§ 5.6 (d)(3)(vi) Wetlands, Riparian, and Littoral Habitat

DEFINITION: Littoral – of or on a shore, especially a seashore

(vi) Wetlands, riparian, and littoral habitat. A description of the floodplain, wetlands, riparian habitats, and littoral in the project vicinity. Components of this description must include:

The floodplain designation for the project area is not a critical factor since the reservoir will not exceed the elevation of the highest high tide. The upper section of the dam or barrage will be constructed within the floodplain as defined by the 100-year storm for the communities of Eastport, Perry, and Pleasant Point. The maximum elevation of the dam will be selected on the basis of floodplain projections and will match the lowest elevation of the existing asphalt road on the Eastport side and on the Perry side. The height of the dam(s) will be, as a minimum, at the +27.0' level (msl) which will provide a buffer against storm surges and potential global temperature change projections.

If a decision is made to install filling / emptying gates in the causeway between Carlow Island and the Passamaquoddy Pleasant Point Reservation, the floodplain elevation will be used to determine upper surface configurations as denoted above while matching the elevation of the existing pavement.

Riparian rights will not be impacted except for the "low spring tide zone" which will be transformed permanently from sometimes intertidal property into submerged areas. Questions associated with the ownership of the intertidal zone will be addressed by the State of Maine during negotiations on the submerged lands lease and by local communities during shoreland zoning procedures. Appendix HMC-05 contains guidance from the State of Maine in addressing riparian ownership and the protection of property rights as controlled under submerged lands policies and regulations.

Wetland concerns as addressed in this section concentrate on two important project features: (1) covering intertidal zone at dam site; and, (2) transformation of sometimes intertidal land into submerged areas in the volume element between lowest low tide and at a boundary approximately 2-3 feet above this reference point. Freshwater wetlands will not be impacted by the proposal. As an estimate of the dam's footprint, the following quantities are provided for the rockfill and tidal wall options:

DAM TYPE	LENGTH [FT]	IMPACTED INTERTIDAL AREA [ACRE]	IMPACTED NON-INTERDAL LAND [ACRE] *
ROCKFILL	1200	4.59	0.78
TIDAL WALL	1200	0.45	0.78

* AREA COVERED BY POWER HOUSE IDENTICAL FOR BOTH OPTIONS (0.72 ACRES) AND INCORPORATED INTO ESTIMATES

The impact on the littoral area will depend on an interpretation for the reservoir boundary as a function of time and as related to the tidal elevation. This impact will have to consider "present use" effects (e.g., existing wharf) and ecological parameters associated with the altered tidal regime in Half-Moon Cove.

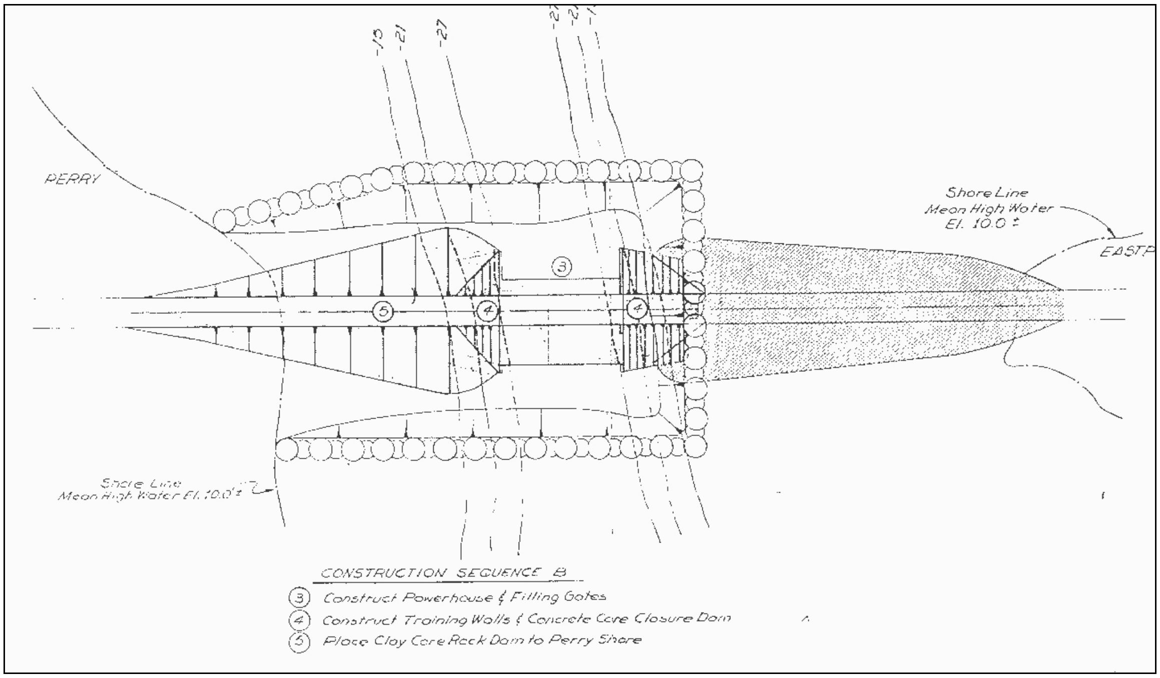


FIGURE HMC-23: PLAN VIEW OF ROCKFILL DAM WITH PARTIAL VIEW OF CAISSON CONSTRUCTION METHOD

The distance between the two shore points is approximately 1200 feet. The estimated dimensional footprint of the rockfill dam has been noted above. Under the method of construction depicted in Figure HMC-23, caissons would be placed on both sides in two phases. The concrete powerhouse would be fabricated either in the dry behind the caisson or would be floated into place. If plans included the placement of a road and / or railroad tracks, the top of the dam would be wider than the placement of a single lane service road. Under spring tide conditions, the distance across tidal waters at low tide equals 380 feet.

For the tidal wall, the footprint of the dam is substantially less than the rockfill dam and would take less time for construction. In this case, the powerhouse would be floated into place after the support structure was completed by a construction method which has been developed for off-shore oil drilling platforms. Environmentally, the tidal wall has a number of significant advantages over a rockfill dam which includes: (1) reduced sedimentation loading during and after construction; (2) less impact on intertidal / wetland area; and, (3) ease of decommissioning. A roadway or railway could be placed with proper design specifications which might include a double tidal wall to increase the width of the barrage. In both cases, the powerhouse's footprint would be the same and would cover an equal amount of submerged land.

2.1.4.1 Estuarine Wetlands

2.1.4.1.1 Support Facility and LNG Transfer System

Split Rock, where the Support Facility is located, is bordered to the east by Western Passage and to the west by Half Moon Cove. The LNG Transfer System pipelines from the Support Facility will cross an area of fringing salt marsh as well as rocky and soft sediment intertidal areas. Specifically, high and low salt marsh communities exist along the western shore of Split Rock. The low salt marsh community is inundated daily and includes small patches of cordgrass (*Spartina alterniflora*) and pickleweed (*Salicornia virginica*). The high salt marsh community is inundated approximately once a month and is dominated by saltmeadow cordgrass (*Spartina patens*), sweetgrass (*Hierochloe odorata*), and sea lavender *(Limonium carolinianum)*. Other species including soft rush (*Juncus effuses*), blue flag (*Iris virginica*), and meadowsweet (*Spirea latifolia*) border the salt marsh community. The rocky, muddy shoreline abutting the western side of Half Moon Cove also contains an area of fringing salt marsh consisting of saltmarsh cordgrass (*Spartina* spp.*)*, saltmarsh rush *(Juncus gerardii*), and other typical saltmarsh plants. The pier and LNG Transfer System will also cross intertidal marine habitats on the eastern and western sides of Split Rock. The rocky and soft sediment intertidal community is discussed in Resource Report 3, Section 3.1.1.1.

3.1.1.1 Benthic Habitats and Species

The general characteristics of the benthic communities found in the Project area are summarized in Table 3.1.1-1. Based largely on the studies and reports that are cited in the following pages, Table 3.1.1-1 represents an overview of habitat characteristics, with the substrate analysis derived from visual characteristics and side-scan sonar interpretation and other geophysical investigations undertaken for this Project (described in Resource Report 6). Benthic substrate characteristics, as interpreted from side-scan sonar survey results, are shown Resource Report 6, Appendix 6B. Note in the table that water depths are in reference to Mean Low Water, such that the intertidal zone extends from approximately +22 feet to 0, and subtidal areas start at zero and extend downward to about 50 feet at the easternmost edge of the pier structure.

Historical records of qualitative investigations of benthic communities within Cobscook Bay have culminated in extensive inventories of richly diverse benthic fauna. Trott (2004a) lists over 800 species of macroinvertebrates in 16 phyla in Cobscook Bay spanning 162 years of collections. Other authors have speculated that the Quoddy region may be the most diverse region in the western North Atlantic north of the tropics (Larsen, 2004b). The major reason for this high diversity is the organizing energy imparted by the tides (Campbell, 2004) results in the variety of intertidal and subtidal habitats and substrates. Also of note is the rather unusual presence of some normally subtidal invertebrates in the intertidal zone and the large size reached by certain species (Larsen, 2004b). The Cobscook Bay floor is covered by 70% gravel (Kelley and Kelly, 2004) and the remainder is a mixture of sand and mud with rock outcroppings. In the upper reaches of the Half Moon Cove fine sediment deposits occur due to wave erosion of upland areas. In addition, salt marsh lines portions of shoreline areas, and eelgrass beds occur sporadically throughout the Bay. The subtidal areas of the outer Cobscook Bay are characterized by infaunal and tube dwelling species in the protected sandy coves and a rich epifaunal community in the extensive current-swept channel areas (Larsen and Gilfillan, 2004). In addition to rich diversity, portions of Cobscook Bay have extremely high abundance of organisms, with densities as high as 300,000 individuals/m^2 with high numbers of deposit-feeding polychaetes and oligochaetes, less an indicator of pollution as a reflection of the extraordinary mixing resulting in high primary production and oxygen levels (Phinney et al., 2004; Vadas and Beal, 2004; Larsen, 2006).

To characterize benthic communities in the proposed project area Quoddy Bay conducted macroinvertebrate benthic surveys during July 2006 (Appendix 3-B). In addition, benthic habitats within the proposed Quoddy Bay LNG project area were characterized by a Sediment Profile Imaging (SPI) survey, also conducted in July 2006 (Appendix 3-C). Sampling stations were established at 25 locations and chosen to represent the range of benthic habitats within the project areas of Western Passage and Half Moon Cove (Figure 3.1.1-1). Macroinvertebrate samples were planned for all stations, while macroalgae, sediment, and SPI data collections were each planned for a subset of stations.

Benthic sampling performed in the summer of 2006 by Quoddy Bay revealed high levels of species richness in which 129 macrofaunal taxa from eight different phyla were identified (NAI, 2006) (Appendix 3-B) Polychaete worms dominated the fauna in terms of richness with 54 taxa collected, followed by crustaceans with 32, and molluscs with 18. The number of taxa collected per station ranged from 19 to 50, and was typically higher in soft-substrate samples than in those from the rocky intertidal. In comparison to the current survey, Larsen and Gilfillan, (2004) report 172 taxa from 12 phyla identified in 20 subtidal, soft-sediment grab samples collected years earlier at a nearby location. It's likely that more intensive sampling within the project area would produce higher numbers of taxa, both from those habitats already sampled and ones not covered by the current survey. For example, no subtidal samples were collected from Western Passage where hard substrates including ledge, rocks, and cobble, often covered by or interspersed with coarse sand and gravel, dominated the benthic habitat. Multivariate analyses discriminated between five distinct, habitat-related faunal assemblages from the 13 samples collected during the survey. These assemblages were associated with particular substrate types, and varied by location in Western Passage versus Half Moon Cove. Such habitat-related differences between benthic communities in the two project areas reflect vastly different physical environments. Tidal currents up to three knots result in the non-depositional, scour environment of Western Passage, while the enclosed embayment of Half Moon Cove allows for particulate deposition and the accumulation of soft sediments (See Resource Report 2).

Multivariate analyses discriminated between five habitat-related faunal assemblages (see Appendix 3-C). These assemblages were identified based on the results of cluster analyses run separately for soft-sediment and rocky intertidal stations. Assemblages differed in terms of their species composition, including the specific taxa present and their relative abundances.

Soft-substrate stations were classified into three separate faunal assemblages (Groups 1-3). Group 1 comprised two stations, located in Western Passage, where samples were taken from pockets of soft-sediment within the rocky intertidal. The fauna in these samples were distinct from other soft-sediment assemblages in the area, including a mixture of taxa that are typically associated with either hard or soft substrate. Numerical dominants in this group included oligochaete worms and the capitellid polychaete, *Capitella capitata*; two annelids that are often associated with organic enrichment. *Mytilus edulis* was also abundant in Group 1 samples. The Group 2 assemblage was represented by, a subtidal location in Half Moon Cove. Sediments at this station were heterogeneous in grain size and contained more coarse sand and gravel than was found in other samples. Annelids dominated this assemblage, with polychaetes such as *Aricidea (Acmira) catherinae*, *Exogone hebes*, and *Amphitrite affinis* distinguishing this group from others in the area. Group 3 included five soft-sediment stations from Half Moon Cove. These stations were characterized by high fractions of silt and clay in the sediments. The Group 3 assemblage was also dominated by annelids. The numerical dominants included oligochaetes, along with polychaetes such as the spionids *Pygospio elegans* and *Streblospio benedicti*, and the cirratulid *Chaetozone setosa*. Relatively high numbers of the ampeliscid amphipod, *Ampelisca abdita*, were also notable for this group.

Rocky intertidal stations were classified into two distinct faunal assemblages; one representing stations located in Half Moon Cove (Group 4), the other representing stations from Western Passage (Group 5). In contrast to other assemblages, Group 4 was dominated by the amphipod *Marinogammarus obtusatus*. Although oligochaetes and *M. edulis* were also among the dominant taxa in this assemblage, their densities were much lower than in samples from Western Passage. Relatively high numbers of the molluscs *Turtonia minuta* and *Hydrobia truncata* also helped to distinguish this group. The Group 5 assemblage was dominated by molluscs, with high numbers of *M. edulis* followed by the common intertidal gastropods *Skeneopsis planorbis* and *Littorina obtusata*. Oligochaetes were the most abundant annelids and most polychaete taxa were found in relatively low numbers in comparison to the other assemblages.

SPI and surface video surveys were taken at station within Western Passage stations Half Moon Cove. A diversity of substrates and abiotic habitats ranging from muddy sediments (3 stations) to sandy (1 station) to cobble/rock (at the remaining 13 stations) were present and are characteristic of boreal, macrotidal estuaries of the region (Larsen 2004b). This variety of abiotic habitats supports a wide taxonomic range of taxa from algae to fish. While algae taxa were more abundant in Half Moon Cove relative to the shallow Western Passage stations, species richness, expressed as the total number of taxa observed, was highest at stations >10 m water depth in Western Passage. Half Moon Cove, a shallow enclosed embayment, and shallow Western Passage stations had lower species richness than the deeper Western Passage stations.

Surface features at all coarse sediment stations were dominated by sediment grains most of which were covered to varying degrees by attached organisms, such as barnacles or hydroids/bryozoans (for example Figures 6 and 8). The cover or drape of organisms and fine sediments over coarse sediments was heavier at deeper stations (>10 meters water depth). In addition the number of taxa was higher at deeper stations. Cluster analysis (Euclidean distance with complete linkage grouping) separated stations into two groups primarily on depth with Group A being shallow stations and Group B deeper stations. The primary attached organisms were algae and barnacles. At the three finer sediment Half Moon Cove stations surface features were predominantly biogenic structures including feeding mounds and pits, burrow openings, and shell. At the shallowest, near inter-tidal, Western Passage stations sediment surface features were similar to those in Half Moon Cove. In addition to large sediment grains, surface features at Group B stations tended to be denser hydroid/bryozoan colonies and larger organisms. Many larger species were more abundant at deeper stations, in particular, the green urchin (*Strongylocentrotus droebachiensis*), the sea peach (*Halocynthia pyriformis*), and the stalked tunicate (*Boltenia ovifera*).

Subsurface biogenic structures associated with infaunal organisms were observed only at three Half Moon Cove stations. These structures included active burrows, water filled oxic voids that were areas of active feeding by head-down deposit feeders, and infaunal organisms.

The most abundant biogenic surface feature was small colonies of hydroids or bryozoans followed by larger sessile organisms such as tunicates and sponge like organisms. Sessile epifaunal organisms were primarily observed on pebbles and cobbles. Some of the more abundant taxa were pink coralline algae, consisting of up to five species such as *Lithothamnium* sp., *Clathromorphum* sp., or *Phymatolithon* sp., kelp (*Laminaria* spp.), brown algae (*Fucus* spp.), green macroalgae, a large solitary hydroid (*Corymorpha pendula)*, and barnacles. The slime worm (*Myxicola infundibulum*) and sea scallop (*Placopecten magellanicus*) were also present, along with the green urchin (*Strongylocentrotus droebachiensis*) and sea peach (*Halocynthia pyriformis*). Blue mussels (*Mytilus edulis*) were abundant at shallow stations in Half Moon Cove and Western Passage. Periwinkles (*Littorina* sp.) were also most abundant at shallow stations Half Moon Cove and Western Passage. The only abundant decapod was the rock crab (*Cancer* spp.). The introduced green crab (*Carcinus* spp.) was observed at one station Half Moon Cove. Sponge-like organisms, which could include species such as the cream sponge (*Halichondria panecia*) and the colonial tunicate (*Didemnun* spp.), were observed at stations only in Western Passage.

Reproduction and recruitment are universal characteristics of ecological communities. In many systems reproduction and recruitment are linked to environmental factors such as temperature, day length or food availability and hence there is a seasonal element to these functions. The strength of expressed seasonality increases as one moves away from the tropics and the seasonal variations in the environment grow more pronounced. Perhaps the ultimate seasonal reproductive and recruitment pulses are those exhibited by certain bivalve, clams, mussels and oysters, where millions of eggs and sperm are simultaneously broadcast into the water column leading to millions of free-floating larvae that are spread by the currents. Other recruitment by benthic invertebrates is more subtle and less synchronized.

Very few quantitative studies of benthic communities have been undertaken in the Quoddy region and none of these has had a seasonal element (Larsen and Webb 1997). The unusual oceanographic characteristics of the region allow us to make certain working inferences on potential recruitment and seasonality. The seasonal temperature range exhibited in Cobscook Bay and Western Passage is moderated by the extreme tidal mixing of the water column. The GoMOOS buoy in outer Cobscook Bay records a water temperature range at depths of one and ten meters of about 0 to 14°C. This seasonal range is less than half of that manifested in the mid-Atlantic region and puts less temperature stress on the resident organisms. In addition, the tidal action produces a high incidence of summer fog that further insulates intertidal organisms for heat stress. The region is, therefore, hospitable to cold water species that cannot tolerate high summer temperatures and warmer water species that cannot tolerate extreme low temperatures (Bousfield and Thomas, 1975). The moderated seasonal temperature range contributes to the high species richness of the area and may reduce the large numerical population swings seen in more variable climates.

Although there is limited information on the successful seasonal recruitment into the benthic communities, there are some data available on the timing and abundance of pelagic larvae in the water column of the Quoddy region. This is a measure of the potential for recruitment. Note that many species, including ecologically important amphipods and gastropods, have direct development and, therefore, will not be represented in the water column and will not exhibit the population explosions of broadcast spawners. Corey sampled several stations in Passamaquoddy Bay and the Bay of Fundy on a seasonal basis. She found that several species of crustaceans including mysids, cumaceans and decapods, including the ecologically important *Crangon septemspinoss* are found in the water column year around. Locke and Corey (1988) found that larvae of the crab genus *Cancer* were the most abundant members of the neuston in the summer. Without noting where and when, Roff (1983) notes the presence in the water column of the molluscs *Mytilus*, *Placopecten* and *Littorina* in the summer and fall. He also found the echinoderms the seastar *Asterias vulgaris* in the spring and the sea cucumber *Cucumaria* from May to September; and the barnacles *Balanus balanoides* in the spring and *B. crenatus* in the late summer and fall. Lacalli (1980) identified 30 species of polychaete larvae representing 17 families in Passamaquoddy Bay. In Penobscot Bay, located 150 km southwest of the Quoddy region and subject to stronger seasonal pulses, Bertrand (1977) found crustacean larvae common in the water column from February to October, gastropod larvae from June to October and bivalve larvae from June to September. The breeding periods of key benthic species in Denmark's Isefjord, which is phylogenetically similar to the Quoddy region, was examined by Rasmussen (1973). Several common species, such as the polychaetes *Nereis diversicolor*, *Polydora ciliata* and *Fabricia sabella*, the crustaceans *Corophium insidiosum*, and the molluscs *Lacuna vinctai and Mytilus edulis* showed breeding activity year around. Other important species such as the polychaetes *Nereis virens*, *N. succinea* and *Paraonis fulgens*, had limited summer reproductive peaks. A majority of the species were summer breeders although several important species such as the polychaetes *Harmothoe imbricata* and *Nephtys caeca* reproduced during the winter months.

3.1.1.1.1 Intertidal Habitats

Intertidal habitats consist of those areas of the shoreline that experience the variation of water depth as the tides ebb and flood. In general, for the Project area, the water surface elevation fluctuates about 21 feet, but because of differences in spring and neap tides, it is possible to get extreme fluctuations between high and low tide closer to 26 feet. Storm surge, wind, and barometric pressure also influence tide levels. Because of this variability at the upper and lower limits of the tide, the intertidal zone grades into terrestrial biota at the upper edge, and into the subtidal zone at the lower edge, without a clearly defined boundary.

The amount of ground exposed during these vertical changes in water surface elevation depends on the slope of the shoreline. For example, in many locations with very gradual sloping ground within Cobscook and Passamaquoddy Bays, the intertidal zone extends hundreds of feet from the high water mark. In other locations, steep shorelines, generally associated with bedrock ledge and outcropping, can have narrow intertidal zones. In addition to slope, the substrate of the intertidal zone can be highly variable, consisting of highly saturated silt sediments, sand, gravel, cobble, and bedrock. Generally, substrates the size of gravel and smaller are considered soft sediment intertidal habitat, and cobble, boulder, and bedrock are considered rocky intertidal habitat. The substrates are a strong determinate in the nature of the intertidal fauna in any one location. Results of substrate mapping and characterization performed by Ocean Surveys Inc. (see Geophysical report appendix to Resource Report 6) revealed a variety of substrates along the LNG transfer pipeline route and at the pier in Western Passage. In Half Moon Cove, progressing from east to west, there is about 400 linear feet of class 3 sediments (class 3 sediments are defined in the Ocean Survey Report as predominantly silts and fine sand) adjacent to Split Rock, then 2400 linear feet of class 1 sediments (class 1 sediments are defined in the Ocean Survey Report as predominantly coarse sands and gravel with scattered rocks) (although there is about 600 feet of this that is subtidal habitat), then 300 feet of class 3 sediments, 400 feet of class 1 sediments, and finally 500 feet of class 3 sediments. In Western Passage there is primarily class 1 sediments except for an area nearer to Split Rock.

The interaction of the large tidal range and Cobscook Bay's geomorphology results in an intertidal area of approximately one third of the total area of Cobscook Bay (Larsen et al., 2004). Habitats range from soft mud to bedrock and quite distinct habitats can be found in close proximity to one another (Larsen et al., 2004). The western shore of Western Passage has a more uniform energy regime and less habitat diversity; principally cobble and gravel with outcroppings of bedrock.

In general, intertidal habitat is an important habitat for invertebrate recruitment and growth, feeding, refuge, and reproduction (Mathieson et al., 1991) as well as macroalgae, submerged aquatic vegetation (SAV) and benthic diatoms all of which support a larger food web of consumers and predators. Intertidal habitats provide the following functions and values (Adamus et al., 1987; USACE, 1995):

- **Sediment/shoreline stabilization:** the structure of the intertidal zone reduces shoreline erosion, especially in areas where the intertidal zone is wide, is densely vegetated, or when fetch is large. The intertidal zone absorbs tidal energy and protects upland areas.

- **Nutrient removal/transformation:** algae in the hard substrate habitat absorbs nutrients and herbivory through its primary production. The level of nutrient removal/transformation is highest in the low intertidal, where algal density is highest. The limiting nutrient in marine water, nitrogen, is always found in excess in the project region (Garside and Garside, 2004). A large proportion of Cobscook Bay's productivity is converted to macroalgal detritus and approximately a third of this is exported to coastal waters (Campbell, 2004).

- **Production export:** Several recent studies have addressed the primary productivity of the Cobscook Bay system (Vadas et al., 2004a, b, c; Beal et al., 2004; Phinney et al., 2004; and Campbell, 2004). A summary of the annual primary productivity is presented in Table 3.1.1-2. Algae support a high diversity of herbivorous invertebrates that consume about one third of the carbon within Cobscook Bay (Campbell, 2004). Tidal action exports algal byproducts to the coastal sea.

- **Fish and shellfish habitat:** several commercially-important species reside in the intertidal zone including green sea urchin (*Strongylocentrotus droebachiensis*), blue mussels (*Mytilus trossulus and edulis*), soft shell clams (*Mya arenaria*), periwinkle (*Littorina littorea*) and Jonah crab (*C. borealis*).

- **Wildlife habitat:** the intertidal zone can provide a forage area for many shorebird species including sandpipers, plovers, and gulls.

The rocky intertidal shorelines along Western Passage are high energy-eroding environments characterized by strong currents, extreme tidal fluctuation, and hard substrates. Similar habitats in Half Moon Cove experience weaker currents but are also subject to large tidal fluctuations. The predominant biota are epifaunal plant and animal species adapted to swift currents and the energy of waves. Various mechanisms enable these organisms to maintain their position in strong currents. The rocky shores provide stable surfaces for attachment of sessile organisms such as barnacles and blue mussels, as well as species such as limpets, chitons, periwinkle, and dogwinkle. In addition, the biota of steep rocky shores often exhibit pronounced vertical zonation that reflects the ability of organisms to tolerate variations in temperature, dessication, light intensity, and other factors related to tidal fluctuation.

In addition to rocky intertidal, the Project area encompasses soft-sediment intertidal habitat, predominantly within Half Moon Cove. The sediment in this habitat ranges from fine silt/clay muds to sand and gravel, depending upon shoreline orientation, bathymetry and depth, and current velocities. In some areas, there are relatively large expanses of uniform sediments while in other areas the intertidal zone consists of a patchwork mosaic of all substrate types. Soft sediment intertidal species are predominantly in-fauna, with species either mobile where they burrow horizontally and vertically through the substrate, such as the clam worm (*Neanthes* spp.), or more or less immobile, such as soft-shell clams or peanut worms (Sipunculida).

Intertidal macrobenthic invertebrates in five locations in Cobscook Bay were assessed during the 1970s and 1980s as part of the Maine State Planning Office, Critical Areas Program. This sampling revealed high abundances and a high diversity of species. These stations were revisited again in the early 2000s to collect transect and quadrat data. Overall, the results revealed a surprising decline in species diversity. Several explanations are posited, including scallop and sea urchin harvesting activities, which result in increased suspended sediments as well as direct physical disruption of the top layer of sediments in subtidal areas of Cobscook Bay (Trott, 2004b). Scallop harvesting occurs on a limited basis within Half Moon Cove.

There are only two quantitative intertidal surveys of the invertebrate communities of intertidal habitats in the project area. Larsen et al., 1979 executed transect studies through intertidal gravel and cobble habitats on the Western Passage side of Carlow Island. The community make-up was similar in each habitat with the annelid worms of the Class Oligochaeta being the dominant group. The numbers of species per 1/4 m^2 sample ranged between 5 and 14 at the gravel sites and 9 and 19 at the cobble stations. The number of individuals per m^2 varied from 1,824 and 8,200 in gravel and 520 and 10,900 in cobble.

Recent work being performed in Half Moon Cove indicates that it may not be as comparable to other areas of Cobscook or Passamaquoddy Bays as it was prior to the construction of the causeways for the Passamaquoddy Tidal Power Project. The causeways have altered water exchange and circulation characteristics within Half Moon Cove, which has resulted in some alteration of benthic conditions. Benthic sampling was performed on July 26 and 27, 2005 as part of Section 203 studies being performed by the New England District of the US Army Corps of Engineers (USACE, 2005). The Section 203 project is assessing restoration alternatives for Half Moon Cove, with a focus on removing or modifying the causeways between the Pleasant Point Indian Reservation and the city of Eastport. Eleven Van Veen grabs were taken in intertidal and subtidal areas for benthic community analysis. Five of the sample locations were along the western side of Split Rock and its adjoining causeways while two others were located immediately to the southeast of Split Rock. Other sample stations were located on the east and west side of the causeway between Carlow Island and Eastport. An additional 11 stations in Half Moon Cove and two southeast of Split Rock were sampled for shellfish.

The 11 benthic community samples yielded 104 putative species. There was an average of 25 species per 0.04 m^2 sample with a range of 12-38 (Table 3.1.1-3). Interestingly, 24 of the 90 species identified to the species level were not found in the checklist of Trott (2004a). This suggests that the benthic communities of the Quoddy region are not adequately studied. Perhaps the most remarkable feature of this small sampling program is the high density of individuals found. Densities ranged between 2,950 and 345,625 individuals per m^2 with a mean of 73,355. As with the cobble and gravel stations in Western Passage, oligochaetes were the first or second most dominant taxon at all but one station. Other abundant species included spionid polychaetes and amphipods. Abundance at this level is often suggestive of organic pollution. In this case, however, pollution indicator species, such as polychaete *Capitella capitata*, were not present. Furthermore, no major outfalls are known to empty into Half Moon Cove where the very high densities are found. Additional studies are needed to determine if this high density is at reflection of the high primary productivity of the region.

Shellfish sampling was also performed on July 26 and 27, 2005 as part of Section 203 studies being performed by the New England District of the US Army Corps of Engineers in Half Moon Cove and Western Passage. Softshell clam densities in Half Moon Cove averaged approximately 3.4 per square foot, of which nearly 2 were of harvestable size (>2 inches, USACE 2005).

Studies currently underway to assess the benefits and feasibility of removing or replacing with bridges, the causeways constructed as part of the Passamaquoddy Tidal Power Project over a half century ago reveal that the reduction of tidal exchange and near isolation of Half Moon Cove from the larger Passamaquoddy Bay estuary has had a detrimental affect on invertebrate and vertebrate biota (Tribal Partnership, 2005/2006). In addition, the causeways have forced water entering and exiting Half Moon Cove to be more isolated from the large volume exchange associated with tidal flows in Western Passage.

3.1.1.1.2 Subtidal Habitats

Subtidal habitats extend from the lower limit of the intertidal zone to the deepest depths in the Project area. For Half Moon Cove, the subtidal area reaches a maximum depth of 27 feet MLW in the middle of the cove along the pipeline corridor. In the vicinity of the pier in Western Passage, the Project facilities are located in subtidal depths up to 70 feet MLW. However, continuing easterly towards the center of Western Passage, water depths reach nearly 300 feet.

The subtidal habitat is an important habitat for feeding, juvenile recruitment and growth, shelter, and reproduction (Ojeda and Dearborn, 1990) of a large number of benthic fauna. Subtidal habitats provide the following functions and values (Adamus et al., 1987; USACE, 1995):

- **Nutrient removal/transformation:** Algae in the hard substrate habitat processes nutrients through primary production, and thus supports herbivores in the food chain. The level of nutrient removal/transformation is a direct function of algal biomass, which is highest in the sublittoral zone and diminishes with depth.

- **Production export:** Producers in the subtidal environment include the fringing kelps and submerged aquatic vegetation (SAV), phytoplankton and microphytobenthos (see Table 3.1.1-2). The Quoddy region operates differently than other coastal systems that are stratified due to thermal or freshwater inputs. Productivity is controlled by the availability of light and not nutrients (Phinney et al., 2004); hence, the seasonal cycle follows the sun angle. In addition, since sufficient light to support photosynthesis reaches the bottom in most parts of the region, the benthic diatoms are the dominant producers (see Table 3.1.1-2). Indeed, microphytobenthos in Cobscook Bay is estimated to have 100 times the biomass and ten times the productivity as the overlying phytoplankton (Phinney et al., 2004). Kelps and SAV are significant producers (Vadas et al., 2004b; Beal et al., 2004) and also provide essential habitat for invertebrates and fish due to their three dimensional growth form. In addition, a high diversity of herbivores is supported by the diversity of algae and SAV.

- **Fish and shellfish habitat:** Several commercially-important species occur in hard substrate habitats, including the green sea urchin, blue mussels, American lobster (*Homarus americanus*), and Jonah crab (*Cancer borealis*). Hard substrate supports fish such as cunner, wolffish (*Anarhichas lupus*), and juvenile pollock (*Pollachius virens*). Additional information on commercial fisheries is presented in Section 3.1.1.4 and Resource Report 8.

- **Wildlife habitat:** The subtidal zone can provide a forage area for certain species of diving ducks, such as scoters and eiders that feed on benthic invertebrates, particularly during periods of low tide when water depths are reduced.

The subtidal habitats of the Project area show a similar diversity of physical attributes as the intertidal zone, with sediments ranging from silt-clay muds, sands, gravel, and boulder/bedrock. In general, Western Passage has higher tidal current velocities and coarser sediments, including an abundance of boulder/bedrock, while Half Moon Cove has areas of higher levels of sediment erosion. In the Project footprint of Half Moon Cove, well over 70% of the workspace is intertidal, and the amount of area that remains permanently under water is isolated to approximately the middle third. The OSI geophysical report (See Resource Report 6 appendices) results reveal that the subtidal area of Half Moon Cove is class I sediments, which are dominated by coarse sand, gravel, and cobble.

Larsen and Gilfillan (2004) report on the results of a 1975 benthic grab sampling effort that quantitatively sampled subtidal communities in Broad and Deep Coves of Outer Cobscook Bay, approximately 3 miles south of Half Moon Cove. This study represents the only other quantitative information from systematic sampling of subtidal benthic communities in Cobscook Bay than the described 203 USACE sampling. The sediment composition in Broad and Deep Coves ranged from very fine sand, to gravel and cobble. Although sampling was conducted south of Half Moon Cove, some of the habitats may approximate those of Half Moon Cove. The inner cove stations have the lowest current levels and the finest sediments, while the outer cove stations have higher currents and slightly coarser sediments. The samples collected from the channel stations may be more representative of the species diversity in Western Passage as it experiences higher tidal fluctuation and swifter currents.

Overall sampling results indicated over 172 taxa from 12 phyla were identified from the 20 grab samples. All cove stations in both Broad and Deep Coves were dominated by infaunal species totaling 104 species, while the channel stations were dominated by high densities of filter feeding epifauna. The annelids were the most diverse group, with 59 species, followed by arthropods and molluscs with 47 and 44 taxa respectively (Larsen and Gilfillan, 2004). In performing similarity analysis, 104 species were found at cove stations and 135 were identified from the channel stations. The cove stations had 38 unique species, while the channel had 68 unique species, and 66 species were common to both areas. In the lower velocity, finer sediment stations of the coves, a handful of species were either limited to the coves or were at their greatest abundance, including: the isopod *Edotia triloba*; the amphipods *Haploops spinosa*, *Leptocheirus pinguis*, and *Unciola irrotata*; and the deposit feeding polychaete *Nephtys bucera*. In contrast, the channel stations had a greater number of species who were exclusive or more abundant. Cnidarians, bryozoans and echinoderms, with the exception of the brittle star *Ophiura robusta*, were found only at channel stations. Larsen and Gilfillan (2004) found that another 18 species ranging from chitons, limpets, and jingle shells to scaleworms, pycnogonids, and pericarids were exclusive or more abundant at channel stations. In summary, the cove stations are dominated by burrowing or tube dwelling infauna while the channel stations are dominated by epifaunal filter feeders or grazers.

§ 5,6 (d)(3)(vi)(A): Wetland Habitants / Species

(A) A list of plant and animal species, including invasive species, that use the wetland, littoral, and riparian habitat;

Benthic Habitat Overview				
Project Feature	**Location Description**	**Substrate Type**	**Range of Water Depths (MLW) (ft)**	**Benthic Community Types**
LNG Pier	East Side of Split Rock	Ranges between silty sands to bedrock outcrops	+22 to 50	Rocky Intertidal, Coarse Sediment Intertidal, Rocky Subtidal, Coarse Sediment Subtidal
LNG Transfer Pipelines	East Side of Split Rock	Ranges between silty sands to bedrock outcrops	+22 to 0	Rocky Intertidal, Coarse Sediment Intertidal
	West side of Split Rock	Ranges between silty sands to bedrock outcrops	+22 to 0	Rocky Intertidal, Coarse Sediment Intertidal, Fine Sediment Intertidal
	Central Area of Half Moon Cove	Silty with high organics	0 to 27	Subtidal soft bottom, Eelgrass bed
	West Side of Half Moon Cove	Ranges between silty sands to bedrock outcrops	+22 to 0	Rocky Intertidal, Coarse Sediment Intertidal, Fine Sediment Intertidal

TABLE HMC-22: BENTHIC HABITAT OVERVIEW [QUODDY BAY LNG]

TABLE 3.1.1-2

Summary of Annual Primary Productivity in Cobscook Bay (Modified from Campbell 2004)

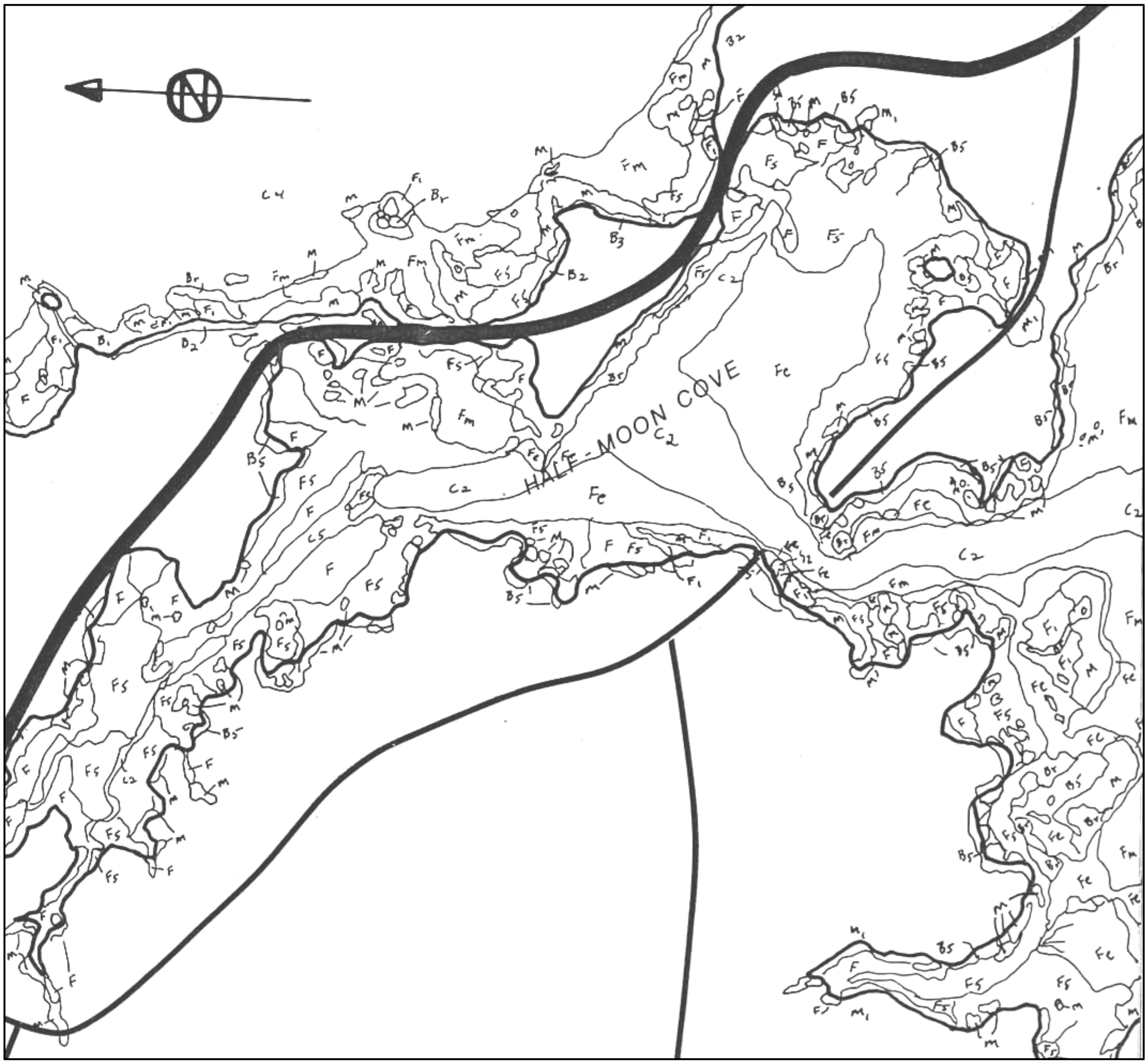
Producer	Primary Production (kgCy^{1} x 10^{6})
Phytoplankton	8.80 x 10^{6}
Benthic Diatoms	19.50 x 10^{6}
Eelgrass	0.24 x 10^{6}
Fucoid Algae	6.25 x 10^{6}
Green Algae	1.11 x 10^{6}
Kelp	0.46 x 10^{6}
Red Algae	0.78 x 10^{6}
Total Production	37.14 x 10^{6}

kgCy^{1} – Kilograms of Carbon per year

TABLE HMC-02: ANNUAL PRODUCTIVITY [*repea*t]

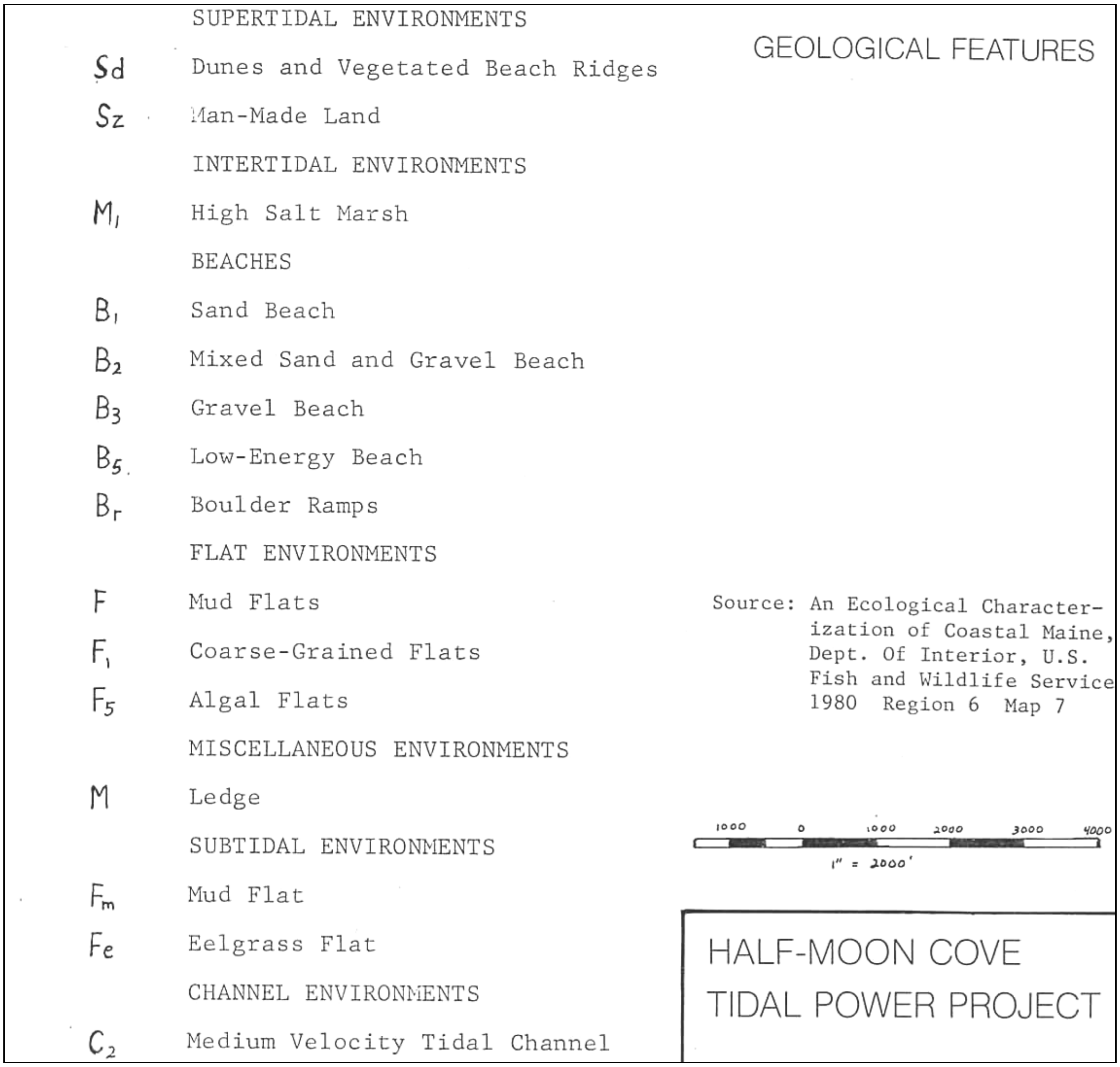
§ 5.6 (d)(3)(vi)(B): Wetland Map

(B) A map delineating the wetlands, riparian, and littoral habitat; and



The code / legend for this drawing is listed below:

FIGURE HMC-15: INTERTIDAL COMPOSITION [*repeated*]



§ 5.6 (d)(3)(vi)(C): Impacted Areas

(C) Estimates of acreage for each type of wetland, riparian, or littoral habitat, including variability in such availability as a function of storage at a project that is not operated in run-of-river mode.

Estimates for acreage of intertidal zone provided on Page 8-1 and in a previous section. In summary, acreage would be transformed from intertidal to permanently covered at the dam site. Approximately 140 acres would be transformed from sometimes intertidal into permanently submerged within the impoundment.

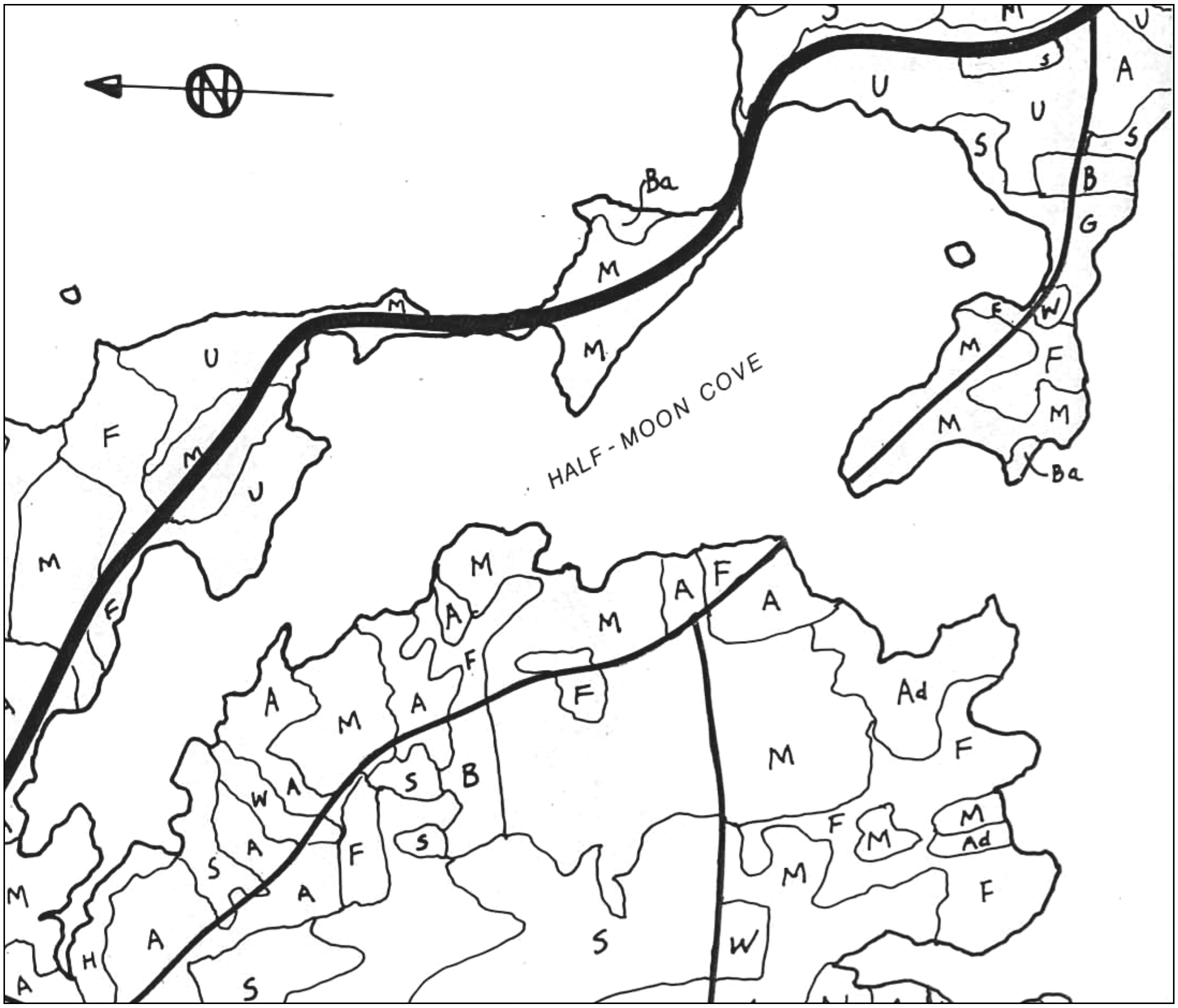
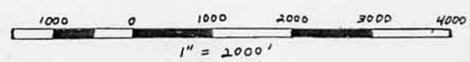


FIGURE HMC-24: LAND USE PATTERN AROUND HALF-MOON COVE

LAND COVER

A	Agricultural lands
Ad	Alders
B	Blueberry lands
Ba	Naturally exposed lands
F	Other fields
G	Grasslands
H	Hardwoods
M	Mixedwoods
S	Softwoods
U	Urban Areas
W	Wetlands

Source: An Ecological Characterization of Coastal Maine
Dept. of Interior, U.S. Fish and Wildlife Service
1980 Region 6 Map 7



HALF-MOON COVE
TIDAL POWER PROJECT

TABLE HMC-23: LEGEND FOR FIGURE HMC-24
[NOT TO SCALE]