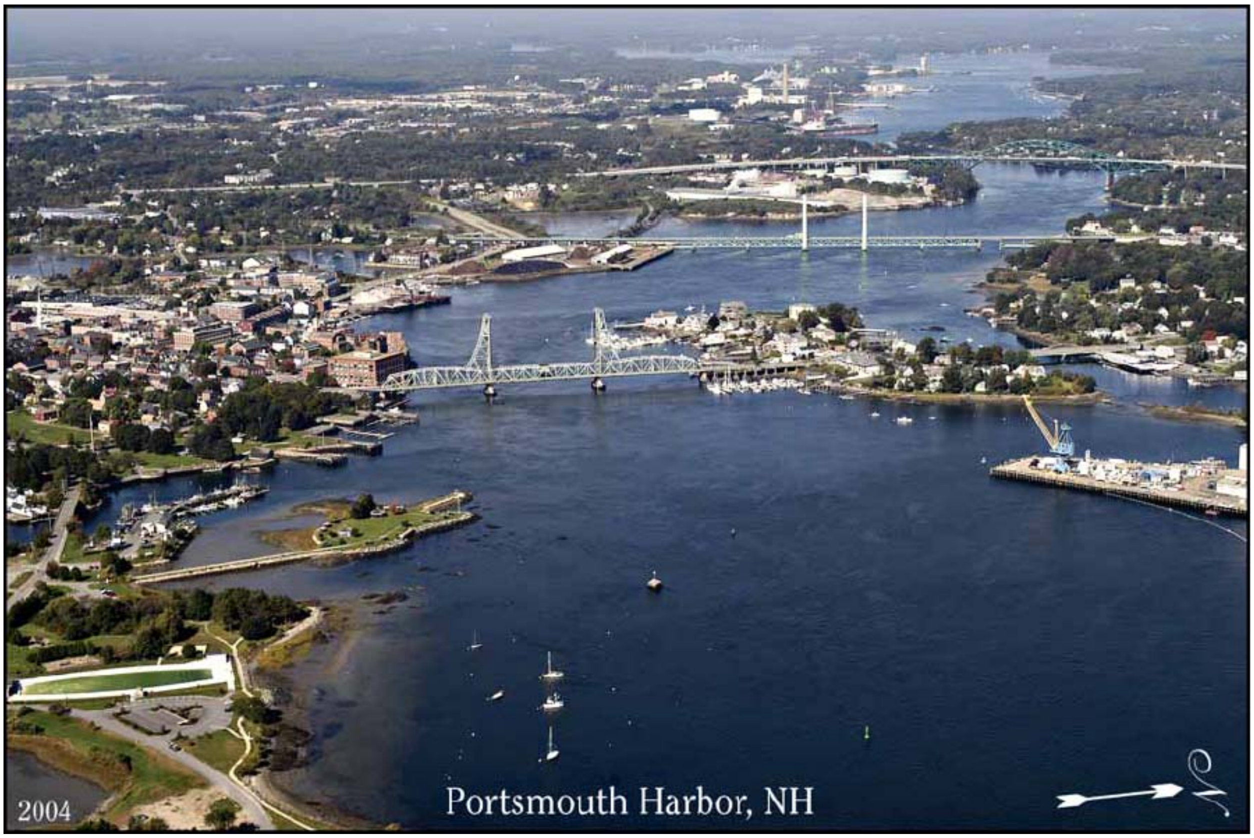


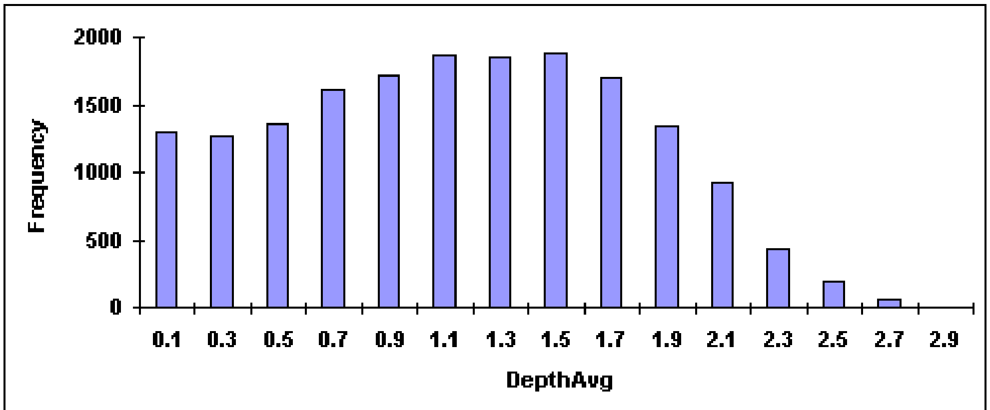
Figure 3.10-1. Aerial photo of Piscataqua River site (Reference 5)

The mean range of tide is 8.7 feet at Kittery Point and 6.4 feet at Dover Point.

General navigation throughout the entire length of the Piscataqua River system is severely hampered by rapid tidal currents. The velocities of these currents differ at various locations because of the irregularities in the width and depth of the river and its tributaries. The maximum average velocity in the river occurs off Nobles Island and off Dover Point at the entrance to Little Bay, amounting to over 4 knots at peak ebb flow.

3.10.1 Tidal In-Stream Energy Resource

The NOAA Tidal Current Tables (Reference 4) have a secondary station in the Piscataqua River just north of Nobles Island and so a year of tidal current predictions is available for this site. These predictions were used to construct a tidal power density histogram, which is given below.



Speed Bin Mid-Point (m/sec)	Tidal Stream Power Density (watts/sq.m)	Number of Cases	Percentage of Cases	Number of Hours	Tidal Stream Energy Density (kWh/sq.m)
0.1	0.5	1299	7.4%	649.5	0.3
0.3	13.8	1272	7.3%	636.0	8.8
0.5	64.1	1363	7.8%	681.5	43.7
0.7	175.8	1613	9.2%	806.5	141.8
0.9	373.6	1716	9.8%	858.0	320.6
1.1	682.1	1863	10.6%	931.5	635.4
1.3	1,126.0	1847	10.5%	923.5	1,039.8
1.5	1,729.7	1880	10.7%	940.0	1,625.9
1.7	2,517.9	1706	9.7%	853.0	2,147.8
1.9	3,515.2	1346	7.7%	673.0	2,365.8
2.1	4,746.3	925	5.3%	462.5	2,195.1
2.3	6,235.6	430	2.5%	215.0	1,340.7
2.5	8,007.8	193	1.1%	96.5	772.8
2.7	10,087.5	64	0.4%	32.0	322.8
2.9	12,499.4	3	0.0%	1.5	18.7
		17520	**1**	**8760**	**12,979.9**
2,300	sq.m section area	8760	hours		**1.482 kW/sq.m**
					Annual Average
3.4	**MW resource base**	1025	kg/cu.m		Power Density

Figure 3.10-2. Tidal in-stream power density histogram for Piscataqua River.

3.10.2 Tidal Channel Bathymetry and Geology

A bathymetric contour chart Piscataqua River is given below, showing the NOAA tidal current secondary station north of Nobles Island, beneath the Maine-NH Bridge.

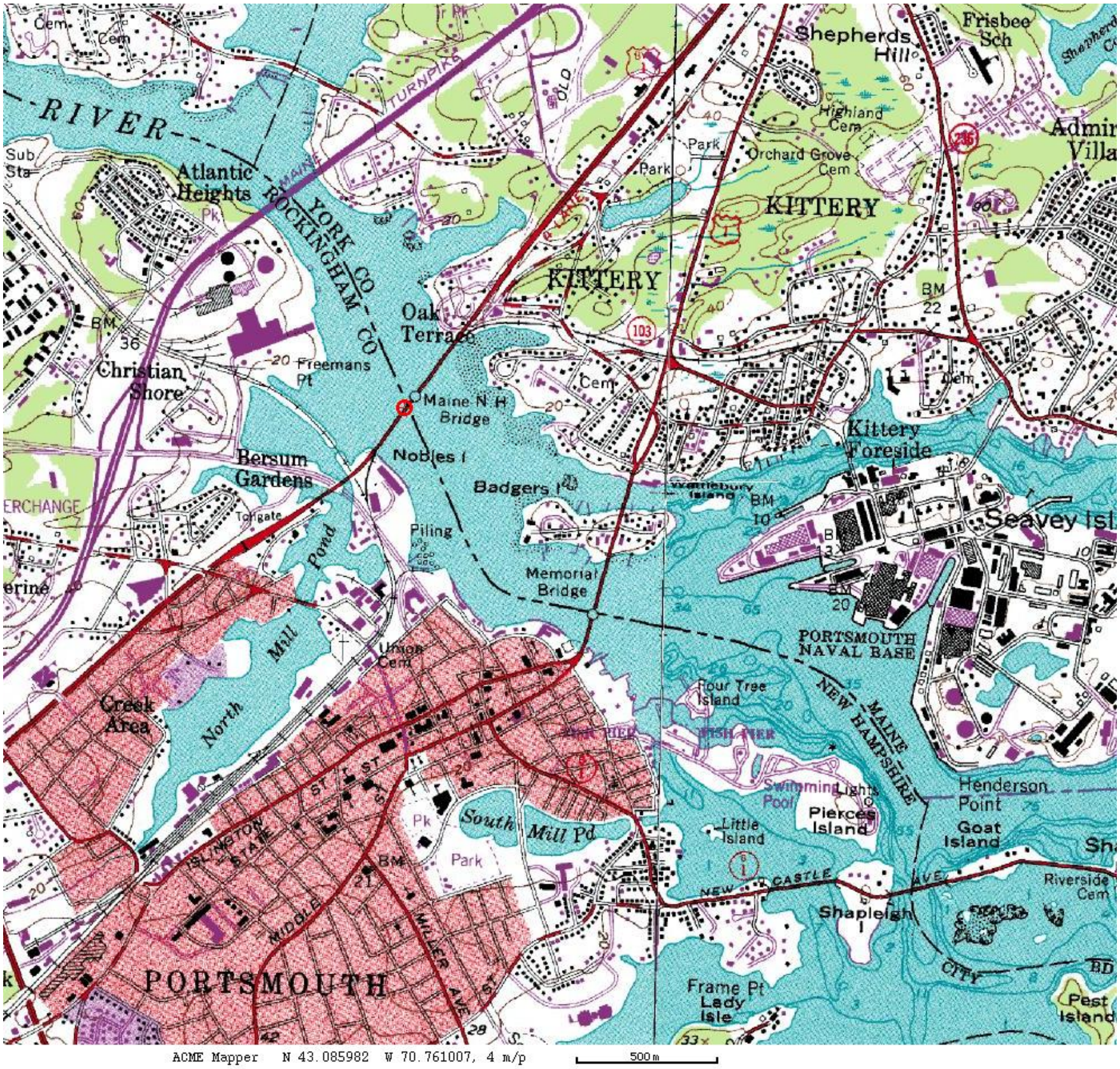


Figure 3.10-3. Bathymetric chart of Piscataqua River site (Reference 7).

Unfortunately, the coastal surficial geology mapped by Reference 8 does not extend this far up the Piscataqua River. Discussions with the local harbormaster indicated that a sand or mud bottom is likely here.

3.10.3 Utility Grid Interconnection

Kittery is served by Central Maine Power Company. The distance from the potential project site to the nearest 34.5 kV transmission connection is about 3 miles and the distance to the nearest 12.5 kV connection point is right at the shoreline.

3.10.4 Maritime Support Infrastructure

All of the commercial deep-draft facilities in use are on the south bank of the Piscataqua River between the first bridge, Memorial Highway Bridge, and Dover Point. All of the facilities have highway connections, and all except the Defense Fuel Support Point, Newington Dock, have rail connections. The alongside depths given for each facility described are reported below.

Granite State Minerals Dock: about 0.3 mile above the Memorial Highway Bridge; 300-foot marginal wharf; 32 feet alongside; deck height, 18 feet; 2 acres of open storage; two crawler cranes with 2½-cubic yard clamshell buckets for combined lifting capacity of 20 tons; 2½-cubic yard front-end loader; 130-ton mobile crane; water and electrical shore power connections; receipt of salt, receipt and shipment of dry bulk cargoes and heavy lift items; owned and operated by Granite State Minerals, Inc.

New Hampshire State Port Authority, Marine Terminal Wharf: about 0.45 mile above the Memorial Highway Bridge and immediately southeastward of the second bridge; 578-foot face; 35 feet alongside; deck height, 14 feet; 43,000 square feet covered storage and 10 acres open storage; mobile cranes up to 165 tons and fork lift trucks; receipt and shipment of containerized and conventional general cargo and shipment of scrap metals; owned by New Hampshire State Port Authority and operated by New Hampshire State Port Authority and John T. Clark and Son of New Hampshire, Inc.

National Gypsum Co., Portsmouth Plant Wharf: about 0.9 mile above the Memorial Highway Bridge; 300-foot marginal wharf; 35 to 34 feet alongside; deck height, 14 feet; hopper conveyor-belt system for handling gypsum rock; receipt of gypsum rock by self-un-loading vessels and receipt of petroleum products; owned by Gold Bond Building Products, division of National Gypsum Co. and operated by National Gypsum Co., and Northeast Petroleum Corp. of New Hampshire.

Mobil Oil Corp., Portsmouth Terminal Wharf: about 1.75 miles above the Memorial Highway Bridge; offshore wharf; 250 feet with dolphins; 37 feet alongside deck height, 10 feet; receipt of petroleum products owned by Public Service Co. of New Hampshire and operated by Mobil Oil Corp.

C. H. Sprague and Son Co. Wharf: immediately northward of Mobil Oil Corp. Wharf; 405-foot offshore wharf, 700 feet with dolphins; 37 feet alongside; deck height, 11 feet; water connections; receipt of coal and fuel oil; owned by Public Service Co. of New Hampshire and operated by C. H. Sprague and Son Co.

Simplex Wire and Cable Co. Wharf: about 2.3 miles above the Memorial Highway Bridge; 130-foot offshore wharf, 690 feet with dolphins; 30 feet alongside; deck height, 15 feet; special equipment for loading cable; water connections; receipt and shipment of wire and submarine cable; owned and operated by Simplex Wire and Cable Co.

Defense Fuel Support Point, Newington Dock: about 2.8 miles above the Memorial Highway Bridge; 344-foot offshore wharf; 32 feet alongside; deck height, 15 feet; occasional receipt and shipment of petroleum.

There are no facilities for drydocking deep-draft vessels in Portsmouth Harbor. Several machine shops can make minor repairs to machinery. The several boatyards are capable of hauling out boats up to 85 feet in length.

3.10.5 Competing Uses of Sea Space

Navigation Clearance Requirements: The U.S. Coast Guard, in cooperation with the Navigation Subcommittee of the Maine and New Hampshire Port Safety Forum, has established recommended minimum under-keel clearances for the Port of Portsmouth, in order to prevent groundings and to promote safety and environmental security of the waterway resources of the Port of Portsmouth. The group recommends that all entities responsible for safe movement of vessels in and through the waters of the Port of Portsmouth operate vessels in such a manner as to maintain a minimum under-keel clearance of 3 feet between the deepest draft of their vessel and the channel bottom when transiting Portsmouth Harbor and the Piscataqua River inside Kitts Rock Lighted Whistle Buoy 2KR.

3.10.6 Unique Opportunities

This would be a highly visible project for U.S. Route 1 highway traffic crossing the bridge between Maine and New Hampshire. The bridge also may provide a lower-cost route for the shore connection cable, minimizing the length of the underwater segment and avoiding the need for a separate shore crossing, by using the bridge's landfall to reach the onshore utility grid.

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Appendix A – "Long List" of Potential Tidal Plant Sites in Maine

Note that only the five sites marked with an asterisk are likely to have sufficient resources for a 10 MW project or larger.

Potential sites off Passamaquoddy Bay:

* Western Passage off Kendall Head, between Deer and Moose Islands (possible joint project with New Brunswick?)

Lubec Narrows, between Campobello Island and Lubec (possible joint project with New Brunswick?)

Potential sites in Cobscook Bay:

* Outer Cobscook Bay entrance, between Cooper Island and Shackford Head

Half Moon Cove entrance, between Quoddy Village and Perry

* Central Cobscook Bay entrance, between Birch Point and Gove Point

Pennaquaman River entrance

South Bay entrance

Inner Cobscook Bay entrance, between Leighton Point and Denbow Point

Straight Bay entrance, between Crow Neck and Coffins Neck

Whiting Bay entrance, between Moosehorn NWR and Crow Neck

Potential sites along Gulf of Maine:

Cross Island Narrows (eastern entrance to Machias Bay)

Entrance to Little Kennebec Bay

Moosabec Reach (bridge from Jonesport to Beals)

* Harrington Bay, off Ripley Neck

Entrance to Dyer Bay

*Entrance to Gouldsboro Bay

West Sullivan, entrance to Taunton Bay (also drains Egypt Bay and Hogs Bay)

Entrance to Skillings River

Mt. Desert Narrows between Eastern Passage and Western Passage, north of Mount Desert Island

Somes Sound, Mount Desert Island

Eggemogin Reach (Sedgwick bridge between Little Deer Isle and Byard Point; submarine cable off Little Babson Island)

Entrance to Southeast Harbor, Deer Isle

* Bagaduce Narrows (educational opportunity at Maine Maritime Academy, Castine)

Fisherman Island Passage between Fisherman Island and Sheep Island (ebb-dominated)

St. George River, the Narrows below Bird Point

* Entrance to Broad Cove and Medomak River

Eentrance to Damariscotta River, the Narrows at Fort Island

* Sasanoa River, Lower Hell Gate between Knubble Bay and Hockomock Bay

Oven Mouth, where Cross River empties into Sheepscot River

Wiscasset, Cosweagan Narrows between Montsweag Bay and Sheepscott River

Kennebec River, south of Doubling Point

Kennebec River, west of Bluff Head

Entrance to New Meadow River

Entrance to Harpswell Sound

Portsmouth Harbor, southwest of Badgers Island

Piscataqua River, north of Nobles Island

Appendix B – Maine Transmission and Distribution Network

Maine Electric Power Company, Inc. (MEPCO) and Central Maine Power (CMP) own and operate the entire 345 kV backbone transmission network in Maine. MEPCO owns all 345 kV lines between the New Brunswick border and Maine Yankee. This is the only interconnection between the Canadian Maritime Provinces and the North American eastern interconnection. Additionally, CMP owns and operates all other transmission in central and southern Maine, west of the Bangor area; Bangor Hydro Electric Com0pany (BHE) owns and operates most of the lower voltage transmission from the Bangor area to Aroostook County; and Maine Public Service Company (MPS) owns and operates the lower voltage transmission in Aroostook County.

An item to be aware of in New England is that the NEPOOL/ISO-NE rules have a 5MW limit that keys involvement with the whole NEPOOL/ISO-NE planning group. As such, any project that exceeds that limit will require significantly more time and effort to accomplish, so as to determine the potential for system impact.

This description of possible grid interconnections points for potential in- stream tidal power plant sites from north to south are described below. Because of security concerns following 9-11, maps of the T&D system and locations of subsystems are not provided in a public document such as this report. Appropriate maps have been provided to the appropriate electricity stakeholders in Maine charged with the responsibility of evaluating potential in stream tidal sites

1. Bangor Hydo Electric Company

Bangor Hydro-Electric Company (BHE) www.bhe.com is an electric utility wholly-owned by Emera Inc. BHE serves a population of 192,000 in an area encompassing 5,275 square miles in eastern and east coastal Maine and provides electricity transmission and distribution service to 107,000 customers and with a system peak approaching 300MVA (see Figure B-1). The electric system is connected to the 345kV backbone at Orrington substation, a shared facility, where the energy is transformed to 115kV, for serving the BHE territory. The 115kV system goes to Millinocket in the north and Jonesboro in the east, with a fairly strong tap to the Ellsworth area. Sub transmission is done with either 46kV or 34.5kV with various distribution voltages below that.

BHE, like all other investor owned utilities in the state of Maine, is not permitted to generate nor buy and sell energy relative to their service territory customer base. As such they are just in the business of providing transmission and distribution services to their native customers.

BHE is a member of the New England Power Pool and is interconnected with other New England utilities to the south and with the New Brunswick Power Corp. to the north.

Figure B-1 BHE Service Area

While the opportunities for large generation projects (>100MW or so) is somewhat limited in the BHE system, there are numerous opportunities for smaller projects. Locations that may be reasonable to get to ocean generation sites and the voltage, a rough estimate of local area load, and a suggested limit to generation injection are listed in the following table.

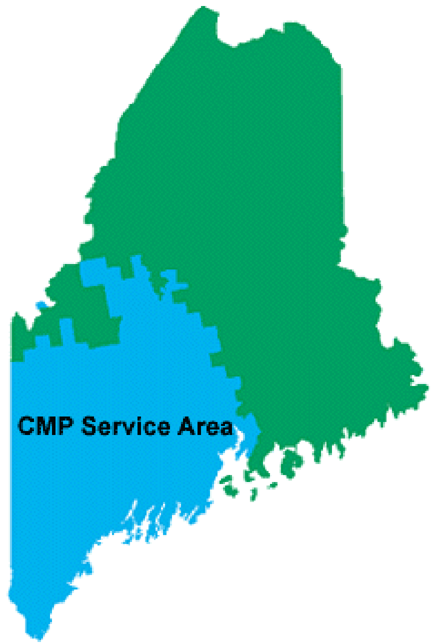
Table B-1. BHE Coastal Substations

Location	Voltage kV	Area load MW	Opportunity MW
Eastport	34.5	4	10
Lubec	34.5	2	6
Cutler	34.5	2	10
Bucks Harbor	34.5	1.5	10
Jonesport	34.5	4	10
Southwest Harbor	34.5	10	15
Northeast Harbor	34.5	6	15
Bar Harbor	34.5	10	20
Deer Isle	34.5	3	10
Gouldsbor/Winter Harbor	34.5	5	15

In addition there may be an opportunity to connect to the 46kV system that ends at Brooksville, and is the source to the Stonington/Deer Isle area. Opportunity is likely to be limited to less than 20MW.

The location of the above listed coastal substations can be determined from T&D grid maps.

2. **Central Maine Power**



Central Maine Power (CMP) serves nearly 565,000 customer accounts in an 11,000-square-mile service area in central and southern Maine. CMP operates 20,000 miles of electrical lines and more than 150 substations.

The transmission system is responsible for carrying bulk electricity from generators, and our ties to the rest of New England and Canada, throughout our service territory. It consists of the highest capacity power lines, capacitors, transformers, circuit breakers, and other high voltage equipment used for transmitting, switching, and controlling electrical power. The transmission system in CMP's service territory operates at three voltage levels:345 kV, 115 kV and 34.5 kV. The following is a breakdown of the three transmission operating voltages and their characteristics.

CMP's transmission system comprises approximately 2,300 miles of transmission lines and 300 substations. This system serves an 11,000-square-mile area, more than the size of Massachusetts and Rhode Island combined. Within this service territory, CMP serves more than 516,000 residential, commercial, industrial, and wholesale customers.

The CMP transmission system operates at three voltage levels: 345 kV, 115 kV, and 34.5 kV. The transmission and distribution lines can be compared to roads and the voltage may be compared to the speed limit. Substations act like the exit ramps or turnoffs. Voltage from one line to the next is changed at the substations. The following is a breakdown of CMP's three transmission operating voltages and their characteristics.

The Interstate Highway - 345 kV - The 345 kV system is the backbone of the transmission system. The 345 kV transmission lines carry more power than any other lines in our entire system. They are the main connection between CMP and bulk power systems to the north, in New Brunswick, Canada, and to the south, in New Hampshire and Massachusetts. 345 kV transmission lines are responsible for delivering electricity from New Brunswick to the rest of the New England Power Pool (NEPOOL). 345 kV substations include, from north to south, Orrington, Maxcys, Maine Yankee, Mason, Surowiec, Buxton, South Gorham, and W. F. Wyman. Two large generation plants, Maine Yankee (nuclear) and W. F. Wyman (oil), are connected through the 345 kV system also. By operating transmission lines at such a high voltage, line losses and voltage drops can be minimized while the lines deliver large amounts of energy to customers throughout the system.

State Highways - 115 kV- The 115 kV system is the workhorse of the transmission system. It is responsible for transmitting power from the 345 kV autotransformers and intermediate sized generation throughout the entire service territory. 115 kV transmission lines are the main arteries for electricity, carrying it to and from every geographical area CMP serves. Many large industrial customers are served directly from the 115 kV transmission system. CMP currently operates over one thousand miles of 115 kV transmission lines, connecting over 60 substations. There are also five 115 kV lines which connect CMP to neighboring utilities to the north (Bangor Hydro Electric Company) and south (Public Service Company of New Hampshire).

Secondary Roads - 34.5 kV The 34.5 kV system transmits power to the distribution substations throughout the power system. These lines also provide connection to some of the more remote locations in the CMP service territory. Many of the intermediate industrial and larger commercial customers CMP serves are fed from the 34.5 kV system. These lines also provide access to many of the smaller hydroelectric generators owned by the Company, as well as to non utility generators (NUGs).

Distribution System - The distribution system is responsible for carrying electricity from substations to CMP's customers. The most common operating voltage for the distribution system is 12.47 kV. However, 4.16 kV and 34.5 kV distribution circuits are used in some locations.

Distribution circuits are most commonly found along the side of the road. The energized, or "hot", wires are found at the top of the pole on horizontal crossarms, or on a pole-top insulator. The neutral wire is typically attached to the pole about four feet below the crossarm. In most cases, telephone and cable television wires are attached further down the pole.

CMP, NEPOOL, and NPCC - Since the early 1970s, CMP has developed and maintained strong interconnections with its neighbors in New Brunswick, New Hampshire and the rest of New England. CMP's interconnections allow the transfer of capacity and energy for both contractual arrangements and economic transactions. Actual interconnection capabilities with neighboring utilities are dependent on system conditions (such as load, status of generators, and transmission facility outages) both in Maine and in other areas at the time of the transfer. Some normal interconnection capabilities are shown below.

CMP Normal Interconnection Capabilities

Transmission Interface	Transfer Limit (MW)
New Brunswick to Maine	700
Maine to New Brunswick	150 to -350
Maine to New Hampshire	900 to 1,400
New Hampshire to Maine	1,100 to 1,500

NEPOOL Normal Interconnection Capabilities

Transmission Interface	Transfer Limit (MW)
Northern New England to Southern New England	1,700 to 3,000
Quebec to Sandy Pond	1,200 to 2,000
New England East-to-West	800 to 2,000
New England West-to-East	1,600 to 2,200
New York to New England	1,300 to 2,200
New England to New York	700 to 1,700

CMP Native Customer Load

Condition	Coincident Load (MW)
CMP System Peak Load	1,500
CMP minimum system load	600

This table illustrates that CMP and other New England transfer limits are large when compared to CMP's customer load. Moreover, these power transfer limits can vary significantly with conditions, and are not necessarily the same in both directions. CMP is a small part of a much larger bulk power system. Therefore, the coordination of system design and operation extends well beyond individual system boundaries.

NEPOOL - CMP is a participant in the New England Power Pool (NEPOOL) voluntary organization formed in 1971 to assure reliability, and to attain maximum practicable economy with equitable sharing of benefits and costs. Therefore NEPOOL has a dual role: reliability and economy. Over 99% of the electrical energy supplied in New England is provided by participants in NEPOOL. New England operates as a single "Control Area". A series of standing Committees and Task Forces provides coordination and peer review for NEPOOL Participants. NEPOOL was originally formed by customer-serving electric utilities, but today includes Non-Utility Generators (NUGs) and Power Marketers and Brokers. NEPOOL relies on its "Reliability Standards", Criteria, Rules, and Standards (CRSs), Operating Guides (OGs), and Operating Procedures (OPs) to reliably design and operate the New England interconnected systems.

NPCC - CMP is a member of the Northeast Power Coordinating Council (NPCC), a voluntary organization formed after the 1965 Northeast Blackout to promote the reliability and efficiency of the electric bulk power systems by coordination of system design and operation. NPCC has a singular role; reliability. The NPCC region includes New England, New York, New Brunswick, Nova Scotia, Quebec, Ontario, Prince Edward Island, and Newfoundland. The Reliability Coordinating Committee and a series of standing Task Forces provides coordination and peer review for NPCC members. Working Groups also perform special reliability assignments. NPCC was originally formed by customer-serving electric utilities within the region, but has recently included other utilities, Non-Utility Generators (NUGs) and Power Marketers. NPCC relies on its "Reference Manual", composed of Criteria, Guides, and Procedures to reliably design and operate the NPCC interconnected systems.

CMP Coastal Substations

1) Rockland/Camden - 12.5, 34.5 and 115kV
2) Booth Bay Harbor - 12.5 and 34.5 kV
3) Cousins Island (W. F. Wyman on Cousins Island)- 12.5, 34.5 , 115 and 345kV
4) Cape, in South Portland - 115 & 34.5 & 13.8 kV
5) Old Orchard Beach - 12.5 and 34.5 kV with project load growth and a planned project to install a 115 kV line
6) Ogunquit - 34.5 & 12.5 kV
7) Kennebunkport - 34.5 & 12.5 kV
8) York - 12.5 and 34.5 kV